Planning for a Changing Climate: ARM'D City Model

The case of the Mediterranean Northern Coast in Egypt

vorgelegt von
M.Sc.
Norhan Aly El Dallal
ORCID: 0000-0003-4412-0277

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Promotionsausschuss:
Vorsitzender: Prof. Dr. Felicitas Hillmann
Gutachterin: Prof. Dipl. Ing. Elke Pahl-Weber
Gutachter: Prof. Dr. Rudolf Schaefer
Gutachter: Assoc. Prof. Dr. Tarek Abou Elseoud

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Hereby I declare that I wrote this thesis myself with the help of no more than the mentioned literature and auxiliary means.

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Abstract

Climate change and rapid urbanization are major concerns in the Middle East and North Africa (MENA) region. The empirical evidence on the reciprocal impact of urbanization and climate change demands interdisciplinary integration and cross cutting between both aspects on various levels to help in the mitigation and the adaptation policies. Interventions should focus on strengthening the capacity of the MENA countries to make their development more resilient to climate. As the complexity of the urban planning process increases, the demand of a platform to cross cut different data using computational and parametric techniques increases. The ability to generate, simulate and assess multiple scenarios opens up the limitations in the traditional rigid process.

The Northern Mediterranean Coast of Egypt is one of the most vulnerable areas in the Middle East and North Africa (MENA) region. Rising sea levels, severe storms, droughts, hotter summers and colder winters are just some of the threats cities face from a changing climate. Urban planners need to be able to take into account these and other effects of climate change to be able to reduce their impact on the urban environment, the economy and people.

Finding the synergies between mitigation and adaptation strategies instead of the dichotomy that has been followed in the past is key to a resilient development. The challenges facing this resilient development are in the content as well as the process.

A methodological urban planning approach, in which climatic parameters are integrated into the planning process to create a prototype for the resilient city is the aim of this research. This study is an attempt to construct a model for the ARM'D City (Adapted, Resilient, Mitigated Development for the city) to become a pilot model that could serve as a benchmark for similar developments. Various strategies generation based on a defined framework and computational models through a decision making tool which acts as a facilitator to integrate climate recommendations in the planning process is the outcome. A final criticism of the strategies is conducted showing the achievability and viability of the proposals.

Zusammenfassung

Der Klimawandel und die rasche Verstädterung sind die Hauptanliegen in der Region des Nahen Ostens und Nordafrikas (MENA). Die empirische Evidenz über die wechselseitigen Auswirkungen von Urbanisierung und Klimawandel erfordert eine interdisziplinäre Integration und die Verknüpfung beider Aspekte auf verschiedenen Ebenen, um die Politik der Eindämmung und Anpassung zu unterstützen. Die Interventionen sollten sich auf die Stärkung der Fähigkeit der MENA-Länder konzentrieren, ihre Entwicklung klimaresistenter zu gestalten. Mit zunehmender Komplexität des Städtebauprozesses steigt der Bedarf an einer Plattform, die es ermöglicht, verschiedene Daten mit Hilfe von Berechnungs- und Parametriertechniken zu überkreuzen. Die Fähigkeit, mehrere Szenarien zu generieren, zu simulieren und zu bewerten, öffnet die Grenzen des traditionellen, starren Prozesses.

Die nördliche Mittelmeerküste Ägyptens ist eines der anfälligsten Gebiete im Nahen Osten und in Nordafrika (MENA). Steigende Meeresspiegel, schwere Stürme, Dürreperioden, heißere Sommer und kältere Winter sind nur einige der Bedrohungen, denen die Städte durch ein sich veränderndes Klima ausgesetzt sind. Stadtplaner müssen in der Lage sein, diese und andere Auswirkungen des Klimawandels zu berücksichtigen, um ihre Auswirkungen auf die städtische Umwelt, die Wirtschaft und die Menschen zu verringern.

Die Suche nach Synergien zwischen Minderungs- und Anpassungsstrategien statt der bisher verfolgten Dichotomie ist der Schlüssel zu einer widerstandsfähigen Entwicklung. Die Herausforderungen, die sich dieser widerstandsfähigen Entwicklung stellen, liegen sowohl im Inhalt als auch im Prozess.

Ein methodischer Ansatz in der Stadtplanung, bei dem klimatische Parameter in den Planungsprozess integriert werden, um einen Prototyp für die widerstandsfähige Stadt zu schaffen, ist das Ziel dieser Forschung. Diese Studie ist ein Versuch, ein Modell für die ARM'D-Stadt (Adapted, Resilient, Mitigated Development for the City) zu konstruieren, um ein Pilotmodell zu schaffen, das als Maßstab für ähnliche Entwicklungen dienen könnte. Das Ergebnis ist die Entwicklung verschiedener Strategien auf der Grundlage eines definierten Rahmens und von Berechnungsmodellen durch ein

Entscheidungsfindungsinstrument, das als Vermittler zur Integration von Klimaempfehlungen in den Planungsprozess dient. Eine abschließende Kritik an den Strategien wird durchgeführt, die die Erreichbarkeit und Durchführbarkeit der Vorschläge zeigt.

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1 Introduction

1.1 Background

Integration of climatology parameters into the urban planning process is not a luxurious asset anymore it's a necessity to reach a more resilient development and reduce vulnerability to climate change. Current research work on forms of urbanism aims at providing alternatives to conventional methods of urban planning by replacing static typologies with adaptive ones (Architectural Association's Design Research Lab (DRL), 2009, p. 25).

Traditionally, researchers in climate responsive planning have aimed to keep local climate parameters as a complementary issue and not the initiator of the conceptual segment of urban planning (Krüger, E., & Rasia, 2010, p. 2068) (El-Deeb, El-Zafarany, & Sherif, 2012)Understanding the impact between built environment and climate parameters was necessary to tackle in order to aid in developing a knowledge base to be the foundation for the research throughout the thesis.

Lack of integration of climate change parameters in the process of planning leads to a deficiency in the resilience of the city and its ability to withstand the foreseen changes and catastrophes. This by turn reflects on the absence of urban resilience, the absence of social resilience and the absence of economic resilience. The underlying problems of the absence of urban resilience include lack of physical safety due to poor infrastructure that is not designed to endure hazardous events, it also includes disruption of ecosystems, inappropriate policy framework, poor state governance and decision makers that are not well informed or well trained to act in disaster or risk prone areas. Thus will cause the deficiency in optimization of resources, unreliable communication & mobility and deterioration of natural & manmade assets (Galderisi, 2014). Another important side is the social aspect, the absence of social resilience especially for the more vulnerable communities that have no resources to overcome the expected climate changes, leads to unequal access to opportunities, degeneration of livelihoods, decline of public health and poor civil governance. The resulting dilemmas comprise social instability, creativity index decline (narrow knowledge-based development) and deficiency in social dynamics (Lang, 2012) (Śnieg, Greinke, & Othengrafen, 2019). As for the absence of economic resilience during the forecasted climate deviations, the difficulties will be faced by most sectors, some examples of the problems are subsistence agriculture,

limited industrial and service sector, collapse of production supply & consumption chains, inadequate flow of energy, decay of local economic development and many more that will eventually cause a low return economy, limited direct & indirect job generation and consumption of GDP (Lang, 2012) (Śnieg, Greinke, & Othengrafen, 2019). This is briefly illustrated in the below figure 1.

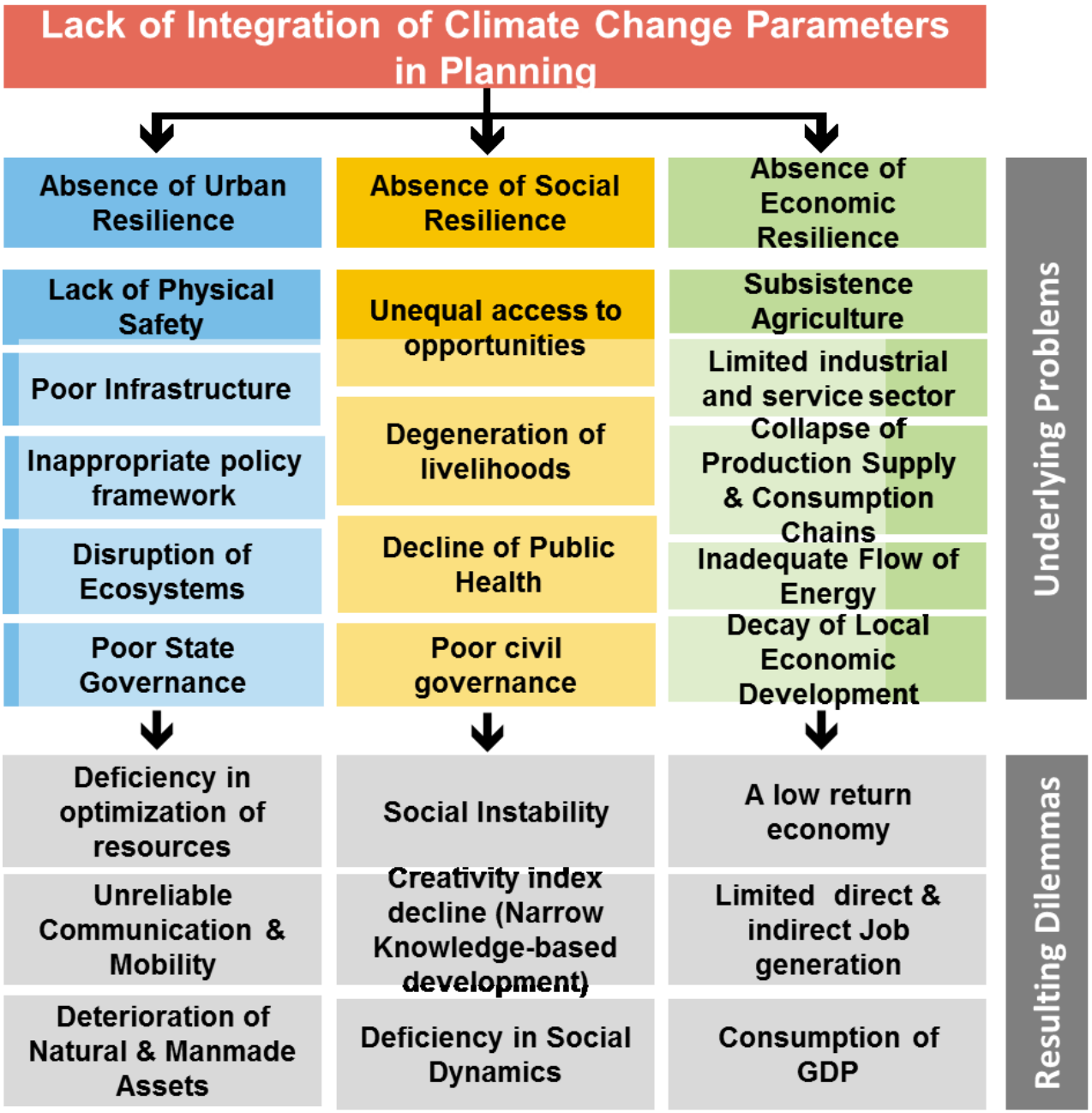


Figure 1 Challenges of lack of integration of climate change parameters in planning. Source: Author

Climate change and rapid urbanization are major concerns in the Middle East and North Africa (MENA) region. The empirical evidence on the reciprocal impact of urbanization and climate change demands interdisciplinary integration and cross cutting between both aspects on various levels to help in the mitigation and the adaptation policies. Interventions should focus on strengthening the capacity of the MENA countries to make their development more resilient to climate. As the complexity of the urban planning process increases, the demand of a platform to cross cut different data using computational and parametric techniques increases. The ability to generate, simulate and assess multiple scenarios opens up the limitations in the traditional rigid process.

The Northern Mediterranean Coast of Egypt is one of the most vulnerable areas in the Middle East and North Africa (MENA) region. Rising sea levels, severe storms, droughts, hotter summers and colder winters are just some of the threats cities face from a changing climate. Urban planners need to be able to take into account these and other effects of climate change to be able to reduce their impact on the urban environment, the economy and people (Elsehamy, 2018, p. 16).

Egypt signed the Convention of Climate Change in 1992, ratified it in 1994. During the first commitment period Egypt was the second African country in terms of ranking in the CDM projects, that has 25 project registered in EB around (Eissa, 2018, p. 10). Egypt's sharing less than 1% from the global greenhouse gas emissions, where the first national communication record 116 million tons of carbon dioxide equivalent for the base year 1990 rose to 193 million tons for the base year 2000. At the same time and in accordance with international and national studies, Egypt is one of the most vulnerable country will be affected by the risks of climate change.

The impacts of climate change that will remain, even after effective mitigation strategies, will be scattered unevenly throughout the world, affecting the least developed countries hardest. This requires institutional, technical, and spatial measures to adapt to these effects (Biesbroek, Swart, & van der Knaap, 2009, p. 30).

1.2 Objective

Integrated planning for a changing climate is a mandatory approach that should be incorporated in the development process. The main objective of this research is to study the impacts of climate change on the built environment and the appropriate measures required to plan a resilient city that could overcome hazardous climate risks as explained in figure 2 below.

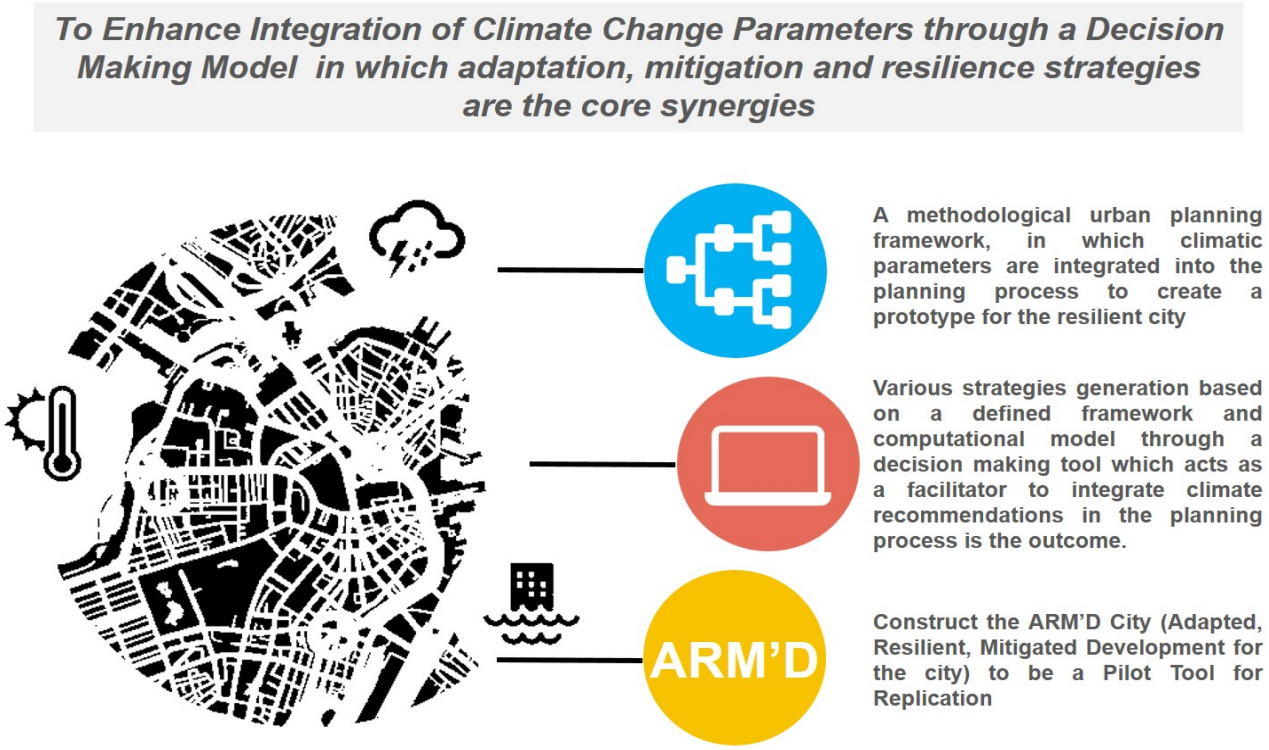


Figure 2 Objectives of the research. Source: Author

The previous illustration demonstrates the aims of this study that will help reach the main objective which is enhancing the integration of climate change parameters through a decision making model in which adaptation, mitigation and resilience strategies are the core synergies. In order to fulfill this, a methodological urban planning framework is developed that will be translated to a computational model and for creating various strategies. These strategies are the foundation of constructing the ARM'D City (Adapted, Resilient, Mitigated Development for the city) to be a pilot tool for replication.

The research aims at getting familiar with the topic of climate change impact on the built environment which could help identify the differences between mitigation and adaptation measures as well as possible synergies.

The objective of this research is not to find absolute solutions to this dilemma. Rather, this study aims to start discussions in an attempt to find the switchboard between mitigation and adaptation. This could be initiated by identifying the role of spatial planning and energy systems in the climate change debate, particularly in integrating mitigation and adaptation strategies at the most applicable level whether horizontally among different sectors or vertically among different scales (Biesbroek, Swart, & van der Knaap, 2009, p. 233).

1.3 Scope

This study adopts the theory that a resilient city is a city that considers the synergies between adaptation and mitigation strategies (Union of Concerned Scientists, 2016, p. 2). The research argues that ascertaining the golden thread of resilience that connects mitigation and adaptation and leads to economic growth, social equity, and environmental sustainability lies in understanding and analyzing the liaison between climate parameters, spatial planning and energy systems of a city.

In spatial planning, the differences between time, space and people fall into one coherent multi-level governance approach, making spatial planning suitable for an integrative approach to adaptation and mitigation (Biesbroek, Swart, & van der Knaap, 2009, p. 233). Integrating climate change considerations in the spatial planning process is a very challenging task and requires a change the policy footing of climate change within spatial strategy (Bulkeley, 2006). Good urban planning practices should also be climate smart planning practices as most climate change actions are an augmented part with the duties of urban planner.

On the other hand energy systems are considered the heart that provides the blood to the city that provides input into almost all sectors of an economy. Energy is a part of the buildings sector, the transportation sector and the industrial sector as well. An integrated approach is necessary to meet the development goals.

As complex as the relation between the spatial aspect and energy aspect of the city is, the integration serves as an accelerator to the vitality of the city or the brake of it. Translating these complex relations into arithmetic equations would lead to a much more simplified decision making process that integrates climate change, and doesn't overlook its impacts. Planners, decision makers and other stakeholders need a facilitating tool to assist in integrating anticipated changes, physical and socio-economic impacts, sectors' synergies and conflicts, as well as potential recommendations in one platform to have a holistic view and be able to evidently weigh and evaluate the situation before policymaking and implementing development plans.

1.4 Methodology

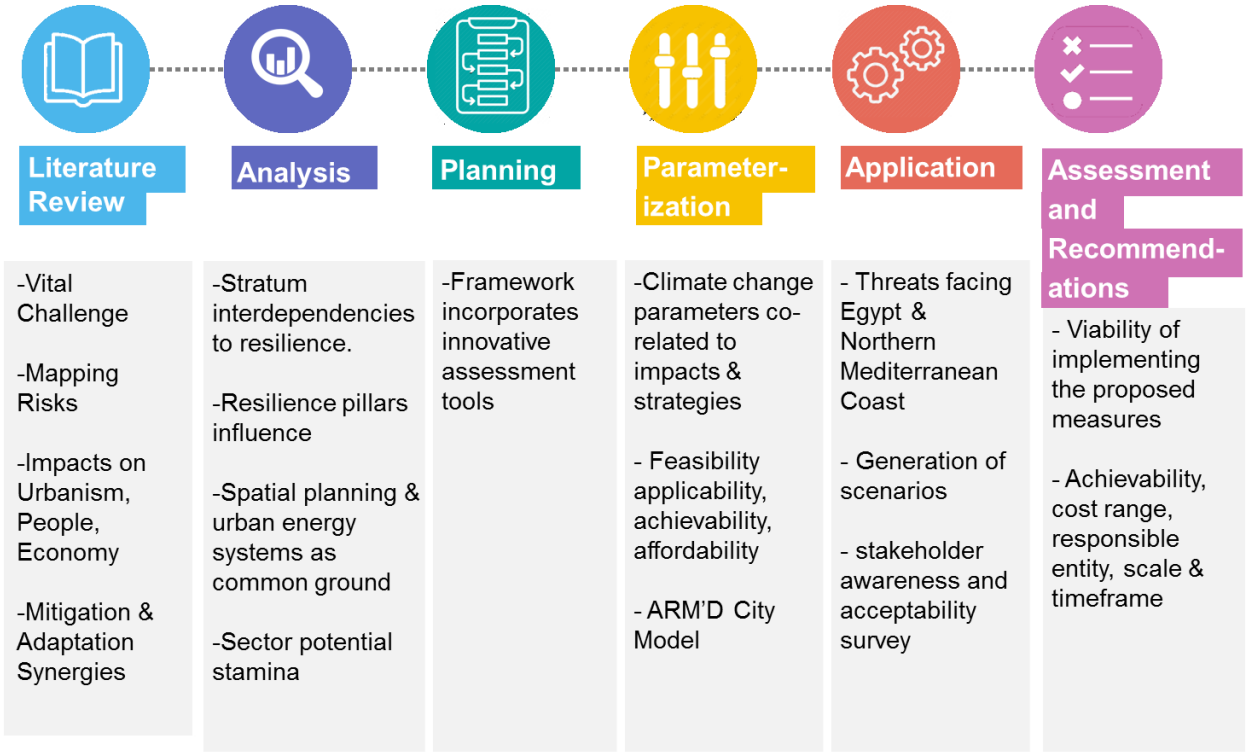
Parametrizing the relation between climate and urban agglomerations will create numerous opportunities for a responsive planning process that is proactive to future anticipations rather than just being reactive. Current research work on urbanism aims at providing alternatives to conventional methods of urban planning by replacing static typologies with adaptive ones (Architectural Association's Design Research Lab (DRL), 2009, p. 25).

In the last few years, parametric design techniques have been introduced to urbanism, as parametric design systems enable the generation of different alternatives of design by the adjustment of parameters. Parametric Urbanism has been developed over the past 15 years and now claiming domination within avant-garde design practice, it succeeds Modernism as the next long wave of systematic innovation (Schumacher, 2009, p. 15).The aim of using such tools is not only that of generating scenarios at the urban scale, but also of assisting planners and public administrations and other stakeholders involved in decision-making related to the urban development process (Fusero, Lepidi, Massimiano, & Tedeschi, 2013, p. 2)

Linking functions to planning and integrating the climatology aspects based on a parametric approach was mandatory to help formulate a starting point for the scope and use of the parametric approach in urban planning issues as a topic of research for the MENA region as a whole. Understanding the impact between built environment and climate parameters was necessary to tackle in order to aid in developing a knowledge base to be the foundation for the research throughout the thesis.

The following Table 1 explains briefly the methodological steps followed throughout the research, commencing by literature review, analysis of drivers and gaps, planning and framework development, parameterization of framework into computational equations, application of created model and finally assessment and recommendations of findings and proposals.

Table 1 Methodological approach of the research. Source: Author



The study is primarily based on literature review and intensive research in an attempt to acknowledge the state of the art in all the integrated sub topics related to the concept of climate responsive planning for the MENA region. The research is commenced by conducting an extensive literature review on the reciprocal impact between the climate change and the built environment, mitigation and adaptation strategies, and resilient cities features. After discussing the different arrays in the topic of climate change the next step was studying the extent of integration of Climate parameters in the planning process in the MENA region.

The first section of the research stimulates a debate on the vital challenge of climate change and the inevitable effects. The next phase of the research is focusing on mapping the risks of climate change globally and specifically on the MENA region climatic conditions studied

previously in the young cities project following the Köppen classification (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23). Then the magnitude of the impacts is observed in relation to urbanism, people and economy.

The second section discusses strategies to withstand the changing climate by arguing that overlooked synergies between mitigation measures and adaptation measures are the pivotal approach to reach climate change resilience.

Subsequent to the literature review is the analysis phase which aims at identifying the gaps found in the literature. This section emphasizes on finding the golden thread for resilience by closely investigating the stratum interdependencies related to building climate resilience. . In this section the discussion revolves around the higher potential of resilience pillars that could have a massive effect on all changes caused by climate change and which could lead to a more widespread influence and control on all levels. Spatial planning and urban energy systems are argued to have the most potential to act as a common ground for the possible synergies between mitigation measures and adaptation measures to reach a resilient status. The next section in the analysis phase is concerned with the sector potential stamina and capacity to endure change this includes framework policies, constraints and opportunities of the major sectors impacted by climate change and at the same time could have an impact on this change.

Post the analysis phase is the planning phase. This section constructs a framework which incorporates innovative assessment tools with a participatory, local values-based methodology to follow when taking action against the changing climate. The framework identifies the scope of the current situation by involving the competent stakeholder and performing vulnerability assessment. Then it tackles the issue of needs and priorities to reach the objective desired. Finally it raises the topic of action planning, by providing options and scenarios and assessing them.

A model for the ARM'D City (Adapted, Resilient, Mitigated development of the City) is the first outcome of the parameterization section. The model first clarifies the included climate change parameters, then it co-relates it to the impacts and potential strategies.
The overall objective of this model is to create a user friendly software application which could facilitate the inclusion of adaptation, mitigation and resilience measures in the planning process of cities by presenting several alternatives along with their technical and spatial

features along with their feasibility, affordability and applicability to each urban scale in the city. This section is composed of two phases; first creating a database for measures - and sorting them into possible synergies' packages - and investigating their technical applicability, the second would consist of evaluating the achievability and applicability of the proposed measures.

To put the model into action, a case study was chosen as a pilot ARM'D City. This section begins with the analysis of threats facing Egypt and specifically the Northern Mediterranean Coast. The case study was chosen based on the vulnerability of the location, people and sectors. Testing the tool begins by declaring the parameters, then the generation of various scenarios for mitigation, adaptation and resilience based on the input data. Afterwards a stakeholder awareness and acceptability survey is conducted on the city of Alexandria the largest city on the Northern Mediterranean Coast of Egypt.

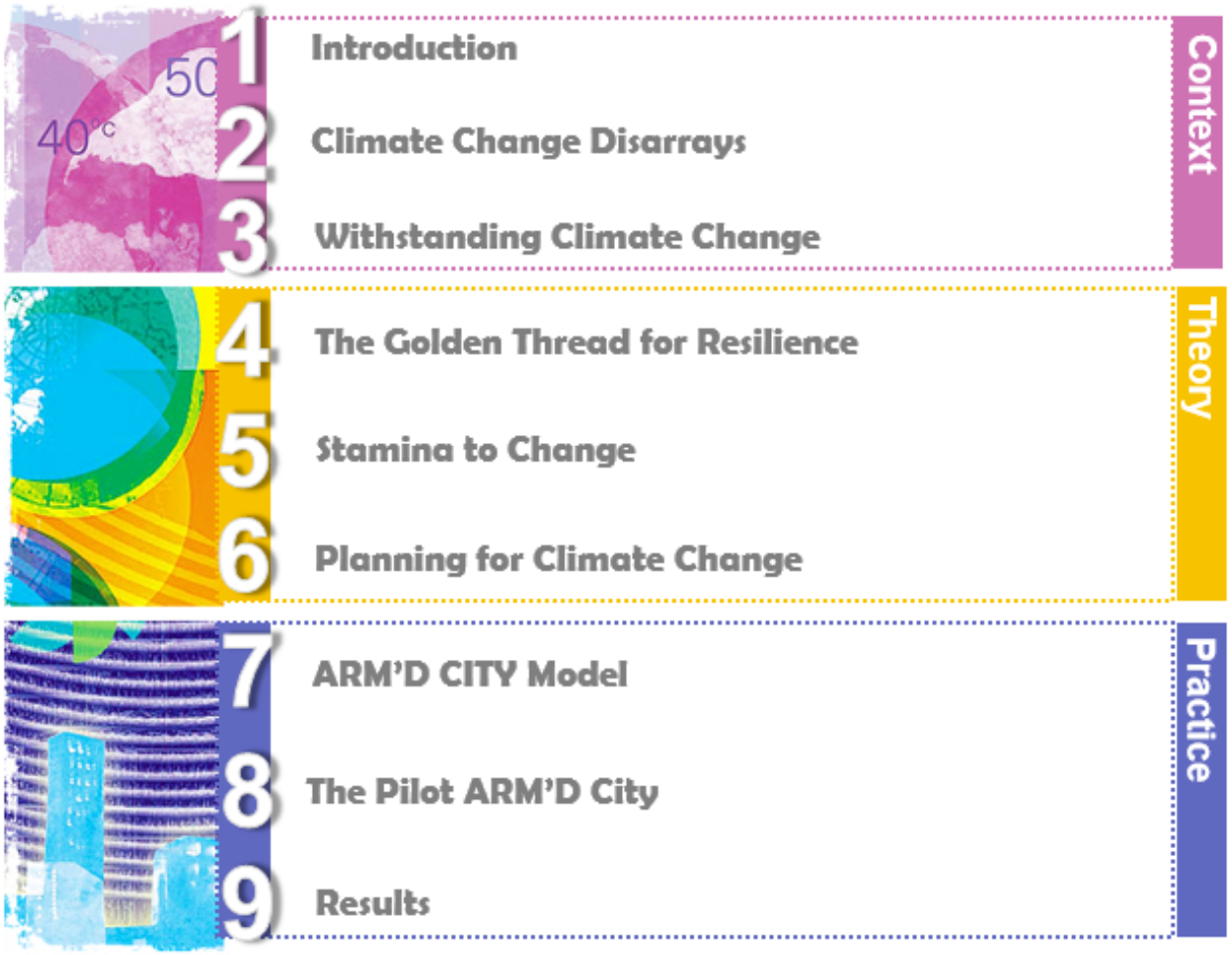
A final assessment is conducted to illustrate the viability of implementing the proposed measures by comparing the achievability of the proposed measures according to the impact of putting it to action, the assumed cost range, the responsible entity for implementation, the scale of application and the timeframe needed for the action.

There were some limitations facing the research process, some of which managing to maneuver around was possible, while others remained obstacles. The main limitation was the gap between theoretical framework and developers' practice, for a building cannot adapt in reality to climate as it does in a theoretical model. Other limitations were the lack of resources such as enough literature on sub topics which have only been studied in the past fifteen years which is parametric urbanism, as well as limited detailed application using this approach as it is still undergoing research. All this narrowed the scope of this thesis to theory and detailed guidelines, and limited the computational application.

1.5 Outline

The research is divided into three core interlinked sections as illustrated in Table 2; context, theory and practice, each comprises three sub-chapters. The first section is concerned with setting the context and highlighting the challenges behind the topic by giving an overview of the current disarrays of the climate change debate. The second section is related to the hypothesis of the research and the argument raised by discussing the potential of various approaches and strategies to act as a theoretical framework for closing the resilience gap in a city's development. The final section is the concrete outcome of the research which is developed by putting the theoretical framework from the previous section into practice and application by creating a model and a decision making tool for resilient cities. The final upshot is the ARM'D City Model that is applied on the city of Alexandria in the Northern Mediterranean Coast of Egypt and is easily replicable on other regions as well.

Table 2 Outline of the research. Source: Author



The following Table 3 describes the structure of the nine chapters. This table gives a brief and clear explanation of the aims and outcomes of each chapter. It also shows the logical linkage between each chapter and the subsequent one and how the conclusion from each chapter feeds in the following one in a rational sequence.

Table 3 Structure and description of the chapters forming the research. Source: Author

Chapter	Description
Context	
1. Introduction	Overview of the background of climate change challenges, objective, scope and methodology of research.
2. Climate Change Disarrays	Literature review on the challenges, global risks of climate change, MENA region conditions and Impacts of climate change on urbanization, People and economy.
3. Withstanding Climate Change	Analysis of literature review on strategies to resist Climate change to identify the gaps in the resilience, mitigation and adaptation actions.

Theory	
4. The Golden Thread for Resilience	Finding the golden thread for resilience by closely investigating the stratum interdependencies related to building climate resilience. In this section the discussion revolves around the higher potential of spatial ad energy pillars in having a massive effect on all changes caused by climate change.
5. Stamina for Change	Identifying the capacity to endure change this includes framework policies, constraints and opportunities of the major sectors impacted by climate change and at the same time could have an impact on this change.
6. Planning for Climate Change	Development of a framework that identifies the scope, the competent stakeholder, vulnerability assessment, needs and priorities, and provides scenarios and assessing them.

Practice	
7. ARM'D City	A model for the ARM'D City (Adapted, Resilient, and Mitigated development of the City) which is a user friendly software application that could facilitate the inclusion of adaptation, mitigation and resilience measures in a city's planning process.
8. The Pilot ARM'D City	Analysis of threats facing Egypt and specifically the Northern Mediterranean Coast. The case study was chosen based on the vulnerability of the location, people and sectors. Testing the tool begins by declaring the parameters, then the generation of scenarios and assessing their implementation for the city of Alexandria.
9. Results	A conclusion for the outcomes of this research along with implications and further research to complement this research.

2 Climate Change Disarrays

This chapter sets forth the long adopted and ongoing interpretations of the climate change dispute to offer a clear understanding of the magnitudes of the encounters that are to be faced eventually. The research argues that a climate change action should be an integrated action on a horizontal level among sectors and a vertical level across scales as it impacts a wide array of segments as it is deliberated below.

2.1 Climate Change Debate

2.1.1 The Vital Challenge

“On 9 December 2007, the IPCC (International panel on climate change) was awarded the Nobel Peace Prize for its 'efforts to build up and disseminate greater knowledge about man-made climate change and to lay the foundations for the measures that are needed to counteract such change'.” (Nobel Media AB 2019, 2019)

The award of this Nobel Peace Prize was a game changing act towards the international acknowledgement of the implications the climate change on human stability. It was an alert to prioritize addressing these impacts in the international and national development policies. Since then climate change has been widely recognized as the current vital challenge facing the globe. The publishing of the fifth assessment report from the international panel on climate change (IPCC), the broad acceptance of local agenda 21 and the impact of the international council for local environment initiatives (ICLEI) on encouraging municipalities to reduce greenhouse gas (GHG) emissions, are all a tangible proof that there exists a general consensus on the fundamental steps that needs to be taken at both; the national and international levels. (Hamin & Gurran, Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia, 2008, p. 238)

The fundamental interpretation by climate scientists about the reality of the significantly changing climate was to consider it as a sheer environmental problem. In the past twenty years this perception has changed intensely when the political and media started focusing and highlighting the impacts of this change in climate and the necessary mitigation and adaptation measures (Grundmann, 2007). After this, the climate change was not a concern for the climate scientists only anymore but it evolved to be a human-influenced development

issue. A shift from a sole natural science research approach to a multidisciplinary research approach by integrating natural and social scientists with decision makers and society to support sustainable development (Weingart, Engels, & Pansegrau, 2000, p. 264).

Over the past decades, the average annual global temperatures have been elevating to stages that were never paralleled before in the last thousands of years as seen in the following graph in figure 3. Researchers explain that this is due to human interference, and that the burning of fuels has been the major contributor to the over emission of Greenhouse gases (GHGs) which create a trapping layer around the earth's atmosphere that holds in the warmth of the sun. GHGs don't dissipate but instead they accumulate and this will keep the temperatures rising further in the future. This elevation in temperatures will result in two main phenomena that will highly affect the natural systems as well as the human built up systems. The first phenomena is the melting of ice bodies that will lead to the sea level rise and consequently the submerging of coasts and nearby land. The second one in the changes in the weather patterns globally, and this is currently occurring and could be seen in the higher incidents of droughts, flooding, landslides and wildfires (Condon, Cavens, & Miller, 2009, p. 5).

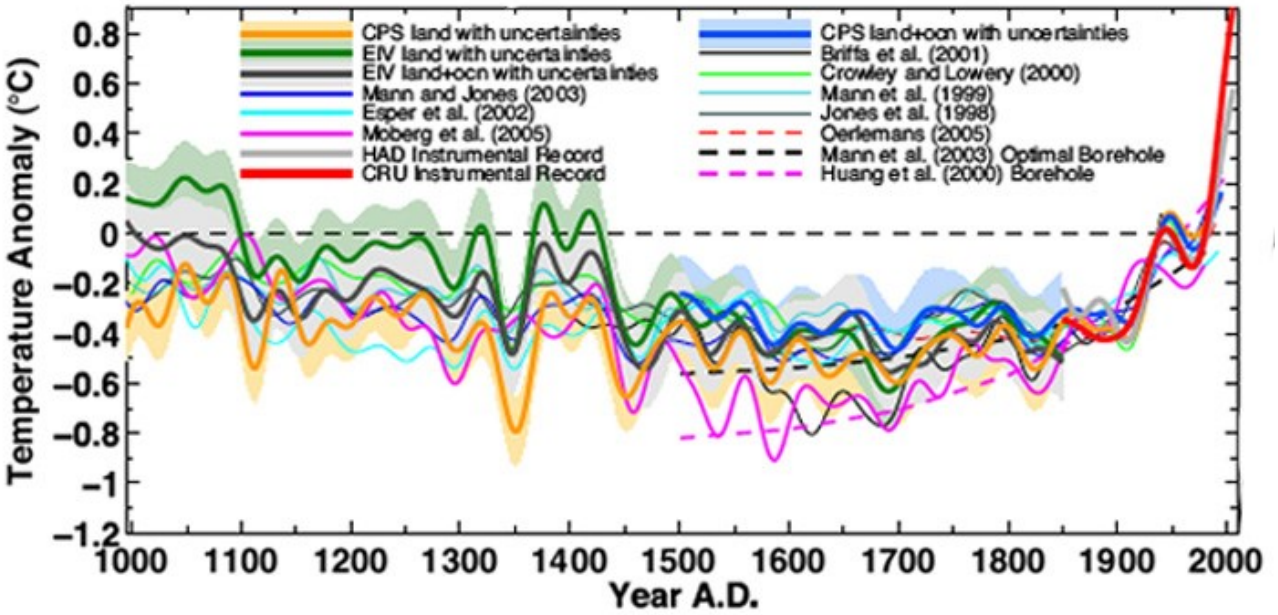


Figure 3 Graph for temperature trends in the past decades. Source: (Schmidt, 2008)

Studies presume that the temperatures will increase rapidly in the coming forty years because of the accumulation of GHGs, and the increasing populations in urban areas. The scientists claim that no matter what actions are done to face these changes an inevitable rise in temperature of one to two degrees Celsius by 2050. This change will definitely have a direct

impact on food supply, natural hazards and economic activity of vulnerable areas and communities (Condon, Cavens, & Miller, 2009, p. 8). The biophysical challenges initiated by the changing climate have a massive impact on cities and the built environment, and the inhabitants as well. As a result planners are responsible for developing policies and programs that can be responsive to future impacts caused by the changing climate.

2.1.2 The Inevitable Effect

Climate change is explained as the changes that happen to the average weather and the inconsistency of the weather patterns of a specific region or the whole planet over an interval of time. These changes are very observable in the temperature, precipitation, wind, storms and sea level rise. However the core indicator that scientists consider to measure the climate change is the average surface temperature of the earth. Over the last half century the Earth's average surface temperature increased by 0.65°C (IPCC, 2014, p. 19). Another indicator is the ocean temperature due to its impact on the surface temperature. The oceans absorb most of the heat supplemented to the earth's climate, but then the oceans' flow releases the heat back into the atmosphere.

The 5th Assessment Report of the IPCC stated that human activity is the reason behind more than 95% of the changes in the last fifty years which is due to the increased greenhouse gas concentration. The dominant cause of increasing the global surface temperature is the burning of fossil fuels and land use change. Both caused an elevation in the carbon dioxide level in the atmosphere (IPCC, 2014, p. 6).

The report also predicted an increase by 0.3 degrees to 4.80 degrees Celsius by the end of this century. This range is highly depending on the actions taken by governments to mitigate this change by controlling the greenhouse gas emissions. The changes in the temperature and the precipitation are leading to increased drought, storms, sea level rise and coastal flooding and erosion. These impacts vary between different regions, but still this variation is uncertain and is still undergoing research. The changes caused by climate will definitely have a severe impact on the human settlements all over the world but particularly the low and middle income countries as they are more vulnerable and have limited capacity to manage and cope with this change (IPCC, 2014, p. 27).

The following figure 4 illustrates the effect of the greenhouse gas emissions worldwide. It shows a comparison between the baseline status and the projections of current policies and pledges.

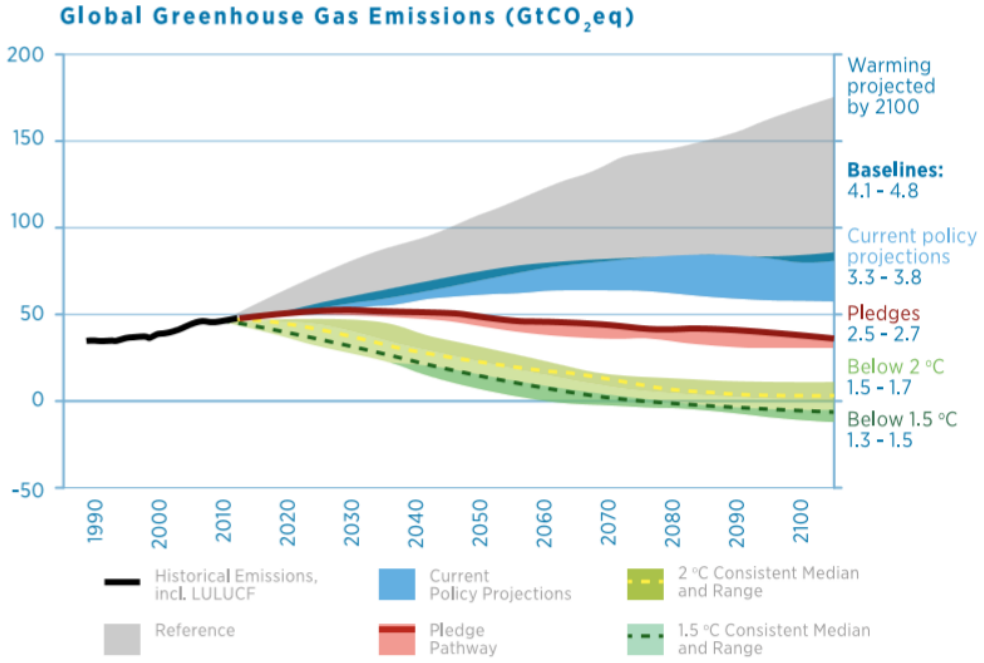


Figure 4 Effect of Current Policies on Global Temperature, Source: Climate Action Tracker 2015

2.1.3 Key Principles

A need to define the common terminology used when discussing the climate change phenomenon is mandatory to overcome any confusion when assessing a country's situation or a social group's status in responding to the changing climate patterns. Most terms used in this guide are based on those used by the Intergovernmental Panel on Climate Change (IPCC), and by the United Nations Framework Convention on Climate Change (UNFCC).

Climate change is defined as the change in climate patterns due to natural or manmade actions and activities that causes a change in the atmosphere in a directly or indirectly over a certain period of time. The climate change impact refers to the effect caused by these changing patterns on the structure and function of a city. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2018, p. 24).

Exposure explains how a city is exposed to climate change, it considers current and projected changes based on the analysis of previous and existing climate data as temperature,

precipitation and extreme weather. It also detects the hazards that result from this change in climate as floods, droughts, storms and sea level rise. The exposure also includes the changes between current and future magnitudes and frequencies in coastal erosion, landslides and ground water depletion (UN-Habitat, 2014, p. 18) (IPCC, 2018, p. 24).

The degree of Sensitivity is the extent to which people, places and sectors are already affected by climate change and the degree of future impacts. The sensitivity analysis is directly linked to the physical facts as the drainage design and technology limitations, the social facts as the poverty level and the economic status as the unified livelihood and income sources (UN-Habitat, 2014, p. 18) (IPCC, 2018, p. 24).

A difference between the risks a country or city is facing and its resilience needs to be framed. The risk is derived from the impacts of the changing climate. It is the extent of hazard that threatens a country or a social group and is directly related to the external factors of the change in climate patterns (UN-Habitat, 2014, p. 18).

On the other hand the resilience is defined as "The ability of a city or town and its citizens to withstand impacts and rebuild or reorganize itself when necessary." (UN-Habitat, 2014, p. 18)

This brings us to the adaptive capacity of a city or community which is explained as the degree to which people, places and sectors are able to adapt to the impacts of the changing climate. Several indicators are used often to determine the adaptive capacity which are environmental indicators, socio-economic indicators and local facts that helps the city to modify its system in accordance to existing and projected risks of climate change. These indicators could point out positive impacts resulting from the change in climate as new urban agriculture activities leveraging due to more precipitation for example (UN-Habitat, 2014, p. 18) (IPCC, 2018, p. 24).

2.2 Mapping the Risks

2.2.1 Global Risks

An interactive map of climate risk, which is shown below, has been created by David Wheeler (Wheeler, 2011) at the Centre for Global Development (CGD) that covers most of the world's countries across four segments: Extreme Weather, Sea Level Rise, Agriculture Loss and Overall risk.

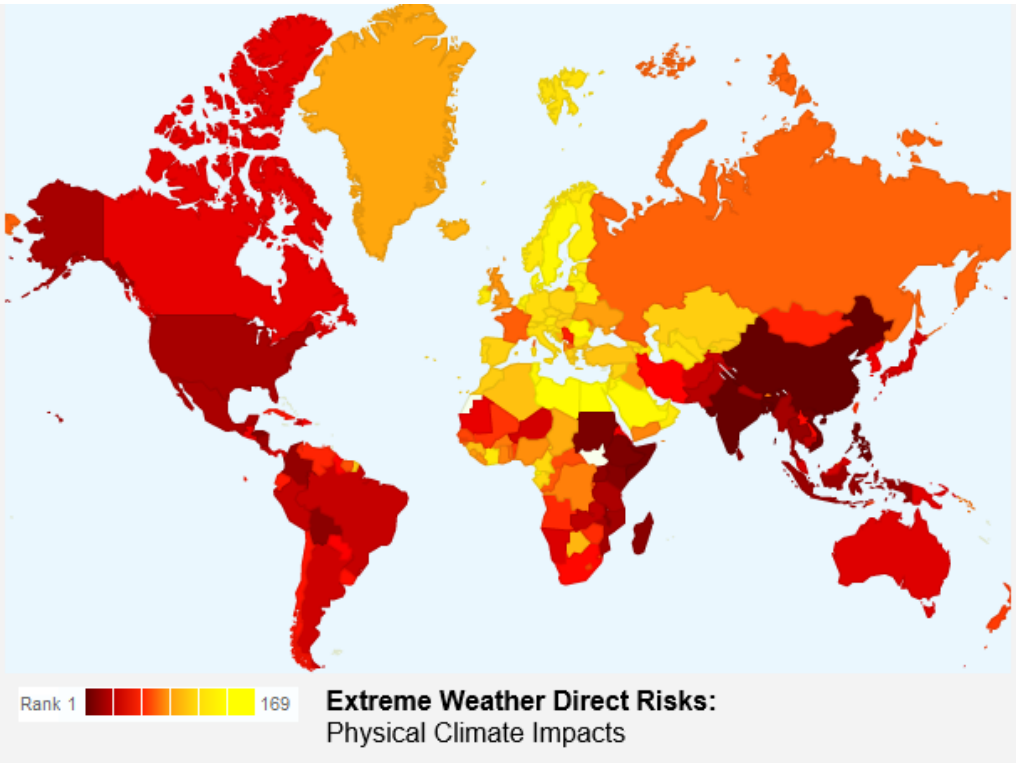


Figure 5 Extreme Weather Direct Risk: Physical Climate Impacts. Source: CDM, 2011
the study was conducted on 169 countries, rank 1 is the highest country and rank 169 is the lowest country.

Extreme weather is any unexpected changes in weather patterns. These changes are unfamiliar as they reach extreme extents compared to the past trends and patterns. Each location has a recorded weather history to help determine the suspicious and sudden changes in the future and these extreme weather events are classified under the uncommon ten percent in the predicted weather conditions (Wheeler, 2011).

The extreme weather impacts map shows the South East Asia as the most vulnerable area, and then comes the Americas as the next affected area, while the MENA region is shown as a less affected zone by comparison to the previously mentioned zones.

Addressing present problems while considering the future: looking beyond existing challenges and considering their future impact is necessary in the planning processes. The planning should address the current needs but also bring future scenarios into the process of decision making.

The resilient city is characterized by specific qualities described below (Rockfeller Foundation, 2019):

- **Reflective:** resilient communities and institutions support mechanisms that constantly modify standards based on emerging indications, instead of adopting permanent solutions based on current stresses only.

- **Robust**: The city systems are designed to survive the impacts of extreme changes and evade the collapse of the city. The system foresees system failures and makes necessities to ensure safety.

- **Redundant**: It is the planning capacity with considerations for increasing demand, in which other components of the system can substitute for failing components.

- **Flexible**: A city with systems that can evolve and embrace alternative scenarios in response to changing conditions. This system adopts decentralization of conventional infrastructure with new technologies.

- **Resourceful**: Communities and institutions invest in predicting future scenarios and define their needs and priorities, and mobilize and combine the resources (human, financial, and physical). This prepares the city to be more responsive to sudden and extreme situations.

- **Inclusive**: A city can't be resilient in isolation; it needs joint ownership and engagement

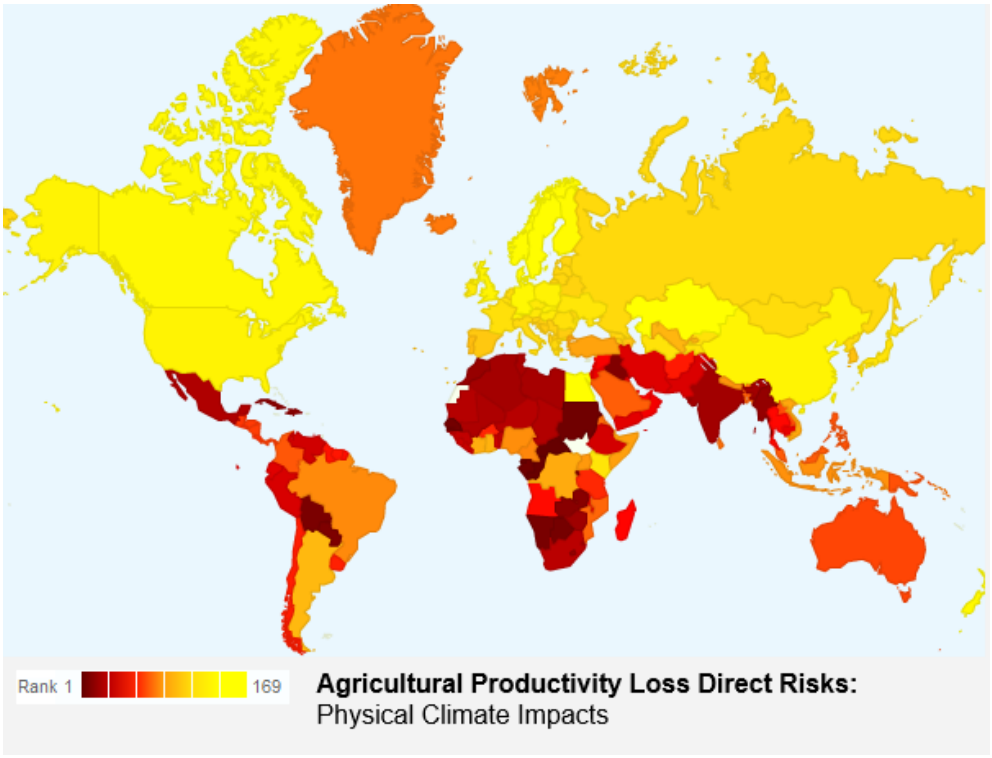


Figure 7 Agricultural Productivity Loss Direct Risks: Physical Climate Impacts. Source: CDM, 2011
the study was conducted on 169 countries, rank 1 is the highest country and rank 169 is the lowest country.

One of the most crucial impacts of the changing climate patterns is the Agricultural Productivity Loss. The consequences of such a loss are directly linked to human lives. It has an impact on the food security, economic situation and social lives of inhabitants as well as the physical properties of land.

The changes in temperature and rainfall patterns as well as the unexpected heat waves that occur and the sea level rise are all causes for the agricultural productivity loss. The most vulnerable areas to this loss are the areas in low latitude. As shown in the map the southern hemisphere is facing the highest risk in impacts regarding the agriculture sector with the MENA region as an extremely threatened region (Wheeler, 2011).

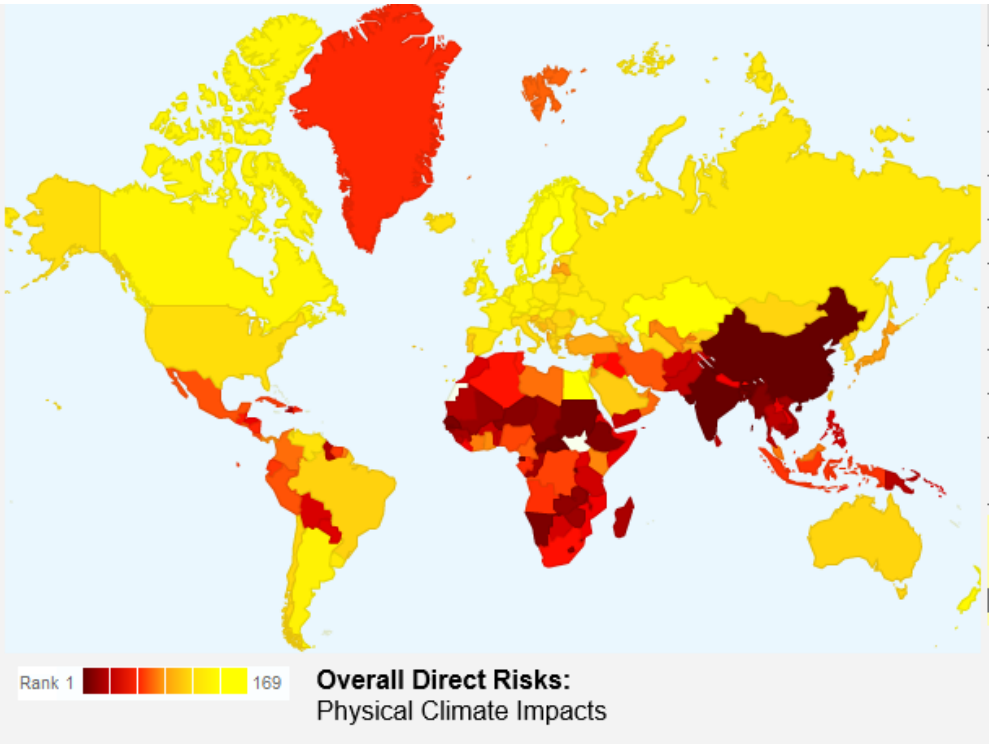


Figure 8 Overall Direct Risks: Physical Climate Impacts. Source: CDM, 2011
the study was conducted on 169 countries, rank 1 is the highest country and rank 169 is the lowest country.

The overall direct risks are shown in the previous map by layering all maps explained above. The MENA region is highlighted as an area of high risk ranking which could also increase when considering the adaptive capacity of each country as the countries of the MENA region are not capable of coping with the extreme weather events that might occur whether it's the people, structures or systems (Wheeler, 2011).

2.2.2 MENA region conditions

Taking a narrower scope than that of the whole globe, the MENA region with its arid and extremely variable climate is predicted to face an even hotter and drier climate according to IPCC's third assessment report (IPCC, 2001, p. 800). Moreover, heat waves, which are an increased heat island effect, water scarcity, decreasing water quality, worsening air quality, and ground ozone formation, are expected to lead to challenging unhealthy living conditions (World Bank, 2019).

A brief outline of the climatic conditions of the region is illustrated in the following maps which were created as part of the young cities joint research project between Germany and Iran (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23), showing the

dominant climate classification if the region, as well as the predicted changes in the mean temperature and precipitation.

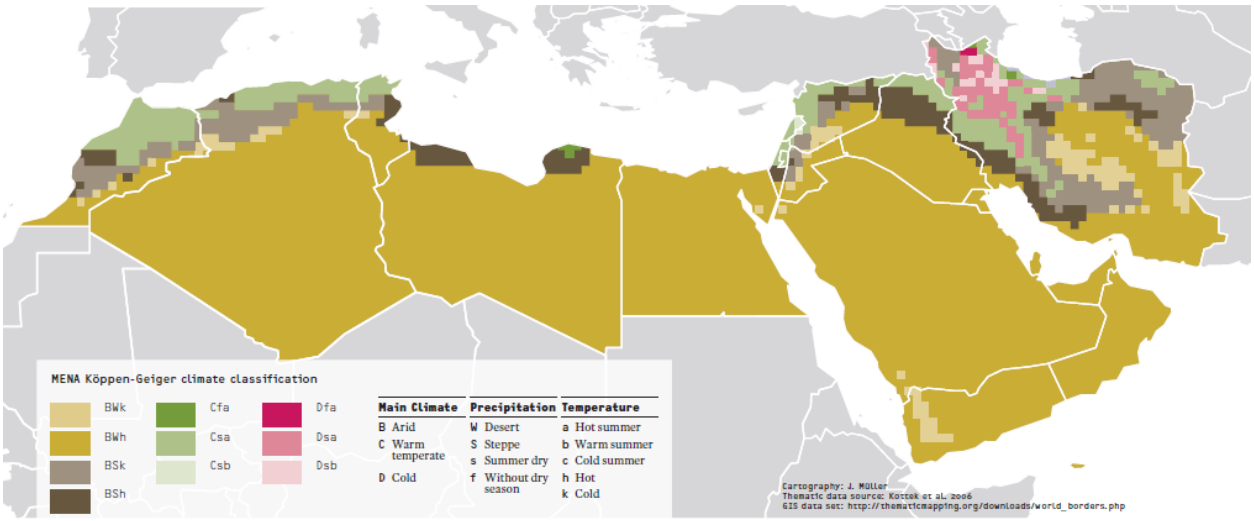


Figure 9Climate conditions of the MENA region. Source: (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 22)

Following the Köppen classification, as in the map above (Köppen 1900), the climate in the MENA region is dominantly arid, but there are also warm temperate regions and cold ones. Nearly 70 % of the MENA region is characterized by an arid climate, nearly 30 % by a warm temperate climate (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23)

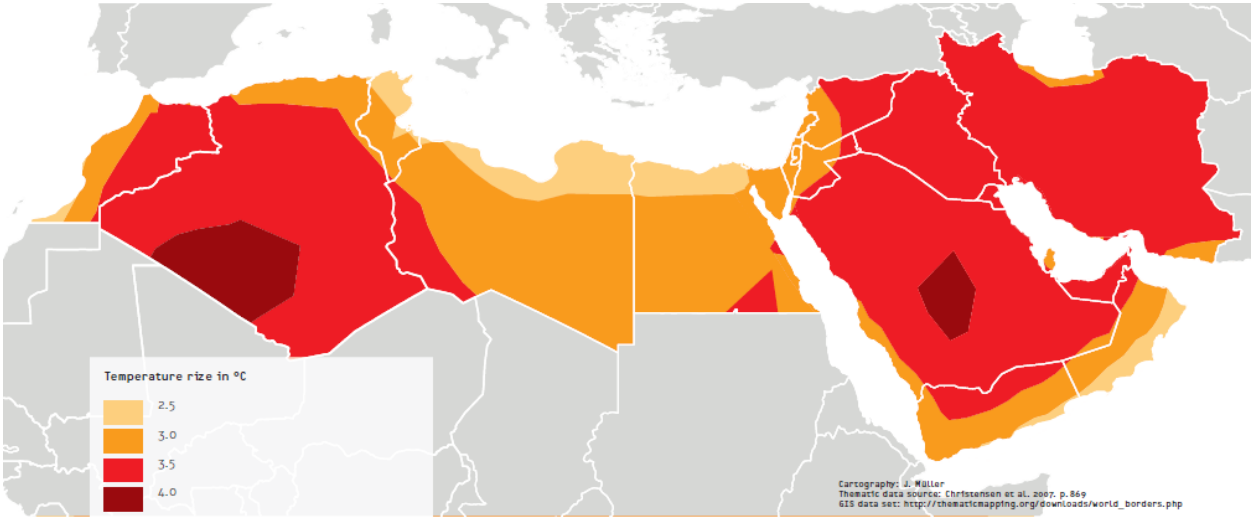


Figure 10 Annual mean temperature changes. Source: (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23

The previous map illustrates the predicted climate changes for the MENA region between 1980–99 and 2080–99, averaged over 21 simulation models based on Christensen et al. (2007). According to the IPCC, temperatures for the region are expected to increase by 3 to 4 °C from the 1980–99 average by 2080–99 (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, &

Seelig, 2013, p. 23)

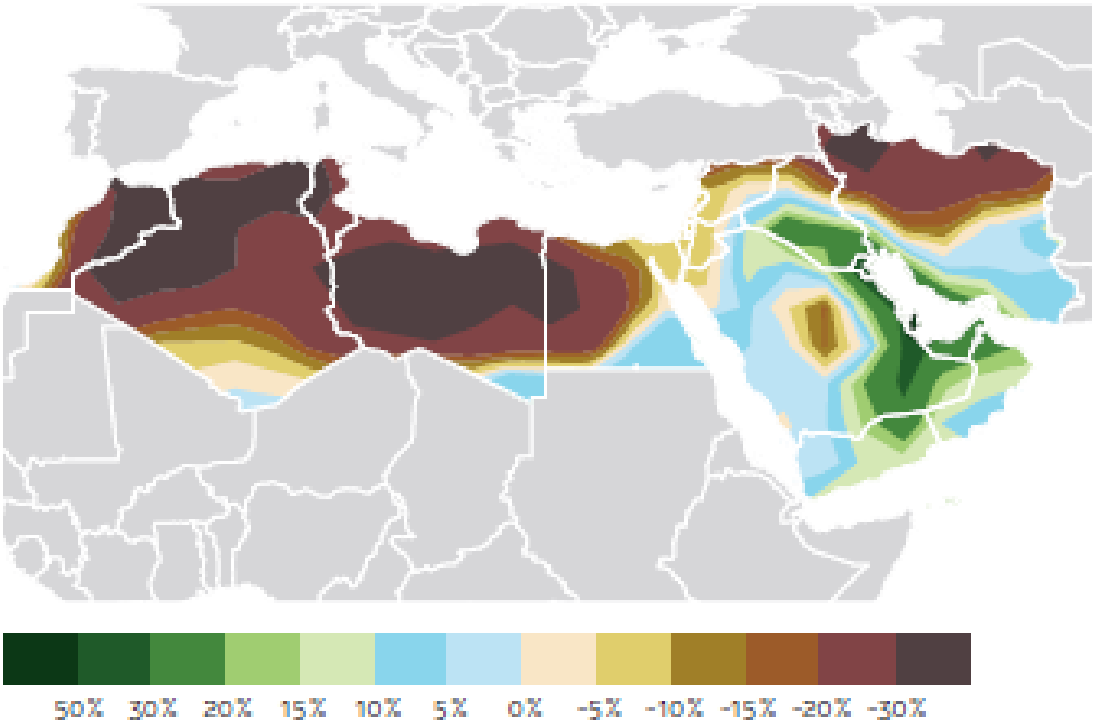


Figure 11 Summer precipitation changes. Source: (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23

As demonstrated in the previous map, the MENA region shows variability in both seasonal and annual precipitation, North Africa will experience a 20 % decrease in mean precipitation by the end of the 21st century, while in Central Asia an increase of 4% precipitation in winter, and a decrease of 13% in summer is expected (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23).

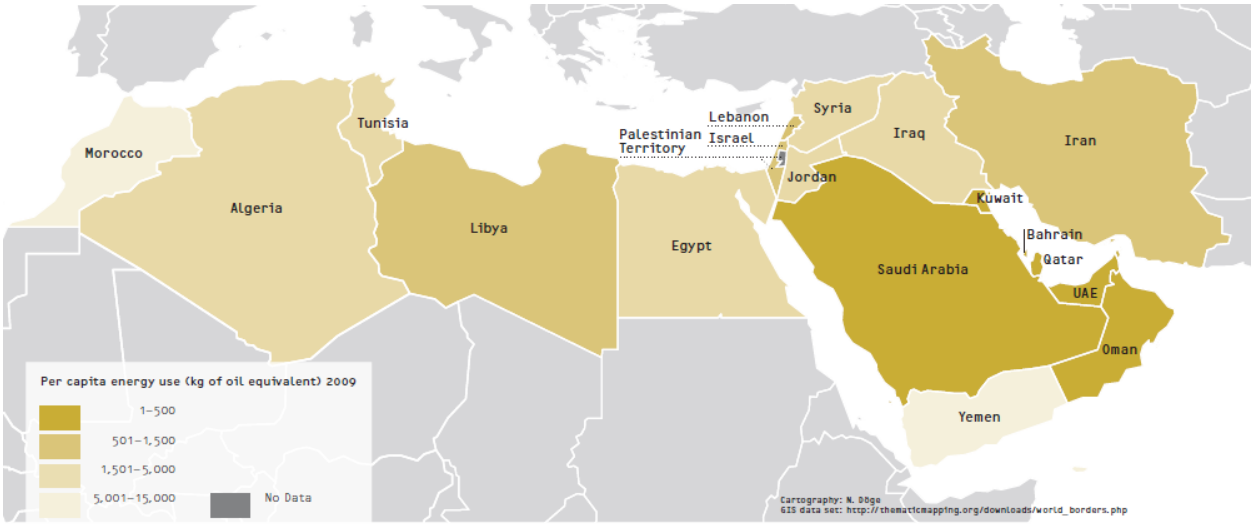


Figure 12 Energy consumption map. Source: (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 20)

The map shows the energy consumption for the whole region. In most MENA countries energy prices are subsidized which led to high energy consumption, harsh environmental problems, and a rapidly increasing load on government finances (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 23).

In summary, the cities of the MENA region have been challenged with several transformations over the past years. These changes are characterized by rapid urbanization, environmental degradation, individual oriented motorization, water scarcity, shifting climate conditions, and an increase in energy consumption and resulting CO2 emissions. As a result, urban settlements confront a massive pressure to adapt to these conditions. This requires an instant intervention s in the urban infrastructures to enhance the city's capability to cope with future urban challenges (Kuhla von Bergmann, Ohlenburg, Pahl-Weber, & Seelig, 2013, p. 30).

2.3 Impacts

2.3.1 Impacts magnitude

Climate change threats are not only concerned with the built environment but also the people living in cities are affected as well. Climate change impacts are categorized as primary, secondary and tertiary impacts. The primary impacts are the ones that are directly caused by hazardous climate events while the other categories are often results of the primary ones. Primary impacts could be explained as the physical impacts of climate change for example; flooding and landslides. Secondary and tertiary impacts are usually linked to socioeconomic impacts (UN-Habitat, 2014, p. 27). However these impacts are not equivalent on all areas and all communities as seen in previous maps. This wide variation of climate change impacts is linked to other external factors which are:

Geographic location

The whereabouts of the area is a key indicator of the impacts that might potentially threaten it. It will give an overview to the changes in the climate patterns over the area which will determine general exposure to climate change and the severity of threats (UN-Habitat, 2014, p. 28).

Specific geographic features

The location solely is not a comprehensive indicator, but also the characteristics of the geographic location gives a more clear understanding of the expected impacts in areas. For example, the coastal locations differ from the river deltas which in turn differ from arid areas and so on (UN-Habitat, 2014, p. 28).

Sensitivity to climate change hazards

The sensitivity of an area can be determined by observing the scale of development on high risk areas such as unstable slopes, flood prone areas and storm exposed lands. Another element is the quality of infrastructure in such areas whether they are built according to standards or are informal settlements with no construction criterions (UN-Habitat, 2014, p. 28).

Vulnerable populations

Aside from the built environment, the communities are an important influence in determining the potential impacts and threats over an area. The vulnerable groups such as the poor societies, the women, the children and the elderly which are living in areas of high risk are more likely to be affected by climate change impacts than other groups. These populations have less adaptive capacity and less resilience to stand up and cope with the predicted changes due to their limited resources (UN-Habitat, 2014, p. 28).

2.3.2 Impacts on Urbanization (Built Environment)

The key impacts that are facing the MENA region according to all previous maps and illustrations are increased flooding, increased heat island effect, and water scarcity. Although there are more impacts that could result from the changing climate, these impacts are the most threatening ones to the MENA region.

Flooding:
Firstly, the flooding phenomenon could be increased in three ways; sea level rise, increased rainfall, and increased river flooding.

Sea level rise: According to the United Nations it is expected that the sea level could rise an average between 18 cm and 59 cm. This increase is due to the melting of the polar ice on one

hand and the increased warming of the oceans which in turn increases the volume of the oceans on the other hand. The impacts of the sea level rise vary according to several factors as location, altitude, and level of adaptation and resilience a coastal region has reached. An estimated thirteen percent of the world's population lives in low altitude coastal areas below ten meters above sea level. This percentage represents the vulnerable percentage of the urban population prone to sea level rise unless action is taken by urban planners to build coastal defenses as sea walls, or preserved protective coastal areas like forests, as well as mapping the hazardous locations to be avoided during development (UN-Habitat, 2014, p. 30).

Increased rainfall

Extreme weather events are expected to include heavy rainfall with increased magnitude and frequency than past weather records in some regions of the world. The increased rainfall will cause flooding in areas that are not prepared for such a hazardous event, where large impermeable surfaces as paved areas and buildings exist. Another factor to consider is limited storm drainage systems which will be flooded during such an event, and open sewage systems which are potential causes of health issues and water borne diseases (UN-Habitat, 2014, p. 30).

The impacts of the heavy rainfall will vary between different regions based on the forecast of each location as well as the level of development of the area. Therefore all development plans of urban areas must encompass storm water systems that are able to face the increased rainfall patterns such as infiltration areas, pervious surfaces, impoundment areas, rainwater gardens (UN-Habitat, 2014, p. 30).

Increased/intensified river flooding

As a result of the changing rainfall patterns increased river runoff and overflowing occurs especially in low altitude areas surrounding the river banks or river deltas. Urban planners must take into consideration the flood plain and control the development in high risk areas, the land use plans should regulate the type of development in these areas and also explore other flood management systems (UN-Habitat, 2014, p. 30).

Water scarcity:

In many urban areas access to potable water is not widely available over the globe, as well as the availability of sanitation systems. Adding to this the future projections of climate change

it is argued that by 2020 a range from 75 million to 250 million people could be suffering from water shortages in each of Africa and Asia as well (UN-Habitat, 2014, p. 32).

The climate change driven water scarcity will origin from the impact on freshwater sources which will increase decrease the available supply. Another factor is the increasing population in the urban areas which is already stressing out the infrastructure systems in cities and towns and increasing the demand segment (UN-Habitat, 2014, p. 32).

The intensity of expected impacts in the water sector varies broadly depending on the location, level and scale of development of the city, the type of water supply for the urban area, the consumption patterns and rates and the efficiency of existing water management systems. Development plans of cities should address the topic of water scarcity and induce water conservation schemes that include reuse of non-potable water in irrigation or ground water recharge as well as implementing rain water capturing systems.

Heat island effect:

Another ultimate impact of climate change is the increase in temperatures especially in the southern continents. The studies expect more frequent heat waves to hit urban areas as a result of the change in climate patterns. These high temperatures are associated with the phenomena of the urban heat island effect; an incidence resulting in urban areas where buildings, paved areas and other infrastructure absorbs and preserves solar heat, which results in increasing the city's temperature with a several degrees that the surrounding non built up and rural areas which have less covering materials that retain the solar heat and more green areas (UN-Habitat, 2014, p. 33).

The effect of the heat island is interrelated to many aspects as well as any other impact of the changing climate as the location and scale of development and the covering surfaces of the city. Urban planners have to assist in mitigating the heat island effects by developing newer types of constructions and materials, developing urban forestry and green surfaces projects within the city (UN-Habitat, 2014, p. 33).

Ecosystem and biodiversity loss

Losses due to the changing climate could be considered the highest for the ecosystem category however uncertainties border these impacts because of the difficulty of measuring them and the limited research in this specific area. In general there exists a risk of extinction for some species. The loss would be due to several reasons, first the changes in the habitat and its nature, second the changes in the predator/prey relationship, third the migration of forests which is considered a key reason for species extinction (Kapos, Scharlemann, Campbell, Chenery, & Dickson, 2008, p. 22).

2.3.3 Impacts on People

Climate change is not only affecting the physical environment but there are many impacts on the human lives that are accompanied with the severe changes in the weather patterns. Therefore it should arouse the attention of the whole society not only scientists, urban planners, and decision makers. Efforts should be exerted by each individual to overcome the social impacts of the changing climate as applying adaptation measures is not a top down approach.

Human amenity

The primary observable societal impact would be the comfort of the people residing in the affected areas. Even the basic needs of humans will not be fulfilled. Food supply will be reduced and access to healthy safe food would be nil. Water shortages as well will spread widely causing dehydration and other associated well-being disorders. The treatment to wastewater will not be sufficient and a need for additional wastewater treatment will be a pressing issue especially in developing countries where funds to support such actions are limited (UN-Habitat, 2014, p. 35).

As a result from the extreme changing weather patterns an escalation in the urban heat island effect is expected. This will definitely call for an increase in energy demands of the population. The overall comfort of human beings will be dysfunctional (UN-Habitat, 2014, p. 35).

Health

The impacts concerning health of human beings could be direct as in direct deaths due to heat waves, or indirect by vector borne infectious diseases. However the impact would vary between different communities based on the level of natural, social and technical capabilities of each local society. For example; the population density, the nutritional status, the level of development of the surrounding area, the socioeconomic situation among other factors, will define their vulnerability (Smith, et al., 2014, p. 716).

The indirect health impacts could by far exceed the direct loses. Some of the expected increased vector borne diseases are malaria or yellow fever, as their insect vectors adjust to new climate conditions.
Other diseases could be associated with poor sanitation standards and decreased access to food and nutrition; and clean water as well. Particularly developing countries are more vulnerable to these vector borne diseases (malaria, dengue, encephalitis), and water borne diseases (acute diarrhea, cholera, dysentery) (Smith, et al., 2014, p. 725)

Titus (1992) and Nishioka et al. (1993) discussed the potential health damages that could arise from water pollution. Whether it's a decrease in the water quality due to increase algae, a decline in river flow due to lesser runoff of water, or a decreased level of dissolved oxygen in water due to higher water temperatures, the damage is certain (IPCC, 1995, p. 191).

Mortality caused by climate change is expected to increase with the Increasing pollution which causes respiratory diseases as well, also extreme heat waves and extreme cold are considered dominant factors in increasing deaths rates. The developing countries are more vulnerable to the increasing mortality effects, this is due to the lack of or limitations in mitigating technologies and strategies (IPCC, 1995, p. 195).

Migration

The impacts caused by the extreme changes of climate could lead to the displacement of millions of inhabitants. It is assumed that around 1.5% of world's population would migrate

in 2050 due to changes like coastal erosions and flooding, severe drought and decline in the quality of soil (Brown, 2008, p. 25).

Pressure lying on the people forced out of their lands due to these changes could be translated in the loss of almost three times the average annual income per capita. However another imminent pressure would lie on the recipient host countries, the cost of integrating the immigrants into the infrastructure would cause a source of pressure on social and budget aspects. Another assumption is an increase of total 35% in immigration due to the climate change (Raleigh, Jordan, & Salehyan, 2008, p. 13) (Brown, 2008, p. 29).

Distress migration is associated with other hardships and stress to be suffered by these refugees. The migration patterns would be to cities and towns due to drought in some rural areas. Not only will the displacement happen from urban to rural but also from informal settlements in hazardous lands to planned areas. Properties as homes and workplaces in coastal areas are expected to face severe damages that will also lead to displacement of population in coastal areas to more safe inlands (Raleigh, Jordan, & Salehyan, 2008, p. 13) (Brown, 2008, p. 29).

2.3.4 Impacts on Economy

The severe changing patterns in climate will not only cause physical and social changes but above all economic impacts that will affect the production and consumption rates of the nations. Every impact has as economic value that will burden the country especially the developing countries that suffer from economic issues already. The discussion below is just to highlight the major expected changes that are to face the economy due to the climate changes.

Agriculture

Agriculture sector is considered one of the major impacted economic sectors. But not all impacts should be considered negative, as it is expected that agriculture will be damaged in areas but increase in yield in other areas.

As for the negative impact it will be due to the decrease moisture of soil, the increasing heat stress, and increased pests and diseases. Also the change in patterns of rainfall and its intensity could increase the erosion of soil in some areas or could cause drought in others

(FAO, 2018, p. 17).

The positive impacts that could benefit some areas would be the longer growing seasons for some crops in some regions and the increased effect of higher carbon dioxide in the atmosphere which increases the fertilization, as these higher concentrations would take part in increasing the photosynthesis (FAO, 2018, p. 17).

Adaptation could reduce the losses in agriculture however the climate has a strong impact on land value. The value of land by implication has a strong impact on the productivity and trade practices (FAO, 2018, p. 17). The loss of productive land would definitely increase the economic stress and lead to higher food prices.

Energy

The net effect on the costs of energy is highly ambiguous and varies between different regions. The apparent impact would be the higher space cooling demands and the lower space heating demands. The arguments fluctuate between three scenarios, the first estimates that the annual cooling loads costs would increase at a higher rate than the savings from heating loads decrease, the second assumes that the overall savings in heating would approximately equal the increase in cooling costs, the third suggests that the savings on heating would surpass the increased costs for cooling. This highly depends on several factors including the location, the development level, the adaptation and mitigation strategies already implemented and others (IPCC, 1995, p. 194) (UN-Habitat, 2014, p. 26).

Most developing countries benefit from their location that conveys base climate conditions and therefore the savings from reduced heating would be limited. On the contrary the cooling demand would induce higher costs. The demand of electricity is assumed to increase by 3.2% in almost most of the regions, this will cause a direct increase in energy prices in general and especially in areas depending on hydroelectricity generation which will be reduced (IPCC, 1995, p. 194) (UN-Habitat, 2014, p. 15).

Infrastructure

The economic translation of urban infrastructure loss would highly cause pressure on developing economies. The costs of damaged properties as homes and workplaces and the

damage caused to infrastructure networks not designed to adapt and cope with the forthcoming changes is vast. The migration and abandoning of cities and towns would disrupt the economies and would put a new demand for residential land and workplaces in other locations with entirely new infrastructure, which developing countries can't afford (UN-Habitat, 2014, p. 31).

2.3.5 Impacts summary

Below is a summary of the primary, secondary and tertiary potential impacts of climate change illustrated figure 13 and detailed in table 4. The primary impacts affect mainly the urbanization segment, while the secondary and tertiary impacts are more indirect and affect the livelihood of the society and economic sectors (UN-Habitat, 2014, p. 29).

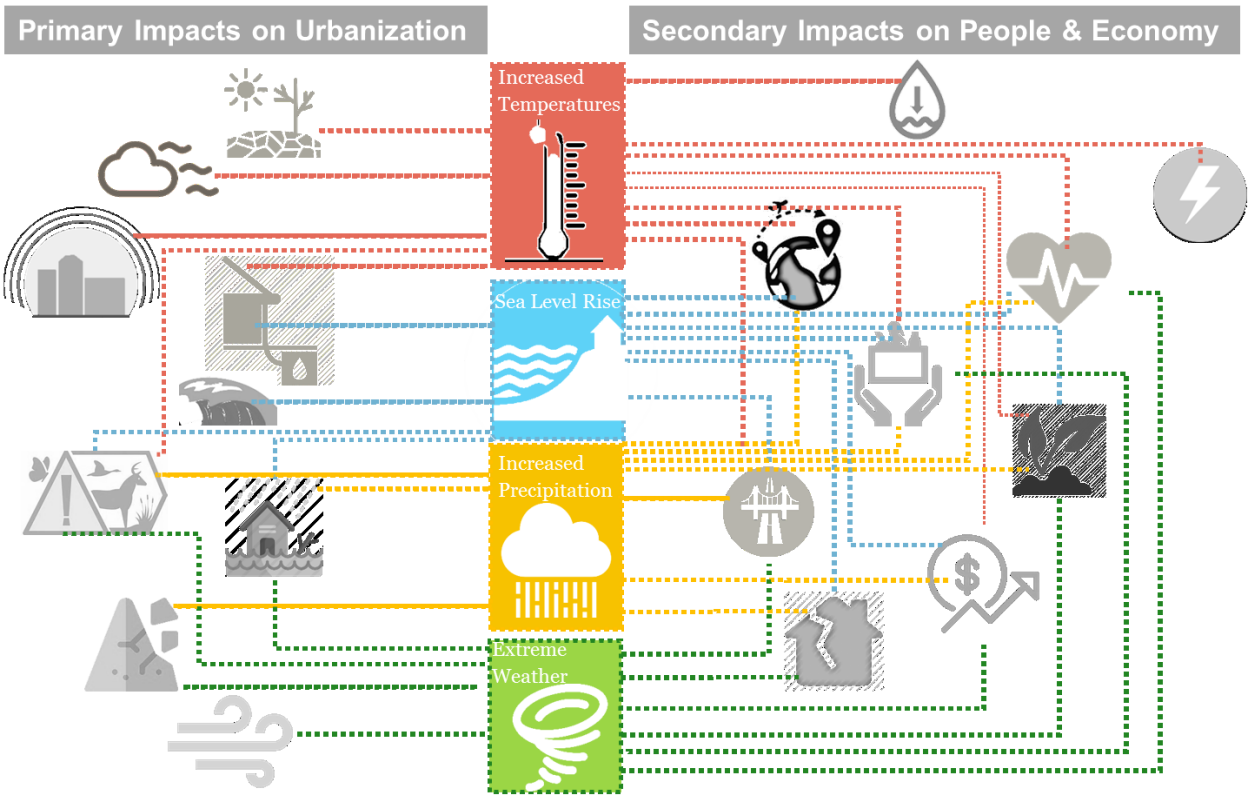


Figure 13 Impacts of Increased Temperatures, Sea Level Rise, Increased Precipitation and Extreme Weather Events on Urbanization, People and Economy. Source: Author

Table 4 Primary, Secondary and tertiary Impacts of CLimate Change, Source: UN-Habitat, 2014)

Climate Hazard	**Potential Primary Impacts**	**Potential Secondary and Tertiary Impacts**
Increased Temperatures	-- Groundwater depletion -- Water shortages -- Drought --Degraded air quality	-- Water shortages -- Distress migration -- Reduced food supply -- Higher food prices

	(smog)	-- Energy price increases -- Exaggerated urban heat island effect -- Increased energy demands for cooling -- Need for additional wastewater treatment -- Population health impacts -- Decreased access to food/nutrition
Increased Precipitation	-- Increased flooding -- Increased risk of landslides or mudslides on hazardous slopes	-- Reduced food supply -- Higher food prices -- Property damage -- Disruption of livelihoods and economies -- Damage to infrastructure -- Distress migration -- Displacement from informal settlements -- Increased vector & water borne diseases
Sea Level Rise	-- Coastal flooding -- Salt water intrusion into groundwater in coastal areas -- Increased storm surge hazard -- Coastal erosion	-- Displacement from coastal areas -- Property damage -- Damage to infrastructure --Disruption of livelihoods and economies -- Reduced food supply -- Higher food prices -- Population health impacts -- Loss of productive/residential land
Extreme Weather Episodes (storms, cyclones, hurricanes)	-- More intense flooding -- Higher risk of landslides/mudslides on hazardous slopes -- Intense and disastrous wind speeds	-- Property damage -- Damage to infrastructure -- Population health impacts -- Disruption of livelihoods and economies -- Reduced food supply -- Higher food prices

Action is needed instantaneously to reduce the previously listed impacts. The risks are no longer exclusive to a particular region, a particular population or a particular sector. Climate change should be the most significant debate of our time as it threatens the whole globe. Risk Scenarios that were only predictions and forecasts a few years ago are now living present with no turning back. Therefore addressing these impacts is now persistent than before in an attempt to halt the changes from aggregating and withstand the changes that occurred already. This is discussed in more details in the next chapter.

3 Withstanding Climate change

This study adopts the theory that a resilient city is a city that considers the synergies between adaptation and mitigation strategies (Union of Concerned Scientists, 2016). This chapter is an attempt to recognize the synergies between mitigation and adaptation strategies in order to determine a common ground for putting into practice.

3.1 International Policies and Agreements

The current landscape of international institutions related to Climate policy is significantly complex. The following figure shows the main professional actors in the field of climate policy. The difference in size and color reflects the various affiliations of the institutions as well as their magnitude of impact relatively. Another key actor is the academia and research sector that is by some means integrated in most of these institutions and represent the intertwine body between them.

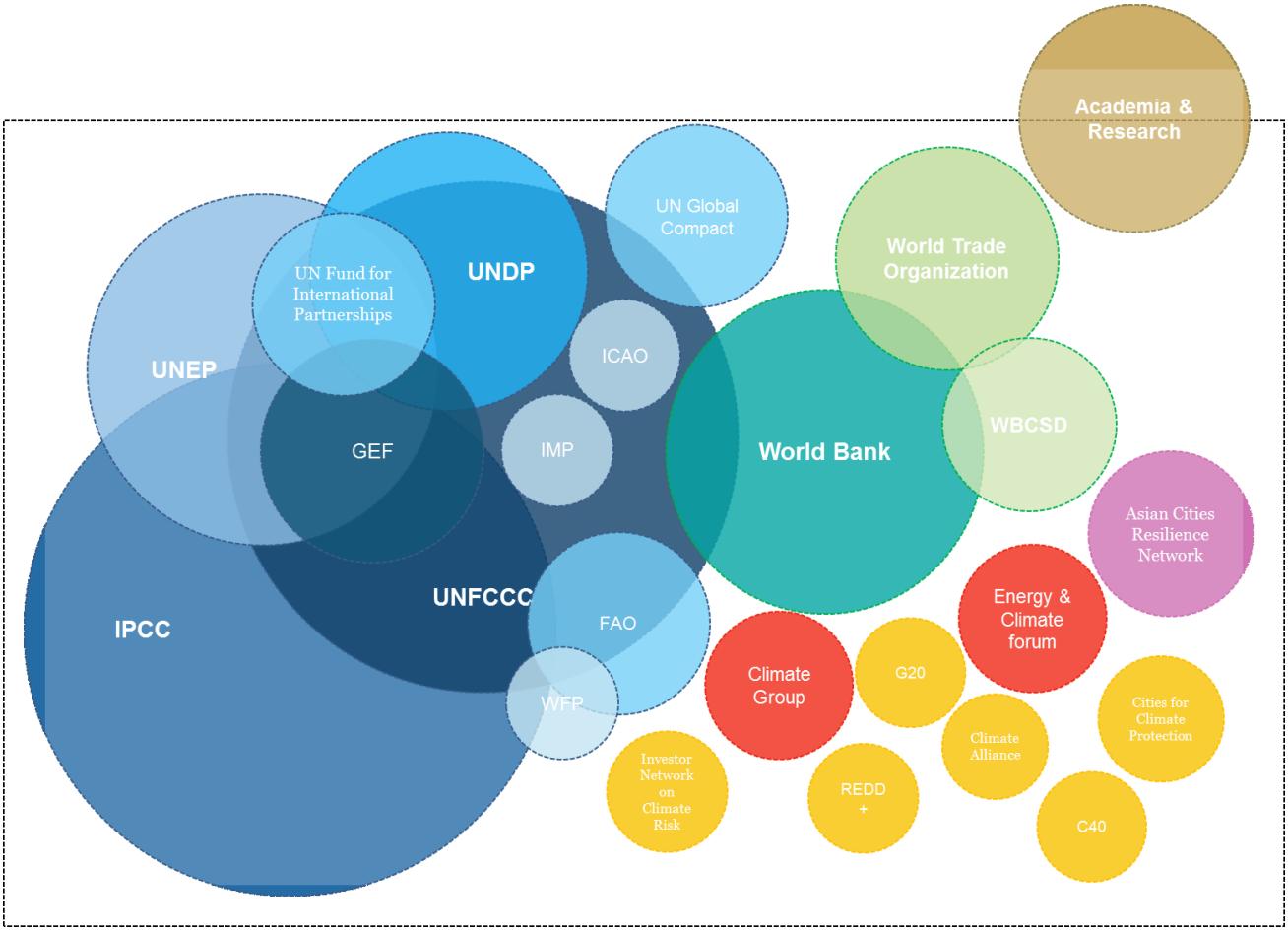


Figure 14 Current landscape of professional actors in the field of climate policy. Source: Author

The issue of Climate change is now tackled in an increasing number of fora. The following figure 15 lists the variety of international, transnational, regional, national, sub-national, and non-state agreements and other collaborations (Stavins, et al., 2014, p. 1012).

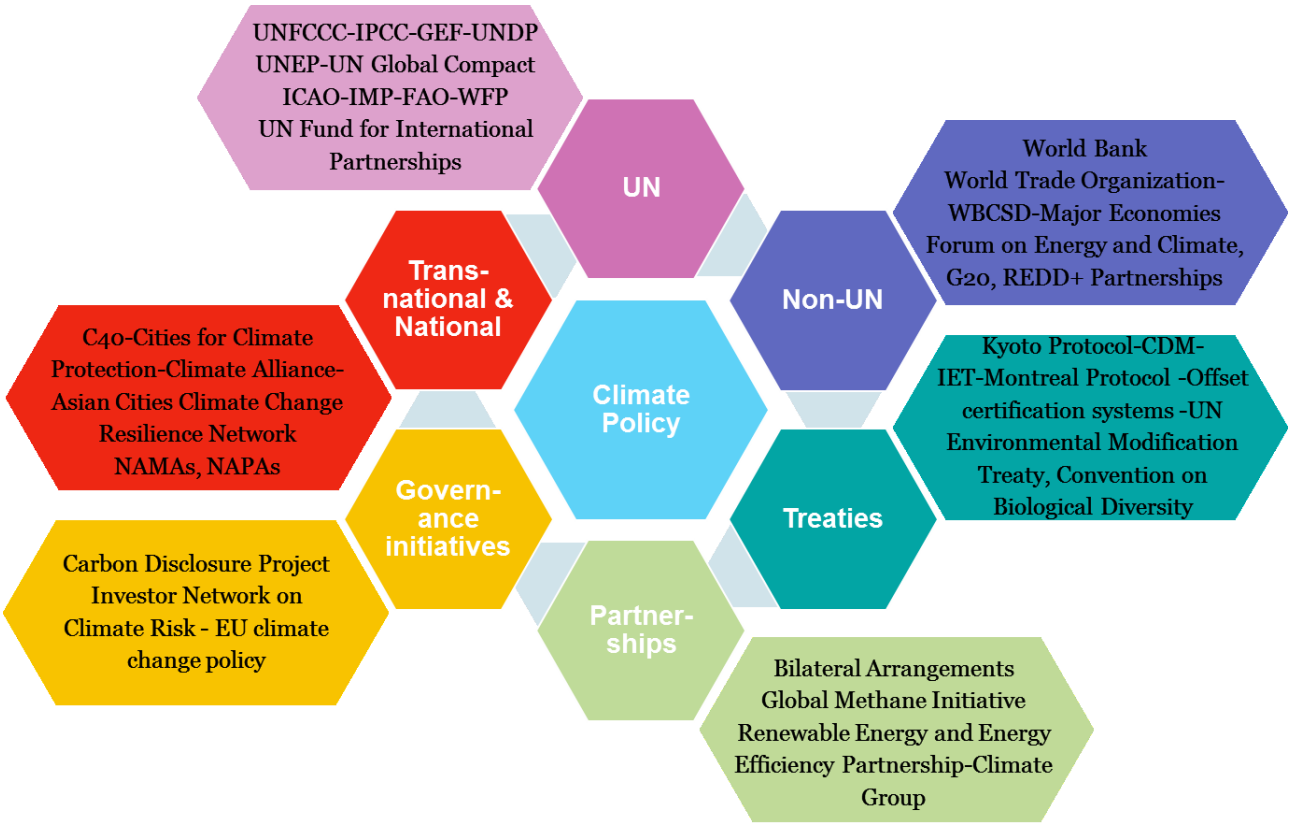


Figure 15 Climate Policies and Agreements. Source: Author based on (IPCC, 2014)

UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) is the main international agreement on climate action. It was adopted at the Rio Earth Summit in 199 and is ratified by 195 countries**.** This includes Kyoto Protocol, Clean Development Mechanism, and International Emissions Trading.

Kyoto Protocol

In 1997, the UNFCCC agreed the Kyoto Protocol, which presented legally binding emission reduction targets for 38 developed countries. The second commitment period of the Kyoto Protocol is from 2013 till 2020. This second period, the participating countries have committed to reducing emissions by at least 18% below 1990 levels. The EU has committed to reducing emissions to 20% below 1990 levels (United Nations, 1998).

The United States has never signed up to the Kyoto Protocol, Canada withdrew during the first commitment period and Russia, Japan and New Zealand are not taking part in the second commitment period. However, more than 70 developing and developed countries have made various non-binding commitments to reduce or limit their greenhouse gas emissions (United Nations, 1998).

Paris Agreement

The Paris climate conference took place 2015. The involved parties reached a new global agreement on climate change. The agreement presents an action plan to limit global warming 'well below' 2°C (United Nations, 2015).

The Paris Agreement entered into force in 2016 after being ratified by more than 55 countries accounting for at least 55% of global greenhouse gas emissions (United Nations, 2015).

Other Actors and Agreements

Other UN Intergovernmental Organizations include Intergovernmental Panel on Climate Change, UN Development Program, UN Environment Program, UN Global Compact, International Civil Aviation Organization, International Maritime Organization, and UN Fund for International Partnerships. As for the Non-UN organizations these mainly include the World Bank, World Trade Organization among others. Several Treaties were adopted as well which include Montreal Protocol, UN Conference on the Law of the Sea, Environmental Modification Treaty, and Convention on Biological Diversity. Other multilateral 'clubs' Major Economies Forum on Energy and Climate, G20 and REDD+ Partnerships **(IPCC, 2014)**. Global partnerships play a massive role in the climate policy setting and implementation as Methane Initiative, Renewable Energy and Energy Efficiency Partnership, Climate Group, Carbon Disclosure Project, and Investor Network on Climate Risk **(IPCC, 2014)**. Regional initiatives and networks as well are key in the landscape of the climate actors and this includes EU climate change policy Regional Greenhouse Gas Initiative, C40, Cities for Climate Protection, Climate Alliance, and Asian Cities Climate Change Resilience Network **(IPCC, 2014)**. Last but not least are the NAMAs, NAPAs which are Nationally Appropriate Mitigation Actions (NAMAs) of developing countries; National Adaptation Programs of Action (NAPAs).

Throughout the past years the climate change phenomena and science have had great attention shifts and a more widespread audience. The following figure 16 illustrates the milestones of the responsiveness to the dispute of climate change.

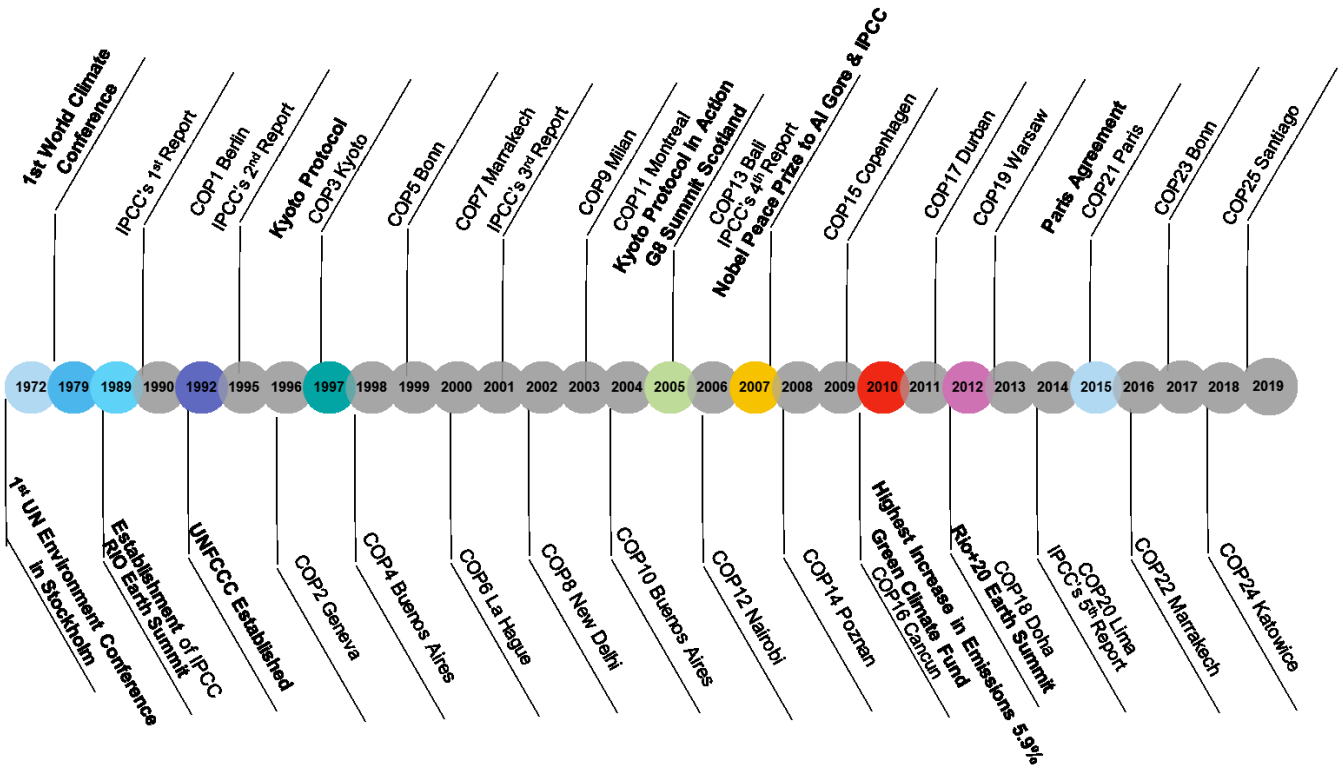


Figure 16 Milestones of the responsiveness to the dispute of climate change. Source: Author

3.2 Urban climate change resilience

Cities are dynamic systems which evolve to acclimatize to external and internal forces that form stress on it. By recognizing the complex structure of the city and the changes forced on it by climate, urban climate change resilience becomes an unavoidable concern. This resilience embraces mitigation, adaptation and risk reduction strategies. A city's resilience is measured according to the Asian Cities Climate Change Resilience Network on three levels: the systems, the people and the institutional structures. The resilience is described as the ability of the city to survive stresses and accommodate them in their decisions.

According to the Intergovernmental Panel on Climate Change (IPCC), Climate change mitigation is defined as "the actions to reduce emission of greenhouse gasses". While climate change adaptation is "the adjustment in natural or human systems in response to actual or

expected climatic stimuli or their effects". The resilience is defined as "the capacity of cities to function so that the people living and working in cities— particularly the poor and vulnerable—survive and thrive in the face of shocks and stresses related to climate change" (IPCC, 2018, p. 4).

Table 5 Difference between shocks and stresses related to climate change. Source: 100 Resilient Cities

CHRONIC STRESSES	**ACUTE SHOCKS**
Chronic stresses are slow moving disasters that weaken the fabric of a city	Acute shocks are sudden, sharp events that threaten a city
• high unemployment • Inefficient public transportation system • endemic violence • chronic food and water shortages	• earthquakes • floods • disease outbreaks • terrorist attacks

Urban resilience considers the capacities, networks and behavior of communities and institutions as well as the physical systems. They are all of critical importance when facing shocks and stresses. The interdependencies between all city systems and sectors can't be neglected. It is vital to understand how the internal and external systems affect how the city functions. Climate change resilience is based on principles and qualities that must be combined into any action (Rockfeller Foundation, 2019) (Carbon Disclosure Project CDP, 2018, p. 9).

The guiding principles of climate change resilience depend on (Rockfeller Foundation, 2019):

Combining hard and soft measures: hard systems as physical systems are not effective solely, as they have to be combined with soft measures. These include new social networks, rules and guidelines, and information systems.

Engaging stakeholders: engaging across different stakeholder groups and integrating the different departments can boost the resilience of a city. Participation of government, business, civil society, and academia in setting action plans is a necessity.

Enlist different governance scales: taking into consideration interlinks between different systems within and beyond the city affect how it functions. These systems include physical, socio-economic, ecological, and political mechanisms

Addressing present problems while considering the future: looking beyond existing challenges and considering their future impact is necessary in the planning processes. The planning should address the current needs but also bring future scenarios into the process of decision making.

The resilient city is characterized by specific qualities described below (Rockfeller Foundation, 2019):

- **Reflective:** resilient communities and institutions support mechanisms that constantly modify standards based on emerging indications, instead of adopting permanent solutions based on current stresses only.

- **Robust**: The city systems are designed to survive the impacts of extreme changes and evade the collapse of the city. The system foresees system failures and makes necessities to ensure safety.

- **Redundant**: It is the planning capacity with considerations for increasing demand, in which other components of the system can substitute for failing components.

- **Flexible**: A city with systems that can evolve and embrace alternative scenarios in response to changing conditions. This system adopts decentralization of conventional infrastructure with new technologies.

- **Resourceful**: Communities and institutions invest in predicting future scenarios and define their needs and priorities, and mobilize and combine the resources (human, financial, and physical). This prepares the city to be more responsive to sudden and extreme situations.

- **Inclusive**: A city can't be resilient in isolation; it needs joint ownership and engagement

of communities specifically the most vulnerable ones.

- **Integrated**: A result that is supported by the city systems, decision making and investments is key to being resilient. Integration considers the systems existing across different scales of operating the city, which requires continuous feedback among all involved systems.

> ***A resilient city is a city that considers the synergies between adaptation and mitigation strategies in order to create a city capable of withstanding the changing climate and decrease the vulnerability of space, people and economy*** (Union of Concerned Scientists, 2016).

3.3 Adaptation and mitigation dichotomy

3.3.1 Mitigation Strategies

Striking changes in the climate are becoming unavoidable, which makes the concepts of adaptation and mitigation a pressing matter on the global level as well as the citywide level.

Mitigation approaches work on reducing the current and potential GHG emissions from its source which includes the built environment and the transportation sector. They are framed mainly using information from technology and economics disciplines and are included in sectoral policy making. Typically mitigation measures are a top down approach that target institutional arrangements usually in industrialized nations included in the Kyoto Protocol for reaching certain limits in GHG emissions by financing supporting technological developments or creating cap-and-trade schemes which is a market-based approach to control air pollution by providing economic incentives for reductions in the emissions. Mitigation strategies aim at reducing GHG emissions and therefore mitigate global warming on the long term (Yohe, et al., 2006, p. 40).

Mitigation strategies are concerned with addressing the cause of the emissions and generally tackle the two faces of the issue; the first one is shifting the sources of energy supply, and the second one is reducing the energy demand.

As the shifting of the energy supply sources to alternative fuels instead of carbon based is a long term strategy, a short term scheme has to be developed to work on the demand decreasing by increasing the efficiency of mobility modes, machinery and buildings. Another short term action should be focusing on the awareness of the society and changing the behavior and consumption patterns of the urban settlements (Condon, Cavens, & Miller, 2009, p. 6).

The mitigation strategies aim at reducing the magnitude or the degree of climate change by reducing the human caused greenhouse gas emissions. Urban areas as cities are the foremost consumers of energy supply and are responsible for the utmost proportion of these emissions. Therefore the cities are the domicile where mitigating climate change has to commence. The change has to embrace all sectors that exacerbate global warming (e.g. the energy consumed by transportation, electricity, heating, industrial processes, waste disposal and land use).
Urban planners have a key role in mitigating climate change through reducing the greenhouse gas emissions. All development plans of urban areas should include climate change mitigation considerations and actions such as: Supporting more compact urban design, encouraging new green building technologies (as buildings as the major energy consumers and green gas emitters not only during construction period but also during the operation cycle), transportation networks and modes improvement, adopting new technologies for solid waste and wastewater treatment that demands less energy, the production of energy and the distribution using more sustainable methods as renewable energy devices (e.g. urban solar and wind power, district energy systems), finally also supporting the conservation and rehabilitation of ecosystems that maintain the mitigation of climate change naturally as forests for example provide carbon sinks (UN-Habitat, 2014, p. 36).

In the below table are measures that could act as mitigation measures as an attempt to reduce emissions and decrease GHG:

Table 6 Mitigation Measures as an attempt to reduce emissions and decrease GHG. Source: IPCC, 2014

conservation and efficiency improvements	Improving the energy supply use in different sectors. This will reduce the greenhouse gases emissions. Some options have a low lifetime cost and can be installed quickly due to modular design.
Co mitigation in energy	Efficiency improvements in residential, construction, commercial, industry, and agriculture sectors.

	Strategies should be based on new technologies, public awareness, management strategies, and institutional reforms.
switching to less carbon-intensive fuels	Depends on the geographic location, type of measure and economic availability of reserves of fossil and alternative fuels.
Renewable energy technologies	Solar, hydroelectric, wind, and biomass. Cost estimates for these technologies vary based on site-specific characteristics, resource availability and energy costs
Nuclear energy	Safety, long-term disposal of nuclear waste and negative impacts on the social, environmental and, political dimensions make it not so appealing.
CO capture and disposal	Limited due to technical and environmental reasons, because some methods of disposal might not prevent the return of CO back in the atmosphere.
Forestry	Decelerating deforestation and increasing reforestation is a must through sustainable management programs that increase agricultural productivity and expand the reserves of forests.

3.3.2 Adaptation Strategies

Adaptation scenarios are actions that could adjust the built and social environment to face the climate changes and become more resilient to the negative impacts of the unavoidable changes (Hamin & Gurran, Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia, 2008, p. 239). Adaptation could be considered a recent policy that is fine tuned to a specific context to efficiently reduce the impact of changing climate. It is a multidisciplinary approach with several key actors involved and is highly dependent on social acceptance (Klein R. , 2010, p. 35) (Klein, et al., 2007, p. 25) (J. Wilbanks & Sathaye, 2007, p. 959). It could be argued that adaptation is a bottom up approach as opposed to mitigation which is a top down approach. The adaptive measures are more concerned with the socio-economic processes, but they can't function alone. They need to be integrated with climate sensitive policy domains and non-climatic drivers for sustainable development. The IPCC's Second Assessment Report introduced an impact assessment

methodology to support developing countries identify impacts and develop adaptation measures on the regional physical scale (Klein, et al., 2014, p. 913). The same methodology was developed afterwards by the UNDP to include the human dimensions of vulnerability and adaptive capacity (Burton, Huq, Lim, Pilifosova, & Schipper, 2002, p. 150). Adaptive measures are generally applied on the local level and don't address the reduction of GHG emissions (Klein, et al., 2007, p. 27).

Adaptation could be defined as the process in which communities prepare to cope with the predicted changes in climate and its impacts. The adaptation actions differ between sectors broadly, but in general adaptation planning could be categorized into four areas; first improving the adaptive capacity of stakeholders by raising the awareness, knowledge, skills and resources. The second area is dealing with the socioeconomic impacts of climate change especially on the most vulnerable communities; these actions could include managing rural-urban migration, supporting their economic resilience, improving local food security, upgrading emergency response systems. Thirdly is to integrate efforts of all stakeholders at the decision making level and the local governments and residents. Finally is the integration of climate change policies in urban development plans, policies and to become a pivotal stake of the planning process (UN-Habitat, 2014, p. 192).

Adaptation efforts are just a few steps towards a more resilient urban settlement and community. The higher the adaptive capacity of a city, the higher its ability to withstand, manage and decrease climate change impacts (UN-Habitat, 2014, p. 192).

The following table shows the dimensions of adaptation:

Table 7 Adaptation Measures Dimensions. Source:. (Klein R. J., 2003)

	Anticipatory		**Reactive**
Natural System			• Changes in ecosystem composition • Wetland migration
Human System	Public	• Early warning systems • New buildings codes	• Compensatory payments and subsidies

		and design standards • Incentives for relocation	• Enforcement of building codes • Reparation of proactive structures
	Private	• Purchase of insurances • Adjustment of housing conditions to extreme weather events	• Changes in farm practices • Changes in farm insurance • Purchase of air-conditioning (maladaptation) • Purchase of artificial snow (maladaptation)

3.3.3 Mitigation and Adaptation Contrast

The research debates that mitigation and adaptation strategies are complementary to each other and not at all comtardicting. The primarily attention to facing climate change was concentrated on the mitigation of GHG emissions. The perception of facing this challenging dilemma was to find solutions to reduce the cause of this change only. Adaptation measures were usually ignored in comparison to mitigation measures (Schipper, 2006, p. 83). However, this strategy changed after recognizing that inevitable changes already took place and are irreversible and that mitigation scenarios can only face the future changes. It was then clear that adaptation strategies were needed to avoid further climate change impacts. The growing recognition that both mitigation and adaptation are fundamental and inseparable to reduce the emissions of GHG and reduce the impacts of climate change respectively (Klein, et al., 2007, p. 33).

Table 8 the misleading differences between mitigation and adaptation (Locatelli B. , 2011)

	Mitigation	Adaptation
Spatial Scale	An international issue	A local issue
Time Scale	Long term effect due to inertia of climatic system	Short term effect on reduction of vulnerability
Sectors	Energy Transportation Industry Waste Management	Water Health Coastal or low lying areas

For a very long time mitigation and adaptation have always been treated as opposite strategies to combat climate change. This used to be justified by at least three reasons that are still arguable and not convincing to a large extent; difference in time, scale and key stakeholders involved. Generally speaking mitigation aims at long term reduction of the cause of the problem which is GHG reduction. On the other hand adaptation aims at short term solutions to the impacts of climate change. At the same time there are non-climate benefits resulting of mitigation and long term non climate benefits of adaptation makes the temporal comparison less convincing (Goklany, 2007, p. 781). In other terms mitigation is a proactive approach while adaptation is a reactive approach.

The second difference between both strategies is the difference on the application and administrative scale. Adaptation measures have an impact on the local level while mitigation measures are oriented towards international and national impacts (Klein, et al., 2007, p. 33) (Schipper, 2006, p. 83). Wilbanks, Leiby, Perlack, Ensminger, and Wright (2007) evaluated the scale factor in the integration of mitigation and adaptation through a bottom-up and top-down approach. The result was that the more local the scale is the more attractive is adaptation from a cost feasibility point of view (Wilbanks, Leiby, Perlack, Ensminger, & Wright, 2007, p. 714).

As argued before Mitigation in principle is a top down approach. Mitigation measures are derived from higher international policy agreements as the United Nations Framework

Convention on Climate Change (UNFCCC) and the Kyoto Protocol signed there, the European Union emission trading scheme (EU ETS) and the Commission of European Communities' climate mitigation strategy of limiting Global Climate Change to 2 degrees Celsius (CEC,2007). The actions are then conveyed from the higher international level to the national level, the efficiency of the mitigation policies is highly dependent on the participation of all national scales which means that the local scale is where the actions are applied to stay below the agreed emissions internationally.

The third difference between mitigation and adaptation is the stakeholders involved. The decision makers and the social networks that are included in the process are not alike in both strategies (Biesbroek, Swart, & van der Knaap, 2009, p. 234). The dominant stakeholders in the mitigation process are the industries, the fossil fuel power generation, the transport sector, the building sector and other domestic sectors. These key stakeholders are responsible for formulating the policy strategies to reduce the GHG emission. For the adaptation strategies the stakeholders are different and this is mostly due to the change in the institutions and entities concerned on the local scale. For example, agriculture, water management, nature conservation and renewable energy are the main realms of action and application (Biesbroek, Swart, & van der Knaap, 2009, p. 234). However more public and private organizations are taking further steps in contributing to the application of mitigation and adaptation strategies. Mitigation strategies can vary from international level to individuals while adaptation is primarily conducted by responsible competent groups, local and regional governments.

Another variance between adaptation and mitigation is the monitoring of the efficiency of strategies. After signing the Kyoto Protocol, all involved countries have set specific targets to reduce GHG emissions in a set period of time. Therefore annual emissions can be compared to the targets to monitor the efficiency of the policies applied. As for adaptation, measuring the effectiveness is much more difficult and there are no quantified targets to monitor although some indicators are currently being developed (Biesbroek, Swart, & van der Knaap, 2009, p. 235).
This dichotomy is summarized in the following table 9:

Table 9 Mitigation and Adaptation Dichotomy. Source: Author

Mitigation		Adaptation
Top Down	Approach	Bottom Up
Proactive	Principle	Reactive
An international/National issue	Spatial Scale	A local issue
Long term effect due to inertia of climatic system	Time Scale	Short term effect on reduction of vulnerability
Industries, fossil fuel power generation, transport sector, building sector, waste management, other domestic sectors, public and private organizations, NGOs	Stakeholders	Health, Agriculture, water management, nature conservation, renewable energy, public and private organizations, NGOs, CBOs & local residents
KPIs	Monitoring	No Quantified Targets

However these misleading contrast are highly doubted and have been for so long deceptive to the actual correlation between mitigation and adaptation. The research debates that mitigation and adaptation strategies are complementary to each other and not at all comtardicting, they should both be considered on the internation and national scale alike and stakeholders involved in implementation of both strategies should be considered again.

3.4 Mitigation and adaptation synergies

The figure below iluustrates the correlation between mitigation and adaptation by showing the closed loop between both and how they both affect the vulnerability to climate change. More detailed synergies between both are dicussed in details in the next section.

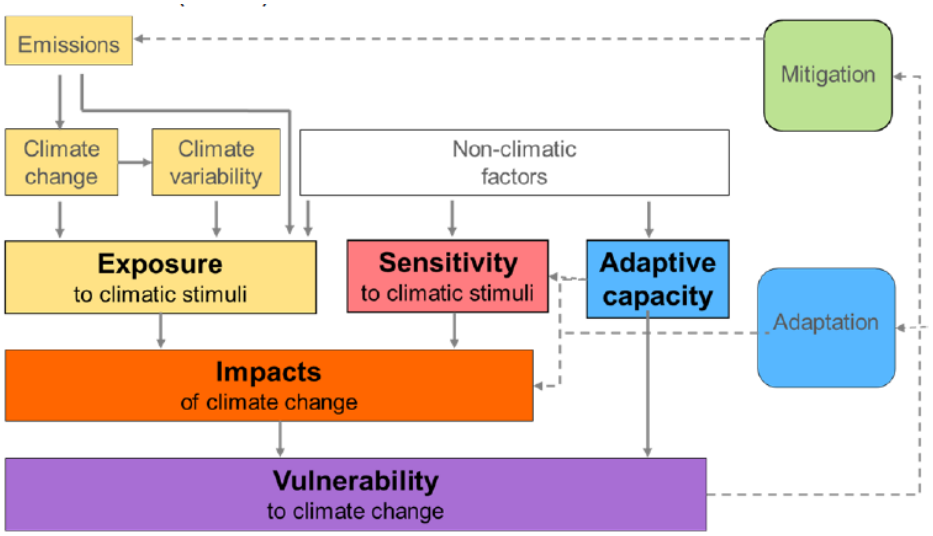


Figure 17 Mitigation and Adaptation correlation Source: Füssel&Klein (2006)

In the former times, mitigation and adaptation have been considered by scientists and decision makers as two separate approaches to deal with the single issue of climate change. After years of disregarding potential trade-offs and synergies between mitigation and adaptation strategies and following separate approaches to face climate change, there is a widespread movement towards integrating both strategies to create the most optimum scenarios through institutions, technological developments, financing, innovations and spatial measures (Goklany, 2007, p. 757) (Klein, et al., 2014, p. 917).

Determining synergies between mitigation and adaptation strategies and actions can assist in confronting the climate change dilemma on two fronts simultaneously. Thus, mitigation and adaptation measures should be treated as a single approach to face climate change as discussed by IPCC in their fourth assessment report:

> *"There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation is necessary both in the short term and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios assessed…(However) Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt. Reliance on adaptation alone could eventually lead to a magnitude of climate change to which effective adaptation is not possible, or will only be available at very high social, environmental and economic costs." - (IPCC, 2007)*

In theory integration between mitigation and adaptation is manageable but in practice it is a very challenging process to integrate them with other sectors as institutional interaction between policies at the same level of government on the horizontal level, with other scales on the vertical level and between various sectors at different scales on a diagonal level.

Following a separate path for each of the strategies resulting in a more complex integration than if integration was adopted from the beginning especially in in the institutional arrangements, policy linkages and spatial application through various scales. The limiting aspect of the integrative approaches is the institutionalization of climate policy.

Measures applied in one policy sector to stand against climate change impacts don't usually consider the impacts of such measures in another policy sector. The European Commission's 'Green Paper on adaptation: options for EU action' signifies the importance for policy coordination in adaptation. Adaptation should be considered in all climate-sensitive policy sectors and the integration with mitigation should take place during implementation and modification of existing and future regulations, guidelines and policies (IEEP, 2007).

The spatial scale is the key determinant to the optimum integration scenario. No comprehensive information still exists on the most convenient strategy for synchronized mitigation and adaptation at different scales (Biesbroek, Swart, & van der Knaap, 2009, p. 232).The challenges to the integration are mainly decentralized but on the other hand the access to policy making and resource utilization are centralized. Top down mitigation strategies are more manageable to implement and monitor while a bottom up adaptive approach exposes the action to more conflicts between stakeholders who have opposing interests in the implementation of the strategy which is often linked to participatory approaches and multi-level governance. Therefore it is clear that overcoming such an obstacle would be a key factor of the integration process between mitigation and adaptation.

Mitigation needs adaptation; a project has a better share to being sustainable if it integrates adaptation measures. For example a mitigating action such as avoiding deforestation aims at stabilizing the carbon and by including adaptation action it can increase the local acceptability as it emphasizes on the local needs (Locatelli B. , 2011, p. 3). Adaptation as well needs mitigation. An adaptation project which also has a role in mitigation can have a better

chance in receiving carbon funding and capacity building from international organizations also adaptation donors may favor projects with global impacts.

To facilitate the integration between adaptation and mitigation several actions could be considered by policymakers to encourage governments, international organizations, local actors and residents to adopt the integration approach (Locatelli B. , 2011, p. 4):

- National policies: national authorities can approve projects that only consider the possible synergies between both strategies.

- International policies: Some countries have asked that adaptation measures should be developed considering the trade-offs between adaptation and mitigation and also provide more incentives to such projects.

- Standards: The Climate Community Biodiversity Standards, which is responsible for evaluating the impacts of land-based mitigation projects, explicitly integrates adaptation standards (Climate, Comunity & Biodiversity Alliance, 2008).

- Knowledge generation, communication and capacity- building: Climate stakeholders have different perspectives about adaptation and mitigation. It is a necessity that all involved participants are informed about both strategies to strengthen their capacities. A demand for more research studies to explore the methods of integration and the tools should be conducted. These studies should show the role of mitigation on the local scale as well as the role of adaptation on the global scale (Locatelli B. , 2011, p. 4).

Possible measures that policymakers could consider to implement cost-effective actions to mitigate emissions of greenhouse gases and adapt to climate change include (IPCC, 2014, p. 20):

- Buildings should be designed in an energy efficient way to support mitigation, and, at the same time, reduce risk of flooding by flood protection techniques such as sealed basements
- Green spaces, green roofs and green walls has potential in both surface runoff management and regulating temperatures indoor and outdoor.

- Energy plants built to increase the energy efficiency of the city but at the same time assuring that this system keeps the city energy secure, which also means that the system is prepared for climate risks
- Implementing energy efficiency measures
- Switching to less carbon-intensive fuels and to renewables
- Enhance reservoirs of greenhouse gases by sustainable forest management and sustainable land use practices
- International cooperation such as implementing coordinated carbon taxes and tradeable quotas
- Development and implementation of national and international energy efficiency standards
- Raising awareness on sustainable development and consumption patterns
- Conduct research to understand the causes and impacts of climate change and provide innovative adaptive and mitigation solutions.
- Reformation of institutional mechanisms, as insurance arrangements, to share the hazards of damages occurring because of climate change.

As a conclusion from the previous dichotomy vs integration debate and listing some measures to achieve integration between mitigation and adaptation, attention should be drawn to the most effective segments that are able to close the resilience gap. However this is not a neglecting of the importance of other segments but to highlight the broad impact of addressing the segments that act as a common ground for applying actions that could be considered both mitigation and adaptation strategies (IPCC, 2014, p. 20).

4 The Golden Thread for resilience

4.1 Stratum interdependencies related to building climate resilience

The city resilience framework depends on many pillars to be able to act as an integrated framework. However, not all these pillars have the same impact on the adaptation and mitigation strategies to withstand climate change. In this chapter the discussion revolves around the higher potential of these pillars that could have a massive effect on all changes caused by climate change and which could lead to a more widespread influence and control on all levels. The segments that are able to close the resilience gap and create synergies between mitigation and adaptation are to be derived from the analysis of pillars and their benefits in this chapter.

Based on literature and tremendous efforts from the Rockefeller foundation the resilience framework is linked to all pieces of the city that could be categorized under three main core dimensions related to the human, space and governance which are (Rockfeller Foundation, 2019):

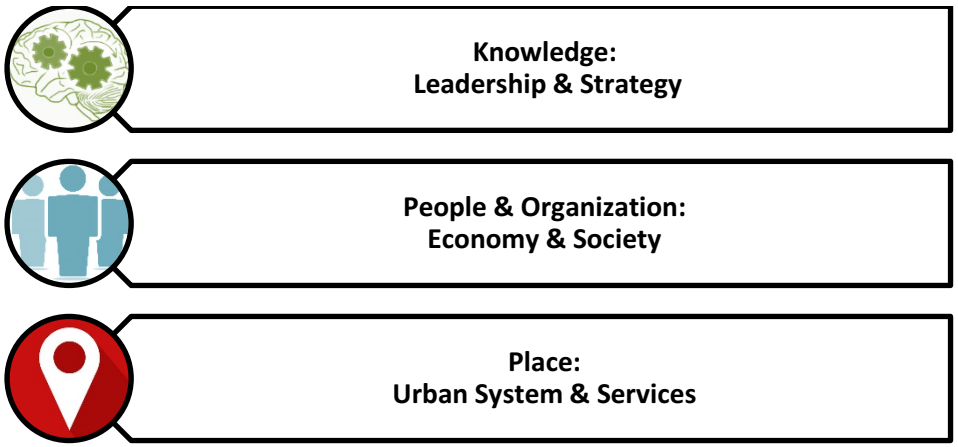


Figure 18Dimensions of Resilience Cities. Source: Author based on (Rockfeller Foundation, 2019)

4.1.1 Knowledge: Leadership & Strategy

The governance system of the city is a main component of the resilience framework. It refers to the promotion of integrated planning of the city. This could only be achieved through an improved decision making process that engages stakeholders in it. Effective leadership and management would definitely create a basis for implementing actions towards resilience

under a policy framework that fosters integrated planning between all sectors and empower stakeholders (Rockfeller Foundation, 2019).

The strategy adopted by a city's managing body is the guide to all sectors and divisions that ensures all pieces fit together to reach the ultimate goal of resilience. In this sense the Knowledge dimension referred to in this section is concerned with the following aspects (Rockfeller Foundation, 2019):

- Communication
- Data & Monitoring & ICT
- Decision making & leadership
- Stakeholder Engagement
- Policies & institutional arrangements

4.1.2 People & Organization: Economy & Society

The main target for implementing mitigation and adaptation strategies is for the benefit of the humans. Therefore they are the center of the resilience process. The society is the main affecting actor as well as the affected actor at the same time. Being a core framework section, attention is highly given to the organization of people's lives to maintain their socioeconomic resilience towards the changing climate (Rockfeller Foundation, 2019).

Each and every inhabitant of the city has the right to survive and thrive. Providing access to basic needs as food, water and sanitation is key to support livelihoods. All services including public health services and education are mandatory to upkeep the resilience of the society. Enabling the community to act collectively and become engaged will definitely add to fostering the economy, supporting employment and ensuring the social stability and justice. The people and organization dimension includes the following sub dimensions (Rockfeller Foundation, 2019):

- Community Participation
- Local Economic development
- Access to healthcare
- Accessible social welfare
- Raising awareness
- Corruption Reduction

4.1.3 Place: Urban System & Services

The common ground where knowledge, strategies, people and organization meet is the physical urban place. It is the natural and manmade systems that connect resources to enable the tradeoffs between knowledge, services and goods that reach the society and foster the economic prosperity (Rockfeller Foundation, 2019).

The urban systems and services represent the spatial aspect of resilience. Providing urban infrastructures and critical services as well as providing reliable networks of mobility are all parts pf the physical resilience strategy. This section is considered the canopy that embraces all manmade and natural assets, this includes (Rockfeller Foundation, 2019):

- Urban Morphology
- Land use Planning
- Green Infrastructure
- Sustainable Mobility
- Energy Efficiency
- Renewables
- Clean & regenerative energy

4.1.4 Resilience Framework Correlations

The previous proposed framework is an attempt to integrate all city to be able to withstand the changing climate and close the gap between mitigation and adaptation strategies. As discussed earlier impacts of climate change could be classified under three main categories; impacts on urbanization, impacts on society, and impacts on economy. However not all parts of the framework have a similar impact on these three pillars; environment, society and economy.

The following figure represents the role of each of the framework dimensions; knowledge, place and people and organization in eliminating or decreasing the impact on the three main pillars of urbanization, society and economy. The figure is proceeded with a matrix that simplifies the benefits of the framework in relation to the climate change impacts. Both figures illustrate the actions that should be taken to reach resilience based on the previous

classification into knowledge based, place based and people based actions. Each of these actions is supposed to eliminate or at least reduce some of the impacts of climate change that were mentioned in the previous chapters that were categorized into social impacts, economic impacts and urbanization impacts. As complicated as the first diagram seems the aim is just to highlight that some actions have limited benefits and others cover a wider range of benefits.

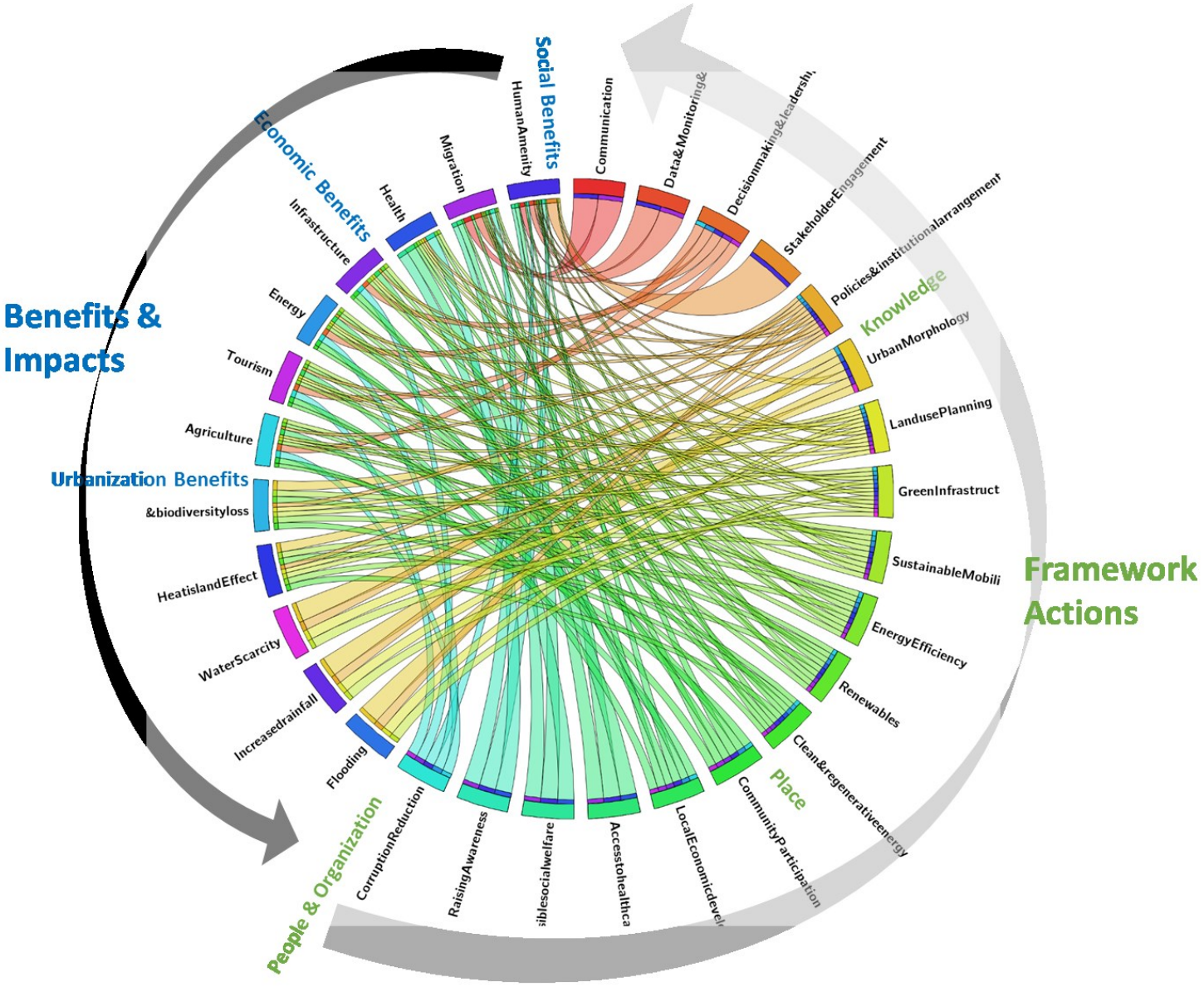


Figure 19 Role of the framework dimensions; knowledge, place and people and organization in decreasing the impact on the three main pillars of urbanization, society and economy. . Source: Author

The below matrix is an attempt to simplify the previous circular chart. The matrix correlates the actions to the benefits of reducing the climate change impacts. The aim of this matrix is to highlight the actions that have the most impact and covers a wider range of benefits. This in turn leads to narrowing down the list and the identification of the most effective strategies for resilience.

By observing the relations it is clear that the place based actions have a far reaching result on most of the expected impacts of climate change. These actions are able to act as mitigation and adaptation actions simultaneously which gives the potential to closing the gap between them to reach the ultimate goal of resilience on the three levels of social resilience, urban resilience and economic resilience. However no actions alone can make a difference without a change in the policies and institutional agreements governing them and paving the way for implementing these actions and strategies.

Table 10 Correlation matrix between the actions and the benefits of reducing the climate change impacts. Source: Author

	Social Benefits			**Urbanization Benefits**					**Economic Benefits**			
	Human Amenity	Health	Migration	Flooding	Increased rainfall	Water Scarcity	Heat island Effect	Ecosystem & biodiversity loss	Agriculture	Tourism	Energy	Infrastructure
Knowledge												
Communication												
Data & Monitoring & ICT												
Decision making & leadership												
Stakeholder Engagement												
Policies & institutional arrangements												
Place												
Urban Morphology												
Land use Planning												
Green Infrastructure												
Sustainable Mobility												

Energy Efficiency												
Renewables												
Clean & regenerative energy												
People & Organization												
Community Participation												
Local Economic development												
Access to healthcare												
Accessible social welfare												
Raising awareness												
Corruption Reduction												

From the previous weighing of the relations between actions and impacts, the scope of this research will focus on the most influential segments of the framework that could lead to a more widespread benefit which are the place based actions. The place based actions could be divided into two dominant segments; the spatial dimension and the energy segment. As shown in the below figure the spatial actions are concerned with the land use planning, sustainable mobility and green infrastructure, while the energy actions include energy efficiency, renewables and clean and regenerative energy. Both segments are governed by the policies and institutional arrangements that could not be neglected and are part of each action that should be implemented.

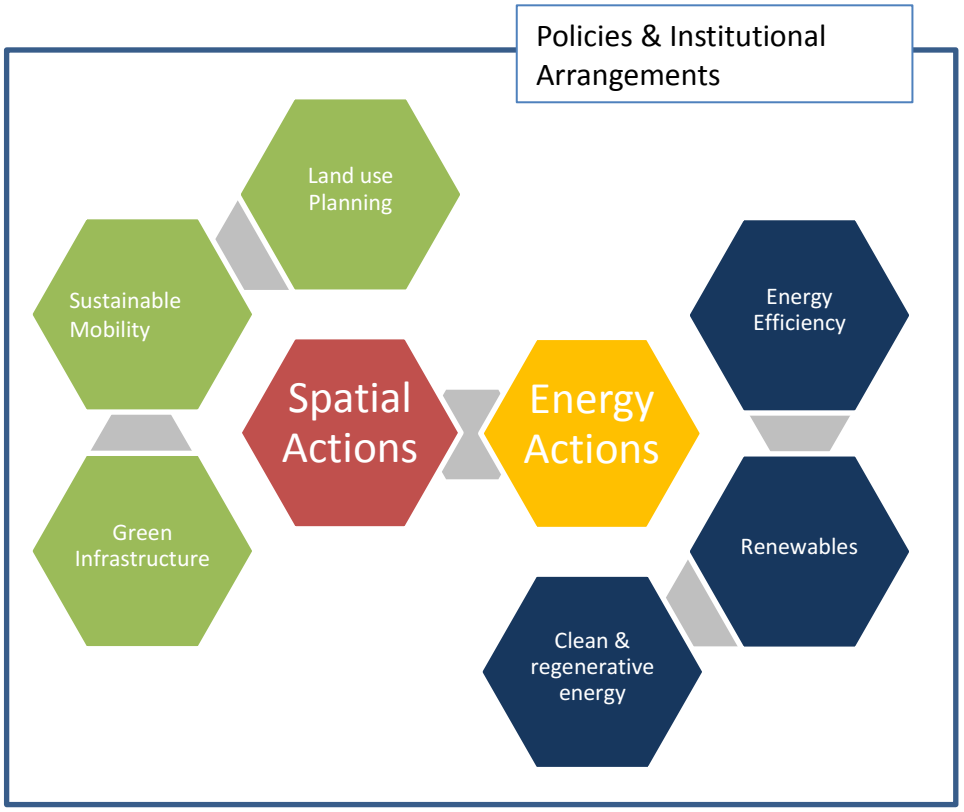


Figure 20 Dominant Segments of the Resilience framework. Source: Author.

The research's hypothesis is that spatial actions and energy actions are the golden thread for resilience, they can act as the common ground for applying synergies and closing the resilience gap as they mutually impact climate change and are an integral part of most segmentations and influences as shown in the previous analysis. The following sections demonstrate the potential of each of these segments; spatial and energy to close the resilience gap and backup the supposition of this research.

4.2 Spatial planning as a "Switchboard" from mitigation and adaptation strategies

The climate change dilemma has always been recognized by climate scientists a one of the primary challenges facing society. On the other hand the same challenge seen from urban planners' perspective that it is only one of the factors in the environmental and socio-economic development process that needs immediate responsiveness (Robinson, et al., 2006, p. 2). The main obstacle in tackling the climate change challenges is usually faced in developing countries. It has been argued that other challenges such as poverty, hunger and water scarcity are of higher priority in the short term development before taking action on climate change (Swart, 2003, p. 19) (Bizikova, 2012, p. 220).

The built environment represented by cities and towns is a dominant center of consumption and production, being huge energy consumers resulted in being major GHG emitter. Buildings are currently responsible for 40% of energy use according to the International Energy Agency. The demand is expected to increase by 60% in 2050 (IEA, 2018). The energy that cities consume is mainly linked to building construction, heating, cooling, electrification, industry and manufacturing, and mobility. The increase in urbanization will definitely lead to an increase in GHG emissions which raises several questions related to the development of cities, the challenges and the opportunities that exist for considering both mitigation and adaptation.

Not all climate change responses can have a resilient spatial dimension however both mitigation and adaptation can have spatial tradeoffs and synergies through different sectors as land and water management, construction, infrastructure development, forestry, environmental planning and renewable energy (Biesbroek, Swart, & van der Knaap, 2009, p. 232).

Spatial planning has the potential to function as a “Switchboard” from mitigation and adaptation strategies and can be the strategic framework where both measures are situated in the wider perspective of sustainable development (Campbell, 2006). It could be considered a common ground to find the linkage between both strategies to reach integration. Spatial planning is usually seen as a holistic approach used to shape physical developments, while coordinating the different relevant socioeconomic objectives as developing transportation systems, housing and local economy, coordinating relevant environmental objectives as water management, nature development and agriculture, and coordinating with sectoral policy objectives.

Integrating climate change considerations in the spatial planning process is a very challenging task and requires a change the policy footing of climate change within spatial strategy (Bulkeley, 2006). Good urban planning practices should also be climate smart planning practices as most climate change actions are an augmented part with the duties of urban planner.

Adaptive measures have an inarguable spatial dimension for example in improving land development near hazard areas (Coastal, flood or slopes), enhancing infrastructure for storm water management, waste management, water safety and mobility, protecting environmentally sensitive areas, improving response capacities for disasters and supporting local economic development to reduce vulnerability of the poor (Heinrichs, Beck, & Kuhlicke, 2009).

Mitigation strategies have a spatial dimension as they have to be implemented at local and regional levels. The local mitigation measures are a result of a top down strategy buy these local measures determine the capacity to reduce GHGs locally such as land cover constraints (Adger, et al., 2007, p. 720).

The IPCC's 4th report (2007) discusses the importance of the necessary shifting in the structure and function of the built environment to simultaneously mitigate the changing climate causes and adapt to its impacts. The spatial dimension may provide synergies, however conflicts may arise as well between mitigation and adaptation (IPCC, 2007, p. 26).

Hamin and Gurran show examples of conflicts and synergies between mitigation and adaptation in the built environment by examining land use plans and policies that address climate change in different countries. Conflicts that could arise for example are creating dense compact urban forms to reduce GHG emissions by facilitating inner transit but in the same time the same dense urban form in hot humid areas will create human discomfort and will decrease adaptation to these climatic conditions, it will also conflict with providing additional open space to enable water, another conflict would be the loss of permeable surfaces and tree cover which in turn will intensify storm runoff (Hamin & Gurran, 2012, p. 317).

In the same paper they also show examples of synergies offered by the built environment between mitigation and adaptation to complement each other. Planting trees in dense urban areas help mitigate carbon and at the same time reduce urban heat stress to adapt to changes. Another important example is shifting to decentralized low carbon energy sources as solar, wind, hydro can act as a mitigation to GHG emissions and simultaneously be an adaptation strategy by reducing the risk of power loss due to storms or from excessive power loads caused from the high temperatures (Hamin & Gurran, 2012, p. 317).

The following table discusses the strength and weakness of spatial planning in facing climate change: (Greiving, 2013, p. 22)

Table 11 Strength and Weakness of Spatial Planning in facing Climate Change. Source: Greiving, 2013

Task	Action
Change proofing	Identification of interaction between land-uses and the changing climate
	New guiding principles (such as "resilience") suitable for the ongoing global change
Mitigation	Land cover constraints
	Renewable energy Infrastructure
	Green infrastructure
	Sustainable mobility
Adaptation	Avoidance of non-adapted developments
	Adaptation of existing spatial structures (settlements, infrastructure)
	Keeping disaster prone areas free of further development
	Differentiated decisions on land-use according to the given sensitivity
	Relocation/retreat from threatened areas

The following table discusses the potential features of climate change against spatial plans of cities. This type of integration is called mainstreaming. Mainstreaming assumes that other plans as poverty reduction, sustainability, etc. – can be enhanced and their by integrating climate change considerations in the planned actions. Mainstreaming helps to guarantee that the plans are not opposing climate resilience plans (UN-Habitat, 2014, p. 40).

Table 12 Potential features of climate change against spatial plans of cities. Source: (UN-Habitat, 2014)

Type of Plan	Potential Climate Change Features
Town Plan City Plan	• Highlights :development" or "no development" areas • Sets policy direction on "climate friendly" or "climate resilient"

Physical Land Use Plan	infrastructure and servicing (i.e. storm water management) • Recognizes climate change and highlights related impacts (i.e. builds public awareness, political support) • Analyze land suitability and the feasibility of development alternatives to determine appropriate spatial relationships
Storm Water Management Plan	• Identifies climate change-related storm water or flooding hazard areas • Directs new infrastructure to "safer" areas not exposed to climate change • Accelerates investment in existing coastal and river flood defense • Identifies options to increase permeability of paved areas in drought prone and flood affected areas
Transport Plan	• Identifies and improves "weak links" in transport networks (e.g. bridges threatened by storm surges, roads subject to flooding) • Identifies and designates emergency transportation networks • Prioritizes transportation network improvements • Supports climate change mitigation through reduced traffic congestion, prioritizing non-motorized transportation
Local Economic Development Plan or Strategy	• Reduces urban poverty levels for key climate change vulnerable groups • Promotes "climate friendly" and/or "green development" opportunities
Informal Settlement Upgrade Plans	• Identifies potential climate change impact risks (e.g. storm water and flooding, slope failures, health) and responses to them (e.g. relocation, infrastructure improvements) • Identifies and relocates housing from high hazard areas and/or develops "planned retreat" or relocation strategy
Public Health Plan	• Identifies and prioritizes health risks associated with climate change • Supports planning improvements to reduce climate change related public health impacts (e.g. supports improved storm water and waste treatment facilities, supports urban greening to reduce heat island effects)
Disaster Risk	• Identifies climate change disaster risks, likelihoods and adaptive

Reduction Plan	capacity • Supports infrastructure and planning improvements to reduce climate change-related disaster impacts • Ensures provision of adequate community shelters and schools, access for emergency services, introduces regulations on back up sources of energy and water supply
Sewer / Liquid Waste Management Plan	• Identifies development or construction guidelines for "climate proof" facilities • Identifies and prioritizes high risk areas where new facilities are most needed to reduce climate change impacts amongst vulnerable groups • Identifies options to reduce or reuse wastewater (grey water) for urban agriculture and horticulture
Energy Management Plan	• Identifies climate change-related risks to energy generation and distribution • Supports climate change mitigation (e.g. green energy, conservation)
Water Management Plan	• Identifies climate change-related risks to municipal water supply, treatment and distribution and adaptive measures to counter them • Identifies water conservation and water demand • strategies and tools to better manage and adapt to water shortages
Solid Waste Management Plan	• Supports climate change mitigation through improved materials recycling or reuse and, where practical and feasible, landfill emissions capture

The spatial dimension of mitigation and adaptation based on the previous section is the common ground for withstanding climate change and applying mitigation, adaptation to achieve resilience and close the resilience gap. The spatial aspect across all previously listed sectors in the last chapter could be summarized into several main categories which are: Green infrastructure, Sustainable land use practices, Energy Efficiency, Renewables, Sustainable mobility and policies and institutional arrangements. The following figure 21 illustrates how the categories of spatial dimension impact the adaptation capacity in the first column and the mitigation capacity as well in the second column.

Figure 21 Spatial Aspect of Resilience as a common ground between adaptaion and mitigation. Source: Author

All mentioned sectors have a spatial magnitude in the proposed strategies and measures below are lists of the spatial potential of each sector which justifies the previous categorization into six main measure categories.

Green Infrastructure

Green infrastructure uses natural processes to create more resilient environments and urban settlements. These infrastructure elements include small scale site design approaches as green roofs to regional planning scales as conservation of land. By combining grey infrastructure with green ones a great advancement in resilience goals can be achieved through increasing water quality and supply, reducing urban heat island effect, withstanding flooding and reducing infrastructure emissions and building energy use (European Comission, 2013, p. 6) (U.S Environmental Protection Agency, 2015).

Sustainable land use practices

Land use planning and policies are a fundamental base for closing the resilience gap and finding synergies between mitigation and adaptation. Land use plans regulate space usage as heights and densities but also control types of activities occurring and could shift development from threatened areas or increase investment in commercial areas to reduce economic vulnerability and achieve multiple benefits. Tools for land use could also help in

sharing the responsibility and risk between all residents. Reaching resilience goals is not the government's responsibility solely it is also a commitment by all stakeholders of the city. The scale of influence of the land use plans has to be considered as well. Some regional issues might affect these plan as watershed issues or heat waves that lead to migration and resettlement. Therefore land use plans and policies must cross political and natural boundaries and address different scales and become dynamic instead of static practices. Some sustainable land use practices are listed in the below table as a route towards resilience (Armstrong, 2016) (U.S. Green Building Council, National League of Cities and the Urban Land Institute, 2017).

Sustainable mobility

Reliable climate resilient mobility is a core element to ensure economic vitality development, guarantee safety and health of residents and safeguard the infrastructure of transport and its embedded value.

Several strategies could be undertaken to find synergies between adaptation and mitigation for creating a climate resilient transport system. These strategies could be summarized under three main headings which are: avoidance strategies, shifting strategies and improving strategies. The avoidance approach for example is based on creating compact and transit oriented cities with sufficient green spaces combined with climate proofed design for infrastructure. This strategy mitigates climate by reducing land conversion, travel demand and emissions through having a reliable public transport, walking and cycling infrastructure. It acts as an adaptive strategy as well by providing cooling through green roads, reducing infrastructure by offering short distances that favor walking and cycling. The shift approach takes into consideration transport demand management measures and offers high quality public transport. As mitigation for climate this approach reduces car trips, road space needed and co2 emissions. Adaptation is achieved through reliable public transport which is vital for disaster management and evacuation in emergencies. The final approach is the improvement. This focuses on improving the standards of vehicles, efficiency and resilience. The energy efficient vehicles help reduce the emissions which mitigates the changing climate. While the resilient vehicles maintain mode share to ensure adaptability (GTZ, 2014, p. 22).

Policies & institutional arrangements

Management of strategies is definitely a core element to ensure the success of implementing the actions and ensure the tradeoffs and synergies between them. Policies and institutional arrangements are the defining guidelines for creating a basis that embeds mitigation and adaptation strategies all together to reach a climate resilience framework.

The success of these policies depend on the integral relation between different sectors. Creating layers that are interlinked and overlapping between the resilience strategies of different sectors is a necessity to build a solid framework. Another important factor for the success of policies is the enforcement of policies and monitoring of implemented actions. This could not be achieved without having a trained team that is able to grasp the importance of withstanding climate change. Policies should tackle all actions that could be undertaken including land use and land cover, mobility, infrastructure, planning morphologies, building standards, energy production and consumption, stakeholder and community engagement, local economic development and more.

4.3 Urban energy systems as the potential synergy

> "Energy is the golden thread that connects economic growth, social equity, and environmental sustainability." —U.N. Secretary General, Ban Ki-moon

Energy provides input into almost all sectors of an economy. A resilient energy sector provides input to GDP, jobs, trade opportunities and welfare benefits in order to achieve a resilient economy. The below figure 23 shows how energy is considered and input into primary, secondary sectors, and tertiary sector services. The words in grey highlight weak energy links, whereas the words in black highlight strong energy links (EUEI, GIZ, 2017, p. 15).

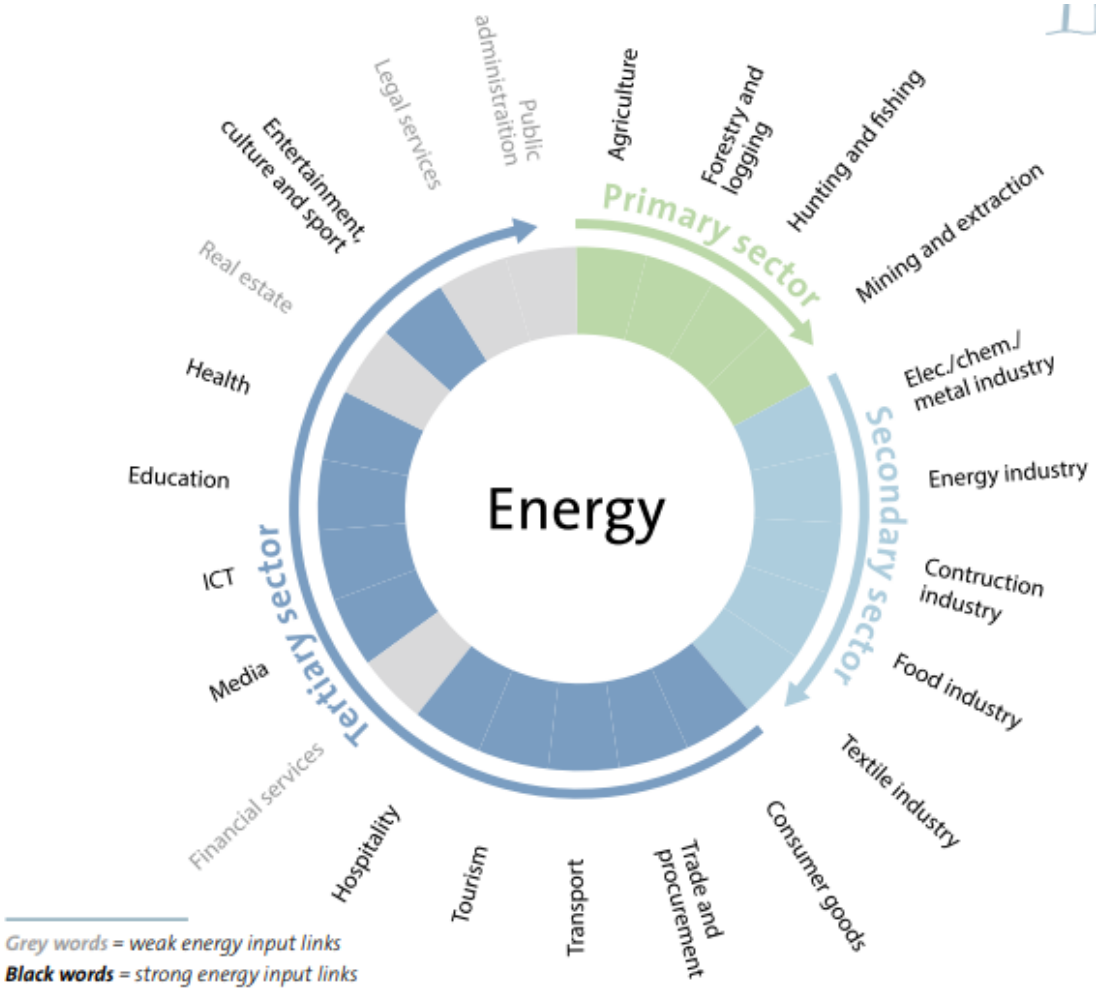


Figure 22 Energy input requirements for all economic sectors. Source: EUEI, GIZ, 2017

Energy systems are considered the heart that provides the blood to the city. As complex as they are they serve as an accelerator to the vitality of the city or the brake of it. Urban areas are responsible for almost 65% of the global energy demand and 70% of CO2 emissions. Therefore solutions should start from the core which are the cities. City planners, decision and policy makers have a crucial role in embracing innovative solutions to meet the challenges imposed by the changing climate in the energy sector through planning, regulation, public procurement, direct investment, provision of services and awareness raising. Energy should be considered as a driver for economic and environmental sustainability (IRENA, 2016, p. 8).

The IPCC defined the energy sector as all energy extraction, conversion, storage, transmission and distribution processes with the exception of those that use final energy in the end-use sectors (industry, transport, building, agriculture, forestry). The energy sector is the major

culprit, however actions in every other sector count. The energy sector has remained the largest contributor to emissions over any other sector for the past years, representing almost 72% of global emissions in 2013 (IEA, 2018).

In the developing countries almost 2 billion suffer from lack of electricity, while 3 billion depend on fuels as coal, charcoal and animal waste. One of the major challenges facing the energy sector is providing the "energy poor" with access to clean, affordable and reliable energy services (SEforAll, 2017, p. 31).

Low carbon technologies have significant benefits. China's investment in solar technologies for example created almost half a million power sector jobs. Also in Germany and Spain projections indicate the employment of 500 000 to 600 000 people by 2030. Other benefits of this transition include energy security, health improvements, rural development in poor countries, and reduced air and water pollution (IRENA, 2016, p. 15) (EUEI, GIZ, 2017).

Realizing the Sustainable development Goals on energy will not only impact the energy system but will also meet other SDGs as poverty alleviation, water, health and cities. Altering the energy services to a more resilient and sustainable system will have a multiplier effect on the development in general. For example reduced health effects will be achieved, as well as the improvement of livelihoods, job creation and enhanced access to water and food (EUEI, GIZ, 2017, p. 30).

An integrated urban energy system plan is a favorable approach in order to achieve a resilient energy system. Supply and consumption of energy should be balanced to decrease the waste resulting from transmition and from behaviour as well. The figure below is an overview of the technologies and concepts for an integrated urban energy system that depends on smart grid solutions (EUEI, GIZ, 2017, p. 30).

Adaptation and mitigation strategies in the energy sector complement each other. Shifting from centralized to decentralized low carbon forms of power generation will reduce GHG emissions and mitigate climate change. These power generation forms could be wind, solar or wave energy. They can also be used as adaptation strategies, as these decentralized forms

reduce the risks associated with the power loss due to weather strikes as storms or excessive power load caused by high temperatures.

Table 13 Energy Sector Potential in mitigation and adaptation. Source: (EUEI, GIZ, 2017, p. 46) (IRENA, 2016, p. 32)

Task	Action
Mitigation	**Cutting emissions from fossil fuel extraction and conversion**
	Switching to lower-carbon fuels, for example from coal to gas
	Improving energy efficiency in transmission and distribution
	Increasing use of renewable energy technologies
	Increasing use of nuclear energy
	Introduction of carbon capture and storage (CCS), and an extension into CCS plants that use bioenergy crops (BECCS) as an approach to achieving 'negative emissions'
	Reducing final energy demand
Adaptation	**Ensure enough adaptive capacity**
	Access to energy in particular in rural areas in developing countries
	reduces climate vulnerability.
	Energy diversification eliminates reliance on one single generation source to enhance security of supply
	Reducing and shifting energy demand away from peak hours and thus smoothing the demand curve for energy over the day and the year, will lower overall required energy capacity.
	Distributed as opposed to centralized energy systems can increase resilience.

The energy dimension of mitigation and adaptation based on the previous section is the common ground for withstanding climate change and applying mitigation, adaptation to achieve resilience and close the resilience gap. The energy aspect across all previously listed sectors in the last chapter could be summarized into several main categories which are: Energy Conservation and Energy Efficiency, Renewables, Regeneratives and Carbon Positive, Smart Grids and policies and institutional arrangements. The following figure 23 illustrates how the categories of spatial dimension impact the adaptation capacity in the first column and the mitigation capacity as well in the second column.

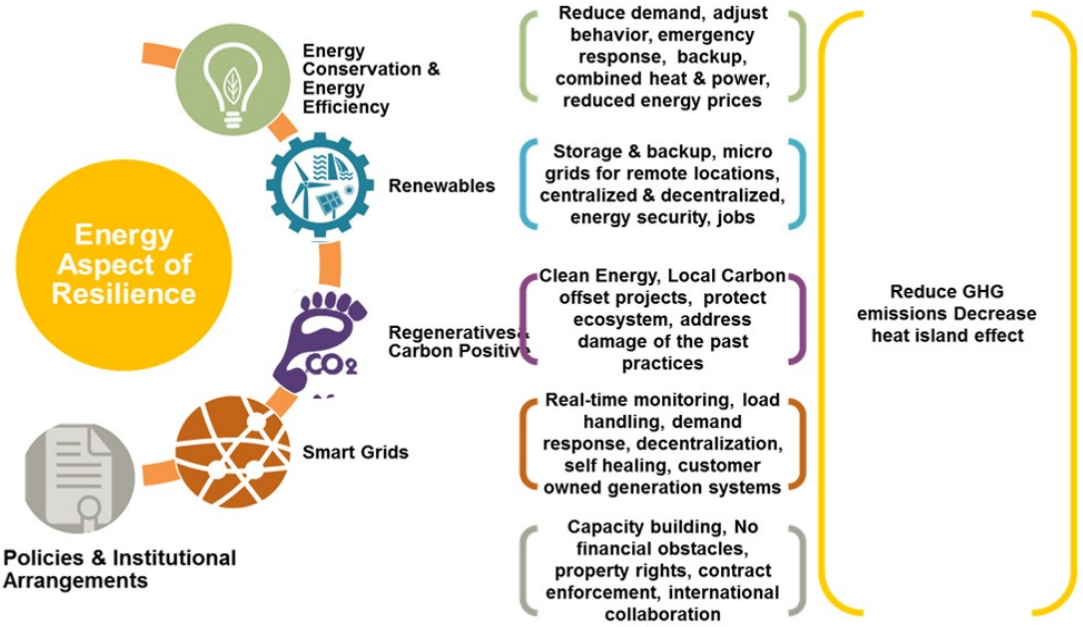


Figure 23 Energy Aspect of Resilience as a common ground between adaptation and mitigation. Source: Author

Energy pyramids as illustrated in figure 24 have been discussed thoroughly in most researches starting from the lowest cost or no cost conservation measures related to behavior then ascending to energy efficiency measures concerned with passive design measures and efficiency of appliances and heating and cooling devices whether centralized or decentralized. Afterwards comes the next step in the pyramid which is the introduction of renewable energy sources for energy supply to cover part of the demand. However not so long after that that the concept of self-sufficient cities and zero carbon were introduced to take the energy pyramid to a higher level of expectations. Just recently the debate has shifted towards

whether the renewables are the real solution to the changes facing the climate and to reach a sustainable future, the argument directed the attention to the novel term of regenerative energy and discussions began to differentiate between clean energy and renewable energy. To reach the ultimate goal of a resilient urban settlement all steps of the pyramid have to be considered beginning at the scale of a single dwelling passing through a whole building and reaching the neighborhood, district and city wide scales. The transition must include all these aspects in order to be able to mitigate the climate changes and adapt to the imposed impacts.

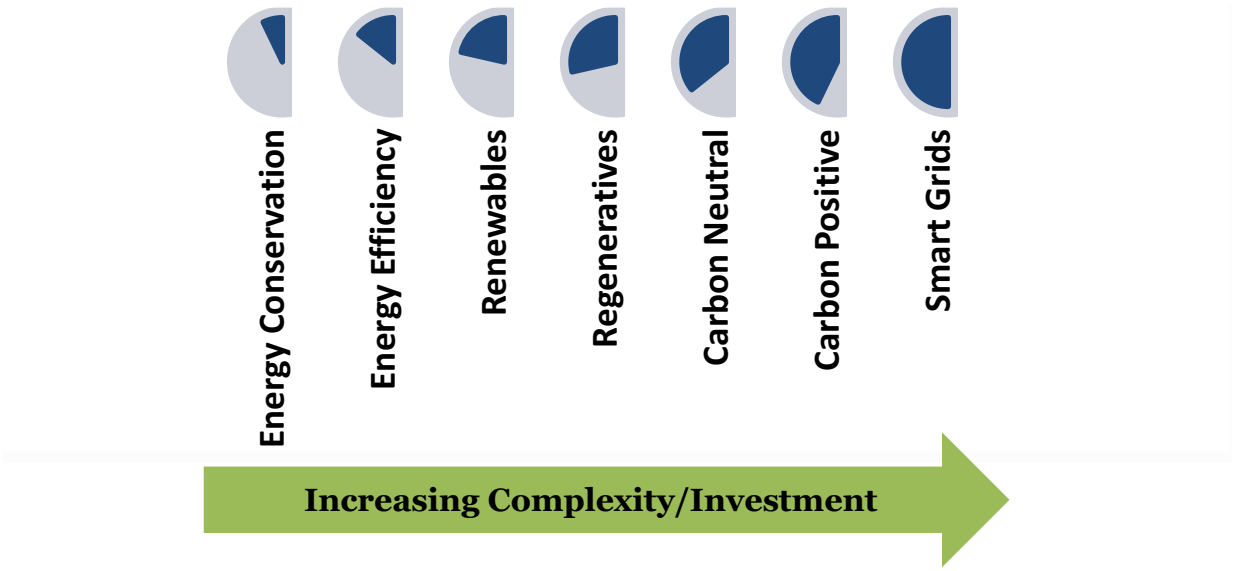


Figure 24 Energy approaches towards resilience. Source: Author

Energy Conservation

Reducing the final energy demand is considered the base of the energy pyramid. It is the lowest cost option for achieving more resilience. Limited energy demand has several benefits including the reduction of the need for new energy supplies,

Energy conservation involves using less energy by adjusting behaviors and habits. Energy efficiency, on the other hand, involves using technology that requires less energy to perform the same function. Therefore raising awareness campaigns have a great role in decreasing the usage of energy and its conservation.

Energy Efficiency

Energy efficiency has a key role in achieving resilience and closing the gap between mitigation and adaptation measures at low cost. It has an impact on the emergency response and

recovery through reduced electric demand to allow for an increased reliability during stress times, backup power supply from combined heat and power to allow for maintaining energy supply during emergency, efficient buildings that maintain temperatures for residents to shelter, multiple modes of transportation to provide options during evacuations. Energy Efficiency has an impact also on socioeconomic aspects, for example local resources may stay in the community, reduced vulnerability to energy prices volatility, reduced spending on energy and improved indoor air quality. Other impacted dimensions are the reduction of GHG emissions and cost effective efficiency investments (Ribeiro, et al., 2015, p. 23).

Renewables

Renewable energy solutions are capable of improving resilience through onsite solutions as well as offsite ones. Energy infrastructure must have the ability to adapt and be ready to face the changes induced by climate and rapidly recover from stresses and emergencies. Renewable energy infrastructure is a crucial element to ensure resilience of the electric supply.

The advancement happening to renewable technologies would allow for more power storage and more robust backups, micro grids for remote locations and emergency settlements, smart controls to allow for the optimum use of renewable generation (Olah, Mathew, Goeppert, & Prakash, 2018, p. 523).

The potential for shifting to renewables varies greatly depending on the characteristics of each urban area. Hot climates and cold climates have different demand profiles, other factors as population density and growth prospects also take part in the framework introduced. Therefore strategies must be tailored to each city depending on its characteristics. For example emerging cities will need to deploy energy efficiency and renewable energy technologies in new buildings on the other hand established cities which have low building turnover rate need to depend on retrofitting the existing buildings and infrastructures. Another comparison could be between high population density communities that could benefit from centralized systems and low density cities that could easily rely on decentralized systems.

The Priority action areas for renewable energy in cities are energy efficiency and renewable

energy in buildings, providing sustainable options for transport, and creating smart integrated urban energy systems. Cities operate through interconnected networks, many of which are treated individually, the switch to renewables offers opportunities to create synergies between sectors

The aim is doubling the share of renewable energy by 2030 to reach 36 % in the energy mix as suggested by SDG 7. This is considered a critical step towards a resilient energy system while also meeting ambitions of the Paris Climate Agreement. The technology costs are decreasing rapidly which makes renewable options less costly, it also helps create more jobs, improve energy security and fosters economic growth. Renewable energy has penetrated the electricity generation sector rapidly followed by heating and cooling sector and is starting to spread in the transport sector. The renewable portfolio provides economic, health, and climate benefits as well as non-market benefits supporting jobs, improved air quality, and global climate benefits (Long, 2013).

Renewable energy sources include wind, solar, hydropower, geothermal, ocean (tidal energy, wave energy, ocean thermal energy) and biomass. By relying on renewable energy sources mitigating climate change can be achieved through reduction of greenhouse gas emissions. However environmental limitations as drought, low wind, and clouds can reduce access and efficiency of these sources, their variability and intermittence are also a problem which makes energy storage necessary for large-scale applications (Olah, Mathew, Goeppert, & Prakash, 2018, p. 523).

Carbon neutral and Regenerative energy

Carbon neutral is defined as an activity which releases net zero carbon emissions into the atmosphere. It is defined by the Australian Sustainable Built Environment Council (ASBEC) (Riedy, Lederwasch, & Ison, 2011, p. 17) as having no net annual emissions from direct fuel combustion (e.g. burning natural gas) and electricity use from operation of building incorporated services. A paradigm shift is needed to achieve this neutrality. The classic 3 Rs; reduce, reuse and recycle, should be shifted to reduce, renew and offset (AIA, 2012).

- **Reduce** - build less, protect natural ecosystems, build smarter and build efficiently.

- **Renew** - use clean energy, restore native ecosystems, replenish natural building materials, and use recycled and recyclable materials.
- **Offset** - compensate for the carbon you can't eliminate, focus on local offset projects. Carbon offsetting is gaining popular, however purchased offsets cannot be generated in adequate quantity to perpetuate and sustain current practices.

Coal, oil and natural gas (fossil fuels) are carbon based and using them involves combustion as the main chemical process which certainly generates carbon dioxide The extensive use of these fuels for energy production, transportation, and other applications led to an increase in atmospheric CO_2 concentration (408.3 ppm as of February 2018) (Olah, Mathew, Goeppert, & Prakash, 2018, p. 523).

Elisabeth Wehling and George Lakoff at the University of California in Berkeley initiated discussions about the differences between renewable and clean energy. They mentioned that the most common understanding of renewable energy includes nuclear power and new coal plants with lower carbon emissions. This gives the intuition that the required transition is not towards a more environmental one but rather towards more modern energy supply in which regenerative sources as solar, wind, bioenergy and others complement conventional power plants. The neglecting of radioactive waste disposal and underground CO_2 storage is definitely not the path if the aim is a true Energiewende.

An approach to mitigate CO_2, is the CO_2 capture and disposal (storage or sequestration, CCS) or utilization (CCU). In CCS, after the capture, the CO_2 is buried in underground geologic formation, which gives no value to the sequestered CO_2 which can be an inexpensive and safe C1 source for fuels. On the other hand, carbon capture and utilization or recycling (CCU or CCR) offers advantages by treating CO_2, not as waste but as a valuable raw material (Styring, Jansen, Coninck, Reith, & Armstrong, 2011, p. 3) (Olivier, Peters, & Janssens-Maenhout, 2012, p. 10).
Renewable sources of energy that contain carbon based on biomass put a burden on agriculture, land and water use, which leads to ecological and environmental problems. Also, biomass on its own is not able to support the energy needs of an Earth population expected to reach 10 billion by the mid-century. On the other hand regenerative carbon fuels are produced by converting CO_2 chemically with hydrogen generated from water, methane or

any other hydrogen source using any energy available, including energy from renewable sources such as solar, wind, hydro, geothermal, etc. The needed CO2 can come from any source (coal and natural gas based thermal power plants, and industrial plants) as well as dispersed sources as the air through capture and conversion to fuels and materials. It is also available in petroleum and natural gas reservoirs, carbonate rock hydrolyte deposits in the ocean beds and many lakes (Olah, Mathew, Goeppert, & Prakash, 2018, p. 523).

In the short term regenerative carbon fuels can supplement fossil fuel-based ones. However In the longer term they could replace them entirely. In the meantime, fossil fuels can also be used to produce the hydrogen needed for CO2regeneration, however, the CO2 generated should be captured and sequestered to avoid its release to the atmosphere. Regenerative carbon fuels can be replenished faster that other fuels by the help of the recently developed anthropogenic recycling technologies and synthetic methods which is considered a carbon neutral approach (Trumper, 2009, p. 45) (Olah, Mathew, Goeppert, & Prakash, 2018, p. 523).

Carbon Positive

Carbon positive means that an activity moves beyond achieving net zero carbon emissions to create an environmental benefit by removing additional carbon dioxide from the atmosphere or by making additional 'positive' or 'net export' contributions by producing more energy on site than the required. Carbon positive projects can make significant contributions by helping to address the carbon intensity and damaging impacts of past building practices and lifestyles, and by offsetting situations where carbon zero projects are not possible (Natural Resources Wales, 2018, p. 13).

While carbon neutral is considered to be the current benchmark of best practice, carbon positive is expected to play an increasingly important role in the future to limit impacts of climate change (Pipkorn, 2013).

Smart Grids

Conventional electrical grids send power in one direction from power plants to homes, industries and offices. A smart grid is an electrical grid that is integrated with a computerized, two-way communication network that provides instant feedback on system operations, power interruptions and usage back to the electrical plant and grid operators. It uses real time monitoring to adjust itself to perform in and optimum way. It is also able to isolate parts of

the network that are at risk of failure, to prevent small-scale interruptions from turning into long-term or region-wide blackouts.

The Smart Grid is an opportunity to create a more reliable, and efficient energy system that will contribute to economic and environmental health. Key features of the smart grid include (Jain & Mishra, 2016):

- **Load Handling:** The total load is not stable and varies over time. In case of peak load, the system can advise consumers to temporarily minimize energy consumption.
- **Demand Response Support:** Guides users with an automated way to use low-priority electronic devices when rates are lower.
- **Decentralization of Power Generation:** A distributed grid system allows the individual user to generate onsite power by employing any appropriate method at his or her discretion.
- **"Self-healing" capacity:** its ability to automatically work around power failures by detecting and isolating outages and rerouting electricity to meet needs.
- **Monitoring and controlling:** When energy demand is high, the smart grid can automatically reduce the energy demand of home : appliances that have a wireless connection to the grid

The benefits associated with the Smart Grid include: (Jain & Mishra, 2016) (U.S. Department of Energy, 2019)

- More efficient transmission of electricity than conventional grids
- Faster restoration of electricity after power disturbances
- Reduced operations and management costs for utilities
- Reduced peak demand
- Increased integration of large-scale renewable energy systems
- Integration of customer-owned power generation systems
- Improved security
- Allow the electricity markets to grow and make business.

The Smart Grid builds on the existing technologies used by electric utilities but adds control and communication capabilities. It is also in a position to use new technologies as plug-in hybrid electric vehicles, solar energy, smart metering, lighting management systems, distribution automation, and others. Smart grids are considered the network than links all previously mentioned parts of the energy pyramid to ensure a robust and resilient energy sector that is able to respond to any sudden impacts of climate change and at the same time be able to reduce these impacts and act simultaneously as mitigating strategy and an adapting strategy (Jain & Mishra, 2016).

Energy Policies & institutional arrangements

The success of energy policies depends on capacity building, elimination of financial obstacles, and the development of a robust legal framework. Property rights, contract enforcement, and emissions accounting are essential for the effective implementation of climate policies in the energy sector.

Government intervention in accelerating the creation of sustainable markets for low-carbon technologies; investing in R&D; supporting the creation of infrastructure; and encouraging international cooperation. Carbon pricing which depends on penalizing higher emissions technologies is not yet adopted enough to create long-term investor confidence. More successful intervention, include capital grants, tax breaks, production subsidies, performance standards, re-shaping investment decisions in CCS projects, electric vehicle fleets and solar PV value chains. Investments of governments in R&D can provide the essential guidance to yield major returns in jobs creation and investment. Financing for large-scale CCS projects is necessary in the short term to allow lower costs to emerge from large-scale activity in the long term. International collaboration between countries and across sectors is a definite step towards stimulating innovation by joint activity and sharing experience (IEA, 2015).

5 Stamina to change

5.1 Sectoral Potential and capacity

As discussed earlier the climate change impacts the urbanization, the people and the economy. Therefore to withstand these impacts, urbanization, people and economy must be prepared.

The graph below in figure 25 presents the baseline and mitigation scenario emissions ranges from major sectors which are transport, buildings, industry, electricity and agriculture, forestry and other land use. This graph compares the no action scenario with mitigation scenarios which shows the huge difference in emissions. This proves that all sectors have the potential to decrease their emissions and mitigate the impacts of climate change by limiting warming to 2°C above pre-industrial levels (IPCC, 2014, p. 8).

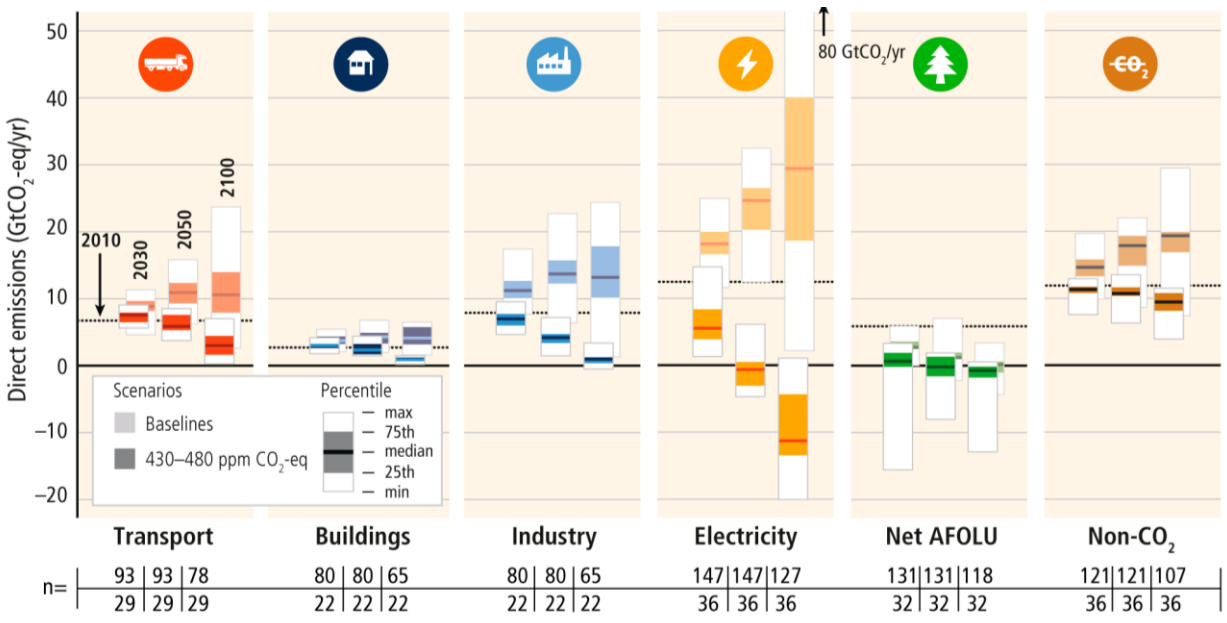


Figure 25 Direct CO2 emissions by major sectors, and non-CO2 emissions, for baseline and mitigation scenarios. Source: IPCC, 2014

As shown in the chart below in figure 26, the potential for GHG mitigation in the building sector is both massive and low-cost which is a huge missed opportunity. Mitigation in the agriculture and forestry sectors comes after the building sector. The energy sector and industry sector have a higher cost for mitigation and finally the highest sectors are waste and transport. This graph reflects the situation in developing countries (IPCC, 2007, p. 72).

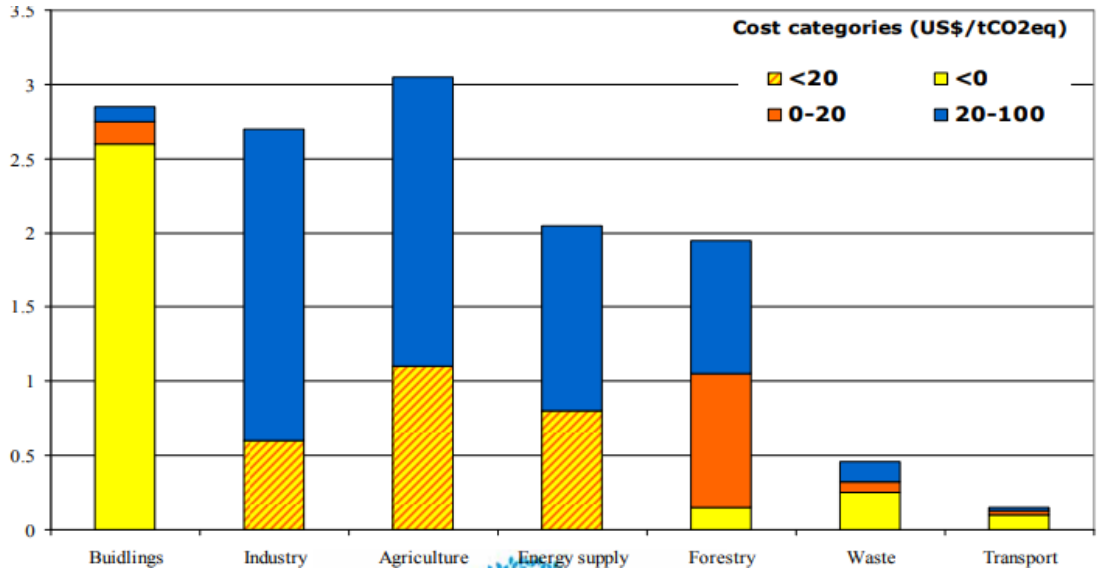


Figure 26 Estimated potential for GHG mitigation at a sectoral level in 2030 in different cost categories in developing countries. Source: Diana Ürge-Vorsatz IPCC, 2007

Based on the approach adopted by this research in finding synergies between mitigation and adaptation strategies, a list was prepared to highlight the possible opportunities in each sector. The following two tables discuss some selected measures of adaptation strategies and mitigation strategies for each sector. Each table includes framework policies, constraints and opportunities of the major sectors impacted by climate change and at the same time could have an impact on this change.

Table 14 Adaptation Strategies for major sectors. Source: IPCC, 2007, P.15

Sector	Adaptation option/strategy	Underlying policy framework	opportunities to implementation	Key constraints
Water	• Expanded rainwater harvesting • Water storage and conservation techniques • Water re-use • Desalination • Water-use and irrigation efficiency	• National water policies • Integrated water resources management • Water-related hazards management	• Integrated water resources management • Synergies with other sectors	• Financial, human resources and physical barriers

Agriculture	• Adjustment of planting dates and crop variety • Crop relocation • Improved land management e.g. erosion control and soil protection through tree planting	• R&D policies • Institutional reform • Land tenure and land reform • Capacity building • Crop insurance • Financial incentives, e.g. subsidies and tax credits	• Longer growing season in higher latitudes • Revenues from 'new' products	• Technological and financial constraints; • Access to new varieties & markets
Infrastructure/settlement (including coastal	• Relocation • Seawalls and storm surge barriers • Dune reinforcement • Land acquisition and creation of wetlands as buffer against sea level rise and flooding • Protection of existing natural barriers	• Standards and regulations to integrate climate change considerations into design • Land-use policies • Building codes • Insurance	• Integrated policies and management • Synergies with sustainable development goals	• Financial and technological barriers • Availability of relocation space
Human health	• Heat-health action plans • Emergency medical services • Improved climate-sensitive disease surveillance and control • Safe water and improved sanitation	• Public health policies that recognize climate risk • Strengthened health services • Regional and international cooperation	• Upgraded health services • Improved quality of life	• Limits to human tolerance (vulnerable groups) • Knowledge limitations • Financial capacity
Tourism	• Diversification of tourism attractions and revenues • Shifting ski slopes to higher altitudes and glaciers • Artificial snow-making	• Integrated planning (e.g. carrying capacity • Linkages with other sectors) • Financial incentives, e.g. subsidies and tax credits	• Revenues from 'new' attractions • Involvement of wider group of stakeholders	• Appeal/marketing of new attractions • Financial and logistical challenges • Potential adverse impact on other sectors (e.g. artificial snow-making may increase energy use)
Transport	• Realignment/relocation • Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	• Integrating climate change considerations into national transport policy • Investment in R&D for special situations, e.g. permafrost areas	• Improved technologies and integration with key sectors (e.g. energy)	• Financial and technological barriers • Availability of less vulnerable routes

Energy	• Strengthening of overhead transmission and distribution infrastructure • Underground cabling for utilities • Energy efficiency • Use of renewable sources • Reduced dependence on single sources of energy	• National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources • Incorporating climate change in design standards	• Stimulation of new technologies • Use of local resources	• Access to viable alternatives • Financial and technological barriers • Acceptance of new technologies

Table 15 Mitigation Strategies for major sectors. Source: IPCC, 2007. P.17

Sector	Key mitigation technologies and practices	Policies	Opportunities	Key constraints
Energy supply	• Improved supply and distribution efficiency • Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); • Combined heat and power • Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas); • *CCS for gas* • Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	• Reduction of fossil fuel subsidies • Taxes or carbon charges on fossil fuels • Feed-in tariffs for renewable energy technologies • Renewable energy obligations; producer subsidies	• May be appropriate to create markets for low-emissions technologies	• Resistance by vested interests may make them difficult to implement

Transport	• More fuel-efficient vehicles • Hybrid vehicles • Cleaner diesel vehicles • Biofuels • Modal shifts from road transport to rail and public transport systems • Non-motorized transport (cycling, walking) • Land-use and transport planning • Higher efficiency aircraft	• Mandatory fuel economy; biofuel blending and CO_2 standards for road transport • Taxes on vehicle purchase, registration, use and motor fuels; • Road and parking pricing • Influence mobility needs through land-use regulations and infrastructure planning • Investment in attractive public transport facilities and non-motorized forms of transport	• Particularly appropriate for countries that are building up their transportation systems	• Partial coverage of vehicle fleet may limit effectiveness • Effectiveness may drop with higher incomes
Buildings	• Efficient lighting and daylighting • More efficient electrical appliances and heating and cooling devices • Improved cook stoves, improved insulation • Passive and active solar design for heating and cooling • Alternative refrigeration fluids, recovery and recycling of fluorinated gases • Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; • Solar photovoltaics integrated in buildings	• Appliance standards and labelling • Building codes and certification • Demand-side management programs • Public sector leadership programs, including procurement • Incentives for energy service companies (ESCOs)	• Government purchasing can expand demand for energy-efficient products • Success factor: Access to third party financing	• Periodic revision of standards needed • Enforcement can be difficult

Industry	• More efficient end-use electrical equipment • Heat and power recovery • Material recycling and substitution • Control of non-CO_2 gas emissions • Process-specific technologies • *Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture;* • *Inert electrodes for aluminum manufacture*	• Provision of benchmark information; performance standards; subsidies; tax credits • Tradable permits • Voluntary agreements	• May be appropriate to stimulate technology uptake.	• Stability of national policy important in view of international competitiveness • Predictable allocation mechanisms and stable price signals important for investments • Success factors include: clear targets, a baseline scenario, third-party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry
Agriculture	• Improved crop and grazing land management to increase soil carbon storage • Restoration of cultivated peaty soils and degraded lands • Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions • Improved nitrogen fertilizer application techniques to reduce N_2O emissions • Dedicated energy crops to replace fossil fuel use • Improved energy efficiency • Improvements of crop yields	• Financial incentives and regulations for improved land management • Maintaining soil carbon content • Efficient use of fertilizers and irrigation	• May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation	

Forestry/ forests	• Afforestation • Reforestation • Forest management • Reduced deforestation • Harvested wood product management • Use of forestry products for bioenergy to replace fossil fuel use • Tree species improvement to increase biomass productivity and carbon sequestration • Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change	• Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests • Land-use regulation and enforcement	• Can help poverty alleviation	• Lack of investment capital and land tenure issues.
Waste	• Landfill CH_4 recovery • Waste incineration with energy recovery • Composting of organic waste • Controlled wastewater treatment • Recycling and waste minimization • Bio covers and bio filters to optimize CH_4 oxidation	• Financial incentives for improved waste and wastewater management • Renewable energy incentives or obligations • Waste management regulations	• May stimulate technology diffusion	• Local availability of low-cost fuel • Most effectively applied at national level with enforcement strategies

By thoroughly going throw the listed measures and policies, it is clearly shown that same sectors could apply adaptation and mitigation measures simultaneously without having to separate the techniques. For example, energy sector, agriculture sector, transport sector, buildings and infrastructure sector, all share the potential of adapting to the challenges posed by the changing climate while at the same time mitigating the changes occurring in climate.

Following the argument of this research which focuses on the synergies between mitigation and adaptation, not only are their sectors that could adapt and mitigate but by taking a closer look to the strategies proposed it is found that some strategies could act as an adaptive measure and a mitigating measure at the same time. For example, in the energy sector, energy efficiency and using renewables are considered once in the adaptation measures and once as mitigation measures. Also in the agriculture sector the land management and crops variety are both considered in the two tables. For the transport sector, investment in public transportation could act as an adaptive strategy for the infrastructure to be more responsive to warming and drainage while at the same time help shift from individual transit modes

which will decrease emissions and help mitigate climate change. One last example would be the infrastructure and building sector, integrating standards and regulations of climate change considerations into design and land use planning acts as a tool with two impacts on both mitigation and adaptation. This concludes that the spatial dimension of the sectors is the mutual dimension between the mitigation and adaptation strategies that could lead to finding synergies and overcoming the long adopted dichotomy.

5.2 Dimensions of climate endurance

The categories for resilience illustrated earlier are once again elaborated in this section but as a dominant factor with reference to all sectors including all possible mitigation and adaptation measures. This section correlates the resilience segments which are the spatial and energy segments and the place based actions described in the beginning of the last chapter to the different sectors in order to put the (Rockfeller Foundation, 2019) dimensions into practice by demonstrating the possible measure for creating synergies between mitigation and adaptation and reaching resilience as illustrated in figure 27.

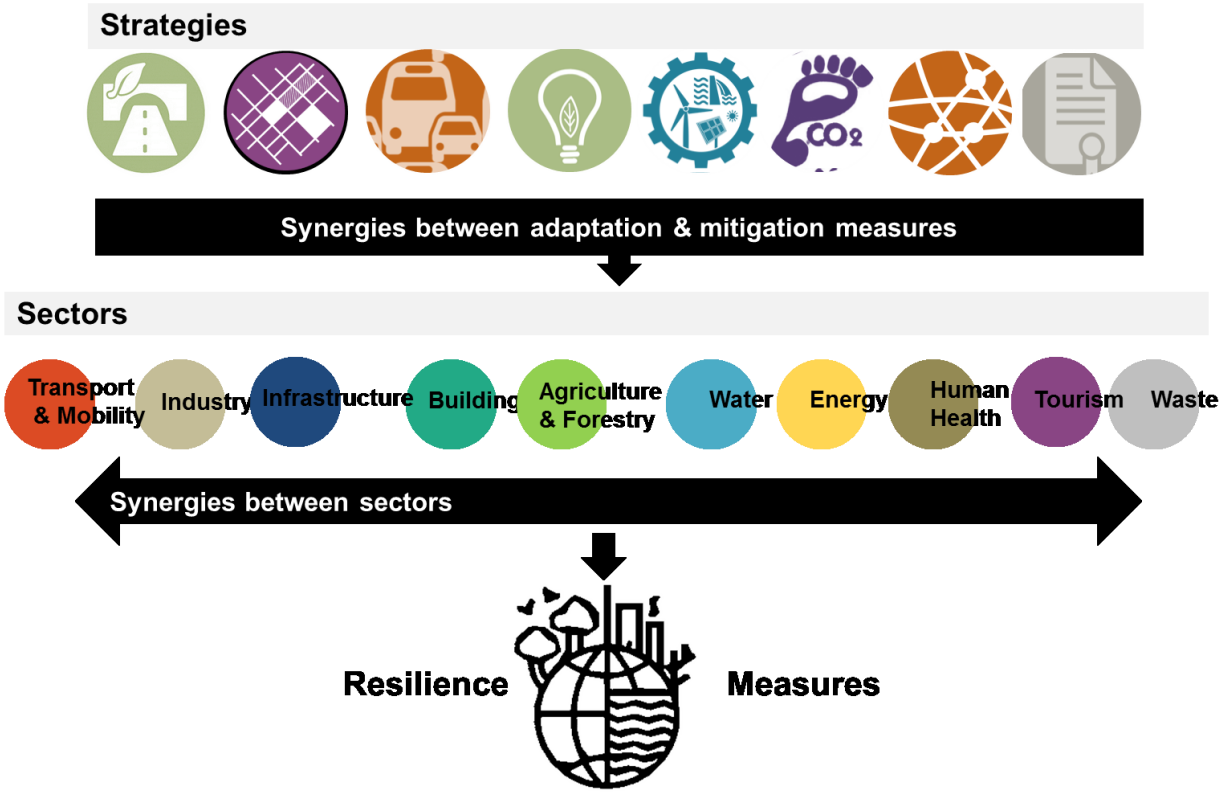


Figure 27 Correlation between resilience strategies and sectors to create synergies. Source: Author

5.2.1 Spatial magnitude of resilience strategies

5.2.1.1 Green Infrastructure

Table 16 Green infrastructure resilience strategies. Source: Author based on (IPCC, 2007) (European Commission, 2013) (U.S Environmental Protection Agency, 2015).

Green infrastructure

Water
Rainwater harvesting
Water storage and conservation techniques
Water re-use
Water-use and irrigation efficiency
Human Health
Safe water and improved sanitation
Infrastructure & buildings
Seawalls and storm surge barriers
Dune reinforcement
Land acquisition and creation of wetlands as buffer against sea level rise and flooding
Protection of existing natural barriers
Transport
Design standards and planning for roads, rail and infrastructure to cope with warming and drainage
Energy
Strengthening of overhead transmission and distribution infrastructure
Underground cabling for utilities

5.2.1.2 Sustainable land use practices

Table 17 Sustainable land use practices resilience strategies. Source: Author based on (IPCC, 2007) (Armstrong, 2016) (U.S. Green Building Council, National League of Cities and the Urban Land Institute, 2017).

Sustainable land use practices

Water
Rainwater harvesting
Desalination plants
Human Health
Heat-health action plans
Emergency medical services
Safe water and improved sanitation
Tourism
Diversification of tourism attractions and revenues
Shifting ski slopes to higher altitudes and glaciers
Artificial snow-making
Forestry
Afforestation
Reforestation
Reduced deforestation
Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change
Waste
Controlled wastewater treatment
Agriculture
Crop relocation
Improved land management e.g. erosion control and soil protection through tree planting
Restoration of cultivated peaty soils and degraded lands
Infrastructure & Buildings
Relocation
Seawalls and storm surge barriers
Dune reinforcement
Land acquisition and creation of wetlands as buffer against sea level rise and flooding
Protection of existing natural barriers
Transport
Realignment/relocation
Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage
Land-use and transport planning
Energy
Strengthening of overhead transmission and distribution infrastructure

5.2.1.3 Sustainable mobility

Table 18 Sustainable mobility resilience strategies. Source: Author based on (IPCC, 2007) (GTZ, 2014)

Sustainable Mobility

Transport
Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage
More fuel-efficient vehicles
Hybrid vehicles
Cleaner diesel vehicles
Biofuels
Modal shifts from road transport to rail and public transport systems
Non-motorized transport (cycling, walking)
Energy
Energy efficiency
Use of renewable sources
Fuel switching

5.2.2 Energetic magnitude of resilience strategies

5.2.2.1 Energy Conservation and Efficiency

Table 19 Energy Conservation and Efficiency Resilience Strategies. Source: Author based on (IPCC, 2007)(Ribeiro, et al., 2015).

Energy efficiency

Energy
Strengthening of overhead transmission and distribution infrastructure
Underground cabling for utilities
Energy efficiency
Reduced dependence on single sources of energy
Combined heat and power
Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas
Improved supply and distribution efficiency
Industry
More efficient end-use electrical equipment
Control of non-CO_2 gas emissions
Advanced energy efficiency
Agriculture
Improved energy efficiency
Infrastructure & Buildings
Efficient lighting and daylighting
More efficient electrical appliances and heating and cooling devices
Improved cook stoves, improved insulation
Passive and active solar design for heating and cooling
Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;
Transport
More fuel-efficient vehicles
Non-motorized transport (cycling, walking)
Higher efficiency aircraft

5.2.2.2 Regenerative and Renewable Energy

Table 20 Regenerative and Renewable Energy Resilience Strategies. Source: Author based on (IPCC, 2007)(Olah, Mathew, Goeppert, & Prakash, 2018)

Regenerative & Renewable Energy

Energy
Use of renewable supply sources
Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)
Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics
Industry
Heat and power recovery
Material recycling and substitution
Forestry
Tree species improvement to increase biomass productivity and carbon sequestration
Waste
Waste incineration with energy recovery
Composting of organic waste
Recycling and waste minimization
Agriculture
Dedicated energy crops to replace fossil fuel use
Infrastructure & Buildings
Passive and active solar design for heating and cooling
Alternative refrigeration fluids, recovery and recycling of fluorinated gases
Solar photovoltaics integrated in buildings
Transport
Hybrid vehicles
Cleaner diesel vehicles
Biofuels

5.2.2.3 Carbon Zero, Carbon Positive and Smart Grid

Table 21 Carbon Zero, Carbon Positive and Smart Grid Resilience Strategies. Source: Author based on (IPCC, 2007)(PipKorn, 2013)(Jain & Mishra, 2016)

Carbon Zero, Carbon Positive & Smart Grid

Energy
Carbon Capture and Storage CCS
Carbon Capture and Reuse CCR
Carbon Capture and Utilization CCU
Carbon Offsets
Two way communication grids
Monitoring and controlling systems
Industry
CCS for cement, ammonia, and iron manufacture
Forestry
Tree species improvement to increase biomass productivity and carbon sequestration
Waste
Landfill CH_4 recovery
Infrastructure & Buildings
Feed in energy supply to grid

5.2.3 Policies magnitude of resilience strategies

Table 22 Policies and Institutional Arrangements Resilience Strategies. Source: Author based on (IPCC, 2007)(IEA, 2015)

Policies & Institutional Arrangements

Water
National water policies
Integrated water resources management
Water-related hazards management
Human health
Public health policies that recognize climate risk
Strengthened health services
Regional and international cooperation
Tourism
Integrated planning (e.g. carrying capacity
Linkages with other sectors)
Financial incentives, e.g. subsidies and tax credits
Industry
Provision of benchmark information; performance standards; subsidies; tax credits
Tradable permits
Voluntary agreements
Forestry
Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests
Land-use regulation and enforcement
Waste
Financial incentives for improved waste and wastewater management
Renewable energy incentives or obligations
Waste management regulations
Agriculture
R&D policies
Institutional reform
Land tenure and land reform
Capacity building
Crop insurance
Financial incentives, e.g. subsidies and tax credits
Financial incentives and regulations for improved land management
Maintaining soil carbon content
Efficient use of fertilizers and irrigation
Infrastructure and buildings
Standards and regulations to integrate climate change considerations into design
Land-use policies
Building codes
Insurance
Appliance standards and labelling
Building codes and certification
Demand-side management programs
Public sector leadership programs, including procurement
Incentives for energy service companies (ESCOs)
Transport
Integrating climate change considerations into national transport policy
Investment in R&D for special situations, e.g. permafrost areas
Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
Taxes on vehicle purchase, registration, use and motor fuels;
Road and parking pricing
Influence mobility needs through land-use regulations and infrastructure planning
Investment in attractive public transport facilities and non-motorized
Energy
National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
Incorporating climate change in design standards
Reduction of fossil fuel subsidies
Taxes or carbon charges on fossil fuels
Feed-in tariffs for renewable energy technologies
Renewable energy obligations; producer subsidies

6 Planning for climate change

6.1 Framework

Subsequent to the listing of resilience dimensions and linking them with sectors and measures, a framework is needed to guide the application of these measures based on a scientific approach. Addressing the climate change dilemma can be an overwhelming challenge. When combined with vulnerable populations, poverty, informality, and housing and infrastructure development, responding to climate change needs a detailed framework to explain the necessary steps for planning. Climate change planning must integrate all policies and plans and development activities across all sectors. Good planning practices are fundamentally climate smart planning practices.

This section introduces a strategic planning framework adopted from comparing approaches of the GIZ Climate Protection Program (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011), the UN Habitat Cities and Climate Change Initiative (UN Habitat, 2014) and the Trust for Public Land's Climate Smart Cities program (Ernst & Blaha, 2015) as shown in table 23 below.

The GIZ Climate Protection Program (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) is composed of 10 modules. The first module is applying a climate lens and it is concerned with the collection of climate data for the specific territory. The second module is interpreting climate data in order to identify areas of concern. The third module is assessing vulnerability. The fourth module is identifying options. The fifth module is selecting adaptation measures. The sixth module is developing an M&E framework. The seventh module is developing institutional capacity for adaptation. The eighth module is the local climate stresses, vulnerability and resilience. The ninth module is taking action at local level and the final module is the integration of climate planning into the project cycle.

The UN Habitat Cities and Climate Change Initiative incorporates innovative assessment tools with a participatory, local values-based methodology to follow when planning for taking action against the changing climate (UN Habitat, 2014). It is divided into four main modules. The first module is concerned with understanding the dilemma and the scope of what's happening by involving the competent stakeholder and performing vulnerability assessment.

The second module tackles the issue of needs and priorities to reach the objective planned. The third module raises the topic of action planning, by providing options and scenarios and assessing them. The final module is more about the monitoring of what has been done and the adjustment based on lessons learned.

The Trust for Public Land's Climate Smart Cities program approach is based on promoting coordination and collaboration across city departments, organizations, sectors and regions. The methodology depends on sharing information at every level to mitigate and adapt to the global impacts of climate change (Ernst & Blaha, 2015). The framework proposed for the decision support tool is designed in four modules. First Module is to identify and integrate all competent stakeholders in order to be able to meet the needs of different types of users. The second module is to set and analyze diverse priorities. The third module is concerned with visualizing and comparing alternative scenarios. The final module is about the implementation and support of collaborative actions.

Table 23 Comparative Analysis of the modules of frameworks for climate change planning. Source: Author based on UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

	Climate Protection Program	Cities and Climate Change Initiative	Climate Smart Cities program
Module 1: Observation			
Climate Data			
Resources			
Stakeholders			
Area of concern			
Module 2: Exploration			
Climate Variability			
Exposure Analysis			
Sensitivity Analysis			
Adaptive Capacity Analysis			
Vulnerability Analysis			
GIS Linking			

Module 3: Orientation			
Objectives			
Priorities			
Module 4: Identification			
Alternatives			
Criteria Weighing			
Ranking			
Module 5: Valuation			
Impact evaluation			
Monitoring			

Below is a figure 28 showing the final framework adopted from the previous mentioned methodologies based on the evaluation of approaches and modules. All methodologies follow the same structure in their framework. The proposed framework has 5 modules. The first module covers climate data collection, and resources and stakeholders identification. The second module is more about the analysis of exposure, vulnerability and adaptive capacity. The third module is concerned with identifying the areas of concern and setting the priorities. The fourth module is action planning through identifying and ranking options. The fifth module is about the monitoring and the evaluation of the magnitude of impact of the proposed solutions.

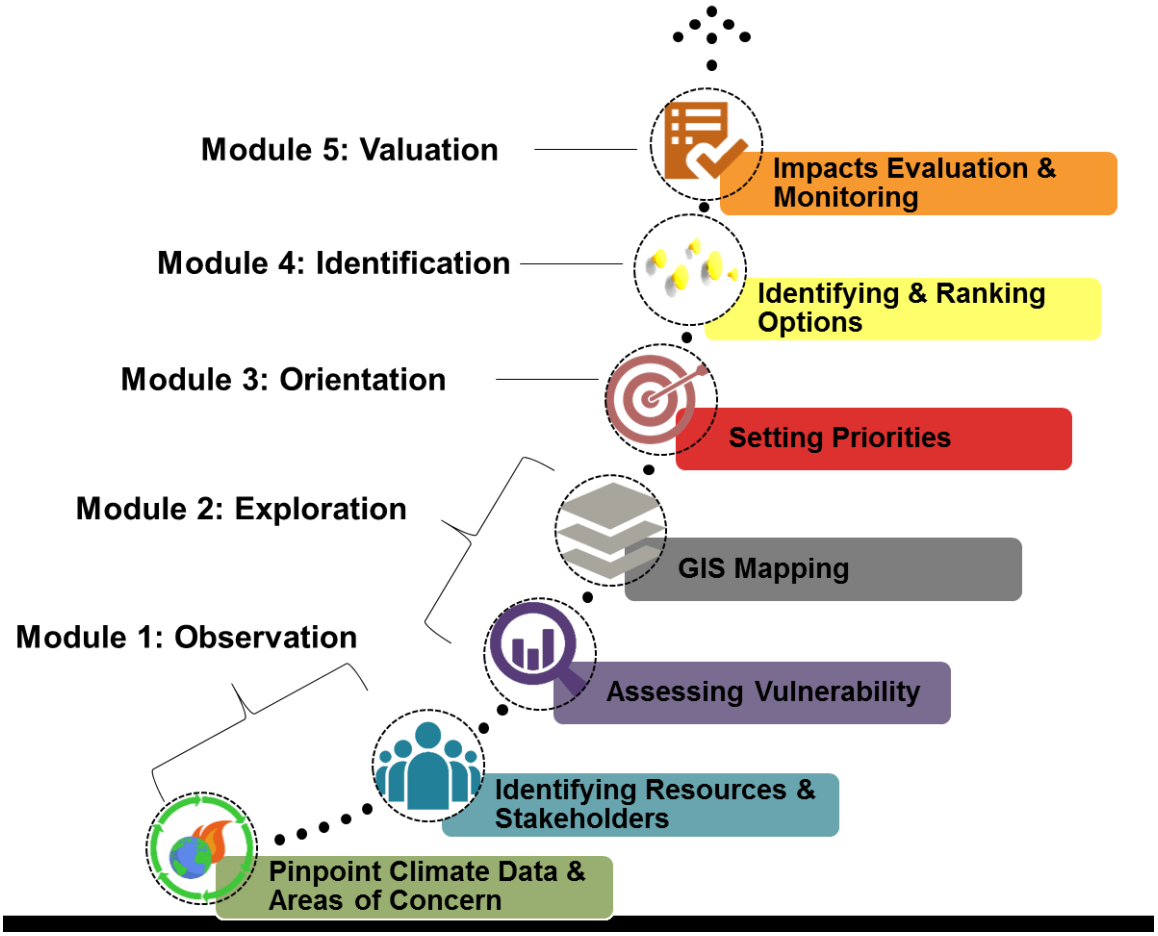


Figure 28 Framework for planning for climate change. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

6.2 Climate change action plan tools

After listing the framework modules in the previous section, this one is a breakdown for all activities that need to be conducted and the assessment tools required. The following set of tools are designed to help planners, or other experts involved in climate change planning projects to develop a climate change action plan that is realistic, feasible and applicable.

6.2.1 Module 1: Observation

This module is considered the foundation for the whole process. It is concerned with stating the scope of the work. It consists of four main steps which are: framing the specific climate change challenge, identifying resources, identifying stakeholders, and area of concern.

Table 24 Planning for climate change framework Module 1. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

Module 1: Observation

Step 1.1: Climate Change Challenge

Identifying the trigger behind starting the action plan is the aim of this task.

- A disaster
- An extreme weather event
- Direct urban growth away from climate change hazard areas
- Built up of environmental, social, or economic impacts
- A national or local government initiative

Step 1.2: Identify Available Resources

- Connections between existing city plans and strategies.
- Ongoing projects or initiatives that could support climate planning

Step 1.3: Identify stakeholders

Government:

- City departments (e.g. planning, engineering, transportation, finance, health)
- Local government elected Representatives
- Neighbouring local government representatives
- District, regional and national governments

Local Area and Non-Governmental

- Environmental groups
- Neighbourhood groups
- Local area leaders
- Local religious groups
- Under-represented groups (e.g. women's and minority groups)

Public Sector

- Sector boards and authorities (health, education, transport)
- Educational institutions (technical schools, universities)
- International agencies

Business and Labour

• Small and medium-sized businesses • Trade and labour unions • Real estate developers • Banks, credit unions and other financial groups • Chambers of commerce and business groups • News media • Professional associations • Privately owned / managed utilities Public involvement through: • Forums • Workshops • Focus groups • Advisory committees • Social media • Conventional media • Cell phone engagement • Flyers or posters • Surveys
Step 1.4: Determine the area of concern
• Identify the type of area (residential, commercial, industrial, mixed-use, etc. • Identify the location features (coastal, river basin, prone to hazard, etc.

6.2.2 Module 2: Exploration

This module is the analysis module. It covers the four steps vulnerability analysis; which are the exposure analysis, the sensitivity analysis, the adaptive capacity analysis and the vulnerability analysis. It is also concerned with linking the analysis to spatial features through GIS mapping.

Table 25 Planning for climate change framework Module 2. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

Module 2: Exploration
Step 2.1: Exposure analysis
Summary:

- Climate Change Hazard
- Influence:
  - Primary Impact
  - Secondary Impact
- Climate Model Scenario Projections
- Summary Climate Change Projection
  - Direction –Uncertainty - Confidence
- Exposure
  - people, places, institutions and sectors

Step 2.2: Sensitivity analysis

- Socio-demographic sensitivity assessment
- Sensitive places mapping
- Community-based sensitivity mapping
- Sensitivity thresholds
- Climate threat plotting

Step 2.3: Adaptive capacity analysis

A high – medium – low scale to asses capacity of threats against:

Economic wealth:

- Access to adequate financial resources and funding
- Resources to respond to a climate related hazard (e.g. access to basic transportation, adequate rations, ability to relocate temporarily, basic shelter)
- Adequate staff and allocated time to plan and implement adaptation actions

Technology:

- Ability to communicate directly with the people/ sector affected

Infrastructure:

- Adequate transport, water infrastructure, sanitation, energy supply and management
- Major infrastructure and/or facilities located in hazard prone areas
- Access to safe, clean drinking water in the event of a hazard occurrence
- Adequate medical services in close proximity

Information and Skills:

- decision-makers and stakeholders aware of a) climate change and b)potential impacts/risks in your
- Area/sector undertaken previous efforts
- Trained emergency response teams for this sector/area

Institutions and Social Capital:

- political willingness to allocate resources to build adaptive capacity
- community/neighbourhood "leaders" that can quickly organize people in the event of a hazard occurrence
- Existing processes or plans that you can integrate with?
- Specific agencies, community groups and/or NGOs that have the mandate and skills to focus on the specific sector/area

Step 2.4: vulnerability assessment

Vulnerability Matrix

- Climate Change Hazard
- Threat Level
- Hazard-specific Adaptive Capacity Status
- Relative Vulnerability (Threat Level divided by Adaptive Capacity)

Vulnerable population

- Sector
- Geographic Locations
- Vulnerable Population
- Settlements
- Livelihoods
- Health

Step 2.5: GIS Mapping

- location of hazards
- population information
- major infrastructure
- land uses
- critical infrastructure
- key environmentally sensitive areas

6.2.3 Module 3: Orientation

This module includes one planning step which will help identify issues of local community and local stakeholders in addition to existing city plans and objectives.

Table 26 Planning for climate change framework Module 3. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

Module 3: Orientation
Step 3.1: Relate issues to objectives
• Align objectives with existing city plans and strategies • Link to climate change (risks, threats and impacts) from the Vulnerability Assessment • Identify gaps and missing objectives
Step 3.2: Develop indicators for objectives
Develop qualitative indicators to assess the achievement of objectives (high – medium – low) and set priorities

6.2.4 Module 4: Identification

This module is concerned with action taking and implementation. It assists in the evaluation and prioritization of options to help mitigate and adapt to climate change based on the specific analysis of each location/sector.

Table 27 Planning for climate change framework Module 4. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

Module 4: Identification
Step 4.1: Options Identification
• Repairing and strengthening existing climate defenses • Climate proofing • New infrastructure • Ecosystem based approach • Smaller-scale interventions • Incremental activities

Step 4.2: Criteria Weighing
Use a descriptive high-medium-low scoring system for options based on: • Stakeholder acceptability • Technical feasibility • Urgency • Ease of implementation • Relative effectiveness • Cost • Mainstreaming potential • Multi-sectoral
Step 4.3: Screen and rank options
• A direct rank from "best" to "worst" • Trade-offs within options to achieve objectives • Trade-offs between options to achieve objectives • Multiplying weight by option's technical score

6.2.5 Module 5: Valuation

This module gives a clear understanding of monitoring and evaluation to evaluate actions against objectives and track the progress of the plan to ensure having the anticipated impact, and fulfillment of stakeholders' roles.

Table 28 Planning for climate change framework Module 5. Source: Author based on (UN Habitat, 2014), (Frankel-Reed, Fröde-Thierfelder, Porsché, Eberhardt, & Svendsen, 2011) and (Ernst & Blaha, 2015)

Module 5: Valuation
Step 5.1: Evaluate results

Evaluate magnitude of impact of actions against indicators, target and objectives
Evaluation questions for each action:
• **Adequacy and effectiveness**
  ○ Has the action been implemented?
  ○ Has the action achieved its stated objective(s)?
  ○ Have sufficient resources been organized to carry out the action?
  ○ Have the leadership and capacities of the individuals and organizations involved been sufficient?
  ○ Will the partnerships and networks formed in the process be sustained?

- Can the results be sustained?

- **Efficiency**
  - Could resources have been used differently to produce more results?
  - Would a different action have produced the same or better results at a lower cost?
  - Were the resources managed in the most efficient way possible to achieve the objectives?

Evaluation questions for the plan as a whole:

- **Local Context and Conditions**
  - Have local climate conditions and circumstances changed (exposure, vulnerability, etc.)?
  - Do the new climate conditions necessitate new or revised actions (phasing, scope, etc.)?
  - Have local priorities changed?
- **Adjustment and recommendations**
  - How must the Climate Change Action Plan be changed to better meet objectives?
  - Have climate and/or community conditions changed that a review of objectives and actions is necessary?

Step 5.2: Prepare monitoring framework and program

- Potential Process Indicators
- Potential Outcome Indicators
- Baseline Measure (Current)
- Target
- Data source
- Data collection frequency
- Data collection methods
- Parties involved

Consider the process a dynamic one that needs continuous update and modification

7 ADAPTED RESILIENT MITIGATED DEVELOPMENT FOR CITY (ARM'D CITY)

7.1 ARM'D CITY Origin

In an attempt to put the previously clarified resilience dimensions and the developed framework into action, a model for the idealistic city is created to serve as a guideline for planning cities that are able to withstand the impacts of climate change, a city that is armed with all pertinent measures to fight climate change. However, reaching such a city must rely on the pillars of synergies between adaptation, mitigation and resilience based on the previously discussed segments as shown in figure 29.

Figure 29 ARM'D City Model. Source: Author

Adapted, Resilient and Mitigated Development (ARM'D) are the main features of the proposed city based on a set of recommended measures that are tailored to each spatial setting and to each expected climate hazard. As the complexity of integrating relevant measures in the process increases, the need for a platform to crosscut different data using automated systems increases.

The overall objective of this model is to create a user friendly software application which could facilitate the inclusion of adaptation, mitigation and resilience measures in the planning process of cities by presenting several alternatives along with their technical and spatial features along with their feasibility, affordability and applicability to each urban scale in the city.

The proposed application will be based on an Excel platform and therefore it is compatible with GIS for carrying out an urban analysis of the current situation and future possible impacts if applying the proposed measures prior to decision making.

The ARM'D City tool could be considered a facilitator for experts and non-experts to have a clear understanding of the possible interventions that could be applied at different urban scales to stand against the impacts of climate change on urbanization, people and economy. The features of the tool are expressed in figure 30 below. It is a rule based design approach that engages all different measures and alternatives in a simple tool to reach an optimal integrated proposal tailored to each specific case. It is an interactive and inclusive platform that consists of a database for all measures and simulates the feasibility of each one of them vis-à-vis the affordability and applicability of them.

The proposed model is a tentative climate roadmap to make urban areas more functional, productive, and efficient and less vulnerable. The proposed model is also concerned with applicative strategies on institutional arrangements necessary to support the implementation of the proposed options citywide. This research study is composed of two phases; first creating a database for measures - and sorting them into possible synergies' packages - and investigating their technical applicability, the second would consist of evaluating the affordability and applicability of the proposed measures.

The ARM'D City tool introduces a shift from typological thinking to procedural thinking. Two segments could be discussed to show the distinction of this software application; the first segment is the different approach and methodology followed in creating and applying the application, the second segment is the function of the software compared to existing partially similar software.

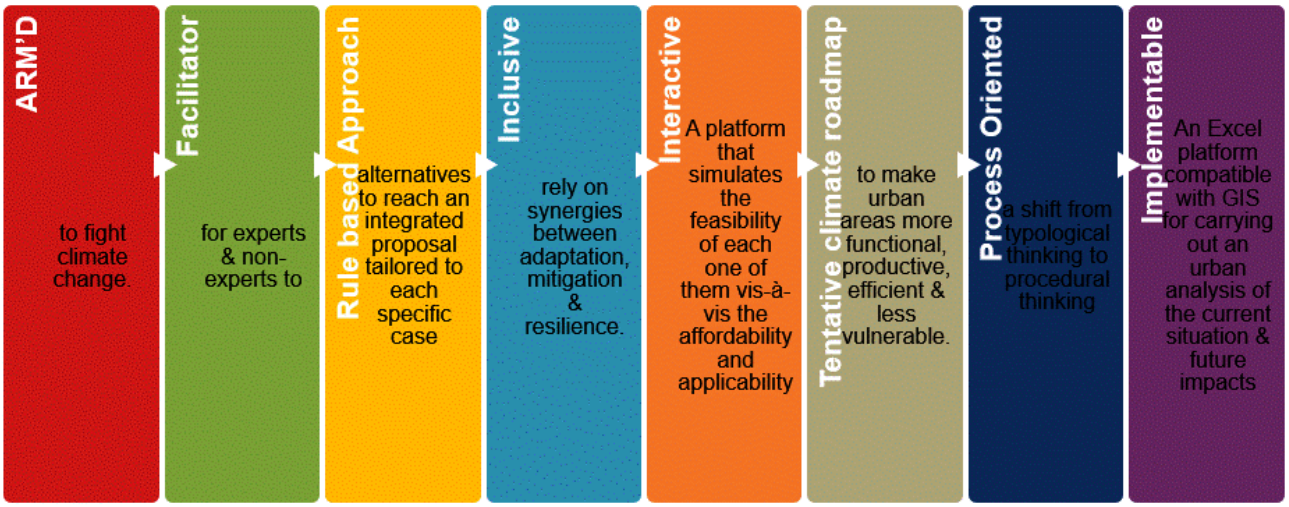


Figure 30 ARM'D Tool Features. Source: Author

An extensive literature review and technologies survey was conducted to ensure the originality and competitiveness of the idea and the function of the tool. The other existing software focuses on collecting existing data on the urban patterns as well as the potential climate hazards to result in an analysis of the current situation without taking into consideration combined measures proposals and feasibility of results which is the core difference in the proposed tool. Below are some of the existing tools spanning between mitigation and carbon footprint tools and adaptation action plan tools:

Table 29 Existing climate related Software. Source: Author

Application Name	Scope
CanVis, NOAA Digital Coast	Climate projections and observations
Climate Change Explorer Tool, White House	
Climate Wizard, The Nature Conservancy	
Healthy Connected Chattanooga, TPL	
InVEST, Natural Capital Project	
Minneapolis Resilience Map, City of Minneapolis	
Scenarios Network for Alaska and Arctic Planning, International Arctic Research Center	
HAZUS, FEMA	Hazard Impact Analysis
I-Heat Evaluation and Assessment Tool, BioMedware, Inc. and Univ. of Michigan	

Integrated Hazards Assessment Tool (IHAT), University of South Carolina	
Interactive precipitation map, Natural Resources Conservation Service	
MOTF Hurricane Sandy Impact Analysis, FEMA	
ADAPT, ICLEI	Climate adaptation
SUDPlan	
Silicon Valley 2.0, Santa Clara County	
Urban Adaptation Support Tool, European Commission, EU, Covenant of Mayors	
Urban Climate Adaptation Tool -CAT, Oak Ridge National Laboratory	
COLE, USFS	Climate mitigation
EPA Facility Level Information on GHG Tool (FLIGHT), EPA	
California Urban Footprint, Southern California Association of Governments	
AUSSSM	
SEMANCO	
AgroClimate, USDA and Southeast Climate Consortium	Agriculture
CropScape, National Agricultural Statistics Services	
VegScape - Vegetation Condition Explorer, USDA's National Agricultural Statistics Survey	
Carbon Storage in Forests, EPA	Forestry
Forests to Faucents, USFS	
i-Tree Canopy, US Forest Service	
Louisville Urban Tree Canopy Assessment, City of Louisville	
Beach-fx, US Army Corp of Engineers	Coastal resilience
Coastal Change Analysis Program, NOAA	
Coastal Change Hazards Portal, US Geological Survey	
Coastal County Snapshots, NOAA, Digital Coast	
Coastal Flood Exposure Mapper, NOAA	
Coastal Resilience Mapping Portal, TNC	
Jamaica Bay Decision Support Tool, Science and Resilience Institute of Jamaica Bay, RAND	
Digital Coast Sea Level Rise Viewer, NOAA	
Sea Change Boston, Sasaki	

SLAMM - Sea Level Affecting Marshes Model, US Fish and Wildlife Services	
Surging Seas: Sea level rise analysis by Climate Central, Climate Central	
Biofuels Atlas, National Renewable Energy	Energy
EcoSmart Landscapes, USFS and UC Davis	
ENVI-met	
TownScope	
RayMan	
Ecotect	
Home Energy Assessment Technologies: HEAT	
DECoRuM, Domestic Energy, Carbon Counting and Carbon Reduction model	
ClimateSmart - NYC, TPL	Spatial Planning
Milwaukee Green Infrastructure DST, Metropolitan Sewerage District, Climate Interactiv	
GOSOL Goretzki	
Habitat Priority Planner, NOAA Coastal Services Center	
Water Supply Stress Index Ecosystem Services Model, USFS	
Resilient Communities, ESRI	Community's resiliency
Economic and Human Impact of Natural Hazards, HVRI, University of South Carolina	

7.2 ARM'D City Parameters

7.2.1 KEY CONCEPTS IN THE MODEL

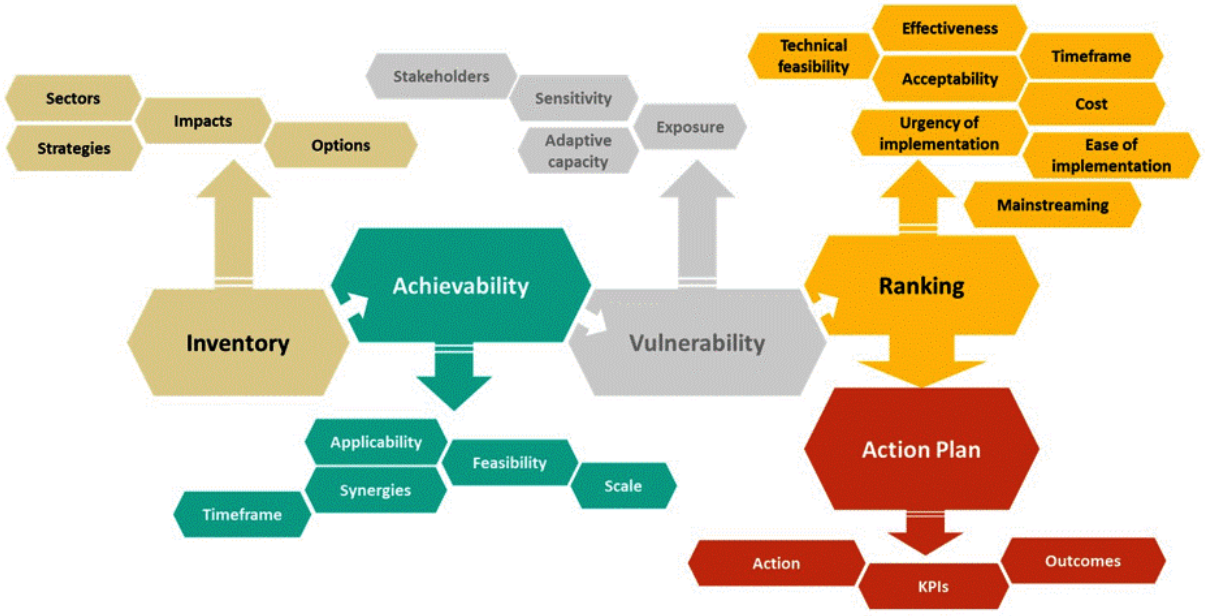


Figure 31 Tool development methodology. Source: Author

7.2.1.1 Inventory

The inventory acts as the foundation for the model. It is a comprehensive scan of the numerous possibilities that could be considered. To assure the consistency of results, the inventory must be thoroughly created to cover the horizontal levels as well as the vertical levels. The horizontal levels represent the different sectors that should work integrally to reach a holistic plan. The vertical levels are the different strategies under each sector that serve as adaptation, mitigation or resilient strategies. As a result of the crosscutting between the horizontal and vertical levels, alternative measures/options could then be derived.

7.2.1.2 Achievability

The abundant options resulting from the inventory depend on several factors to prove their achievability. The achievability of an option varies from a neighborhood to another depending on the geographic location, impact of changes, promptness of systems and vulnerability of people. However the factors are somehow constant. These factors are the possible synergies and combining of measures, the average cost of implementation, the required capacity to apply the measure, the scale of application and timeframe. All factors combined together result in determining the achievability of options.

7.2.1.3 Vulnerability

The vulnerability assessment is the pivotal step in the model. Based on the assessment, the most appropriate options are presented. The assessment covers the stakeholders, exposure, sensitivity and adaptive capacity. By performing this detailed analysis, the model will filter the options to match the results of the inquiries of the analysis. These options are filtered according to the hazardous event, the impacted location/sector, and the physical, social and economic risks.

7.2.1.4 Ranking

Ranking the already filtered options is linked directly to their achievability which was previously elaborated. The screening and ranking of options is calculated on a numeric scale of weights for each option to compare easily. The ranking step is the key to selecting the most applicable and efficient measures that will have a major reaction to the impacts of the changing climate.

7.2.1.5 Action Plan

To transit from the theory to the implementation stage an action plan is required. This action plan comprises a breakdown of all activities that are required in order to implement the chosen actions. These activities include the resources needed, the key performance indicators and the monitoring and evaluation of results which measures the adequacy, effectiveness, efficiency and recommends adjustments to the plan.

7.2.2 ARM'D City Model Parameters

The first step to develop this software application is a comprehensive literature review to identify the most appropriate measures to be adopted at different urban scales and contexts. These measures are classified into different strategies and sectors. A study is then conducted for all these measures for each of the proposed measures which includes synergies, applicability, feasibility and scale.

The next step is defining parameters and categorizing them to fixed ones and variables. These parameters include technical parameters, spatial parameters and socio economic parameters. The main idea behind creating the tool is to have independent parameters which are the variables that control the dependent parameters which are the fixed ones that include the algorithms. By changing the input of these variables the fixed cells are altered automatically.

Afterwards the algorithms that link it all together are created. These algorithms are created between the strategies, measures and the vulnerability analysis. Finally all these features are linked by a generic algorithm that is responsible for displaying the resultant of the whole process. The final step is testing the tool on a concrete case study for validation.

The main features of this study are:

- The physical, social and economic risks
- The vulnerability of the people, places, institutions and sectors
- Possible synergies between mitigation and adaptation measures
- The achievability of implementation

The following illustration explains the base parameters of the developed model which takes us step by step starting from the assessment features passing through the features of alternatives till the generation of proposals.

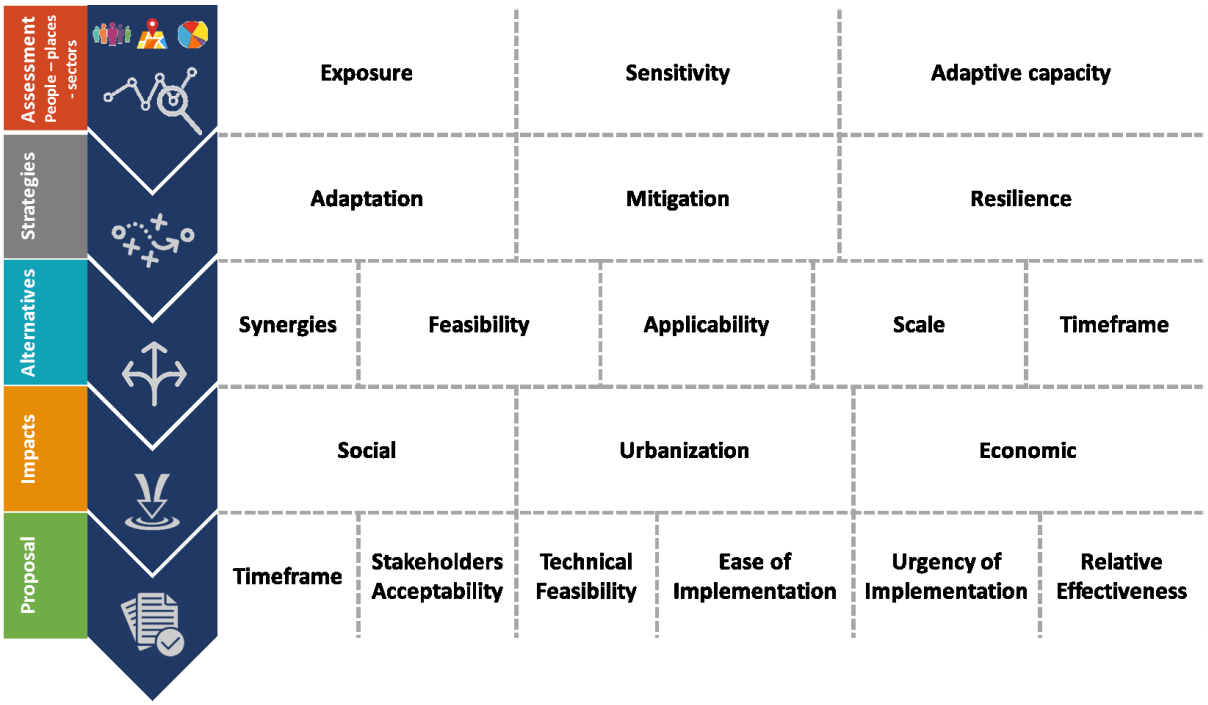


Figure 32 Main parameters of the research study. Source: Author

7.3 ARM'D City Model

7.3.1 ARM'D City Model Scheme

The software application is designed on excel to be used by experts and non-experts in the field of urban planning for climate change. It could be used to convince decision makers to adopt any of the measures or to convince them to create new policies and/or action plans.

After the generic overview presented in the last section, here the detailed scheme is elaborated. The Excel tool is composed of four key files that are linked together to produce package alternatives suitable for each case studied. The key concepts and features of the tool are reflected in these files which are the database file, the analysis file, the options file and the proposals file. Each file consists of several worksheets that cover the broad perceptions that were discussed throughout the whole research study.

The tool embodies the whole process of planning for a changing climate starting at the data collection phase to the implementation phase. By integrating the climate endurance measures and the planning framework from the last two chapters, the excel model can help create resilience packages that could be applied to the most vulnerable communities and highly impacted places.

- The first file is the database file which could be considered the backend of the tool. It contains all the constants that feed in the rest of the files. It covers the general resilience data and stores it as fixed values that could only be modified by the tool architect and not by the user.

- The second file is the analysis file. It is the initial user interface through which all inputs are variables entered by the user himself according to specifics of the case. This file is linked directly to the database file. It contains all the necessary analysis that need to be done prior to the decision making.

- The third file is the options file and could be considered as the subsequent user interface. This file is linked to the analysis file based on the input of the user which are constrained variables. It contains as well variables that could be tailored to each case by the user himself in order to be able to screen and rank the options.

- The last file is the proposal file. It is the resultant of all the algorithms and processed performed in this tool. It automatically generates a list of possible measures that could be applied to the specific case study based on the users' input and helps in deriving an action plan as well to assure the ease of implementation. The action plan is prepared by input from the tool architect for each case as data and resources could vary from a case to another.

The following chart explains the broad scheme behind the four files and their links showing more details about the specific worksheets inside each of the general files.

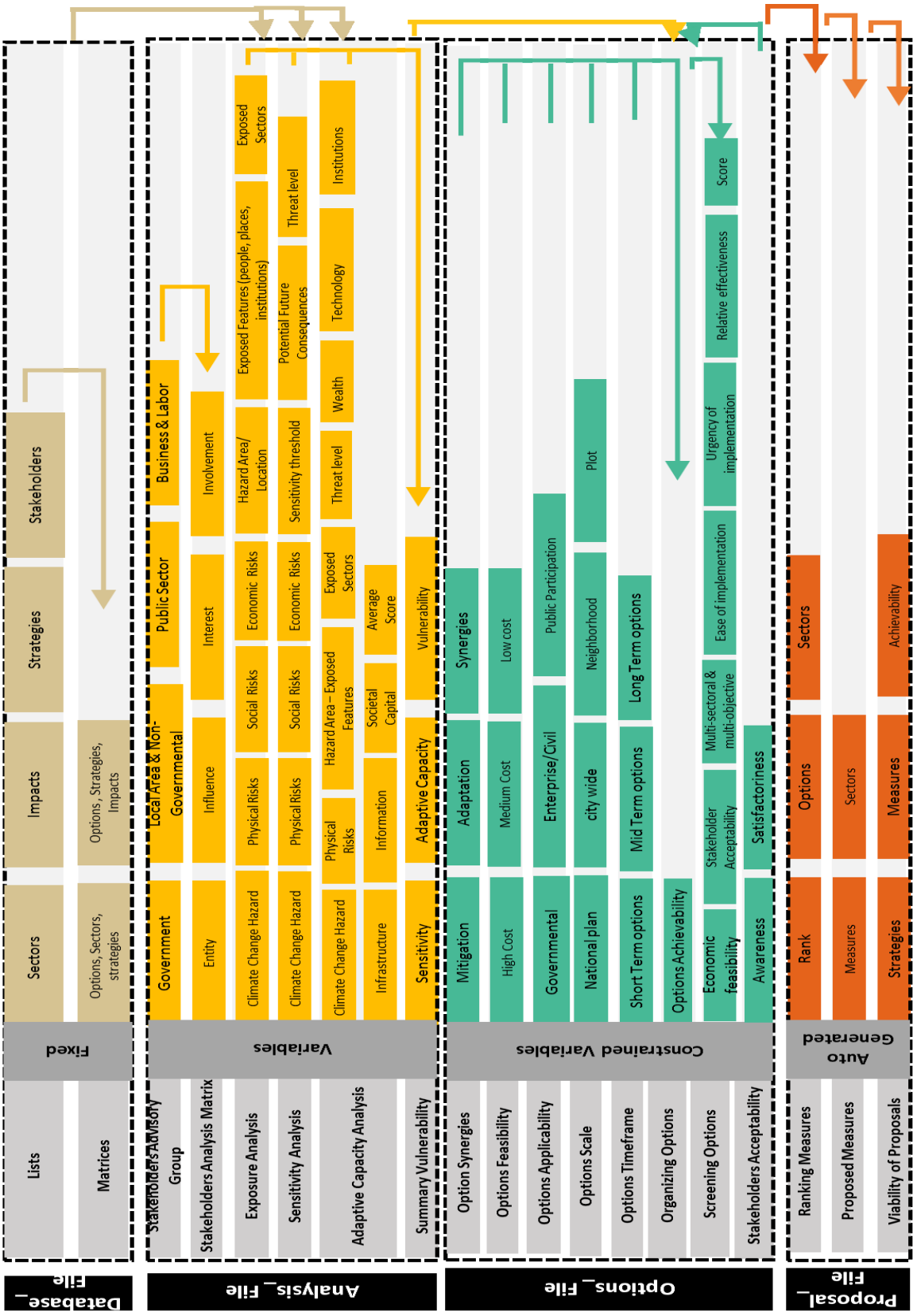


Figure 33 Scheme behind the ARM'D CITY Tool. Source: Author

7.3.2 Excel Application Interpretation

This section elaborates more on the details of the scheme presented earlier. The Excel application lays the foundation of a matrix where the above-mentioned methodology provides options to match eventually all the variables as summarized in the following table 30.

Table 30 Excel Application interpretation. Source: Author.

#	File	worksheets	Description
1	**Database file**	Sheet1: Sectors, Strategies and Impacts listing	The key sectors taken into consideration in the study are grouped in this sheet: Water, Agriculture, Infrastructure/ settlement, Human health, Tourism, Transport, Energy, Buildings, Industry, Forestry, Waste
			The broad strategies that were derived from the literature review conducted in this study are listed in this sheet: Green Infrastructure, Sustainable land use practices, Sustainable mobility, Energy Conservation and Efficiency, Regenerative and Renewable Energy, Carbon Zero, Carbon Positive and Smart Grid, Policies & institutional arrangements
			The impacts discussed earlier in this study are mentioned in this sheet: Social impacts, impacts on Urbanization, impacts on Economy
		Sheet 2: Options vs Sectors	Based on sectors listed in sheet 1, options are categorized into adaptation & mitigation options for each sector.
		Sheet 3: Options, strategies, impacts	In this sheet, the previously listed options are classified according to the fitting strategies and the impact that they could

			eliminate/decrease
		Sheet 4: Options Matrix	This sheet lists the possible options in each sector categorized by the climate hazard occurring.
		Sheet 5: Stakeholders listing	This sheet lists the stakeholders that are likely to be involved in the planning and their expected roles
2	**Analysis file**	Sheet 1: Stakeholders Advisory Group	This sheet lists the stakeholders that are likely to be involved in the planning and the user has to choose the relevant ones for the specific case.
		Sheet 2: Stakeholder Analysis Matrix	Based on the choice from the previous worksheet, the analysis matrix is generated to define the role of each of the stakeholders by setting their interest and influence. (leverage – mobilize – persuade – co-opt)
		Sheet 3: Exposure Analysis	This analysis sheet helps the user choose from a list of Climate Change Hazards along with their Physical, Social and Economic Risks. Then the user identifies the Hazard Area/ Location – Exposed Features (people, places, institutions) - Exposed Sectors. The aim of this sheet is to identify the assets exposed to the climate change impacts.
		Sheet 4: Sensitivity Analysis	This sheet identifies the threat level by considering the probability of the climate change consequences and their magnitude which are inputs from the user. (High – Medium high – Medium – medium low – Low)

		Sheet 5: Adaptive capacity analysis	This analysis is based on scoring to assess the capacity of threats against: Economic wealth, Technology, institutions, Infrastructure, information and social capital. The scoring is inserted by the user by answering a series of questions.
		Sheet 6: Summary vulnerability analysis	The relative vulnerability is automatically calculated by dividing the threat level by the adaptive capacity and the key hazards are emphasized
3	**Options file**	Sheet 1 Options synergies	The options are then categorized once again according the possible synergies between them to highlight the potential of the option to have mutual benefit. (mitigation – adaptation – synergies)
		Sheet 2: Options feasibility	The options are categorized according to their average cost of implementation (high-mid-low)
		Sheet 3: Options applicability	This sheet categorizes the options according to the responsibility of application (Governmental – Civil/enterprise – Public participation/individual)
		Sheet 4: Options Scale	Here the options are categorized according to size of implementation (National plan – city wide - neighborhood – plot)
		Sheet 5: Options Timeframe	Finally the options are categorized based on the timeframe for implementation (Long-term – mid-term – short-term)
		Sheet 6: Organizing Options	Based on The Vulnerability analysis from the Analysis File the competent options are listed with a summary of their achievability extracted from the previous 5 sheets in this

			file.
		Sheet 7: Screening Options	Scoring is given automatically to options based on the achievability measured in the previous sheets
		Sheet 8: Survey Responses	A structured questionnaire is conducted for measuring awareness and satisfactoriness of stakeholders, the response sheet is automatically generated.
		Sheet 9: Stakeholder Acceptability	The satisfactoriness for the proposed options is copied in this sheet and an average score is given to each, which by turn is added to the screening options worksheet.
4	**Proposal file**	Sheet1: Ranking measures	The previously scored options are then automatically ranked based on the highest score for each sector.
		Sheet2: Proposed Measures	Automatically generated based on calculations from previous file to underpin the most optimum measures for implementation.
		Sheet 3: Viability of Proposals	The options are categorized according to the strategies: Green Infrastructure, Sustainable land use practices, sustainable mobility, Energy Conservation and Efficiency, Regenerative and Renewable Energy, Carbon Zero, Carbon Positive and Smart Grid and Policies & institutional arrangements.

7.3.3 Interactive and user friendly tool: A Step by Step Guide

This is intended to be an easy to follow manual that consists of describing all steps to be done in order to use the tool or adapt it to different conditions. The tool was tested in Egypt but could be applied on the whole MENA region by adjusting the variable cells in the excel worksheets. The target users of this application are the experts in the field of climate change and urban planning as well as the decision makers and eventually the NGOs buffering city dwellers and decision makers.by showing the personal benefits and boosting the proposed measures acceptance. The following flow chart in figure 34 shows the process behind the algorithms of the tool. The data is differentiated into input by users, constants already defined and fixed, constrained variables that could me adjusted for different cases, valuation equations already defined and could also be altered based on different cases and finally outputs from the tool.

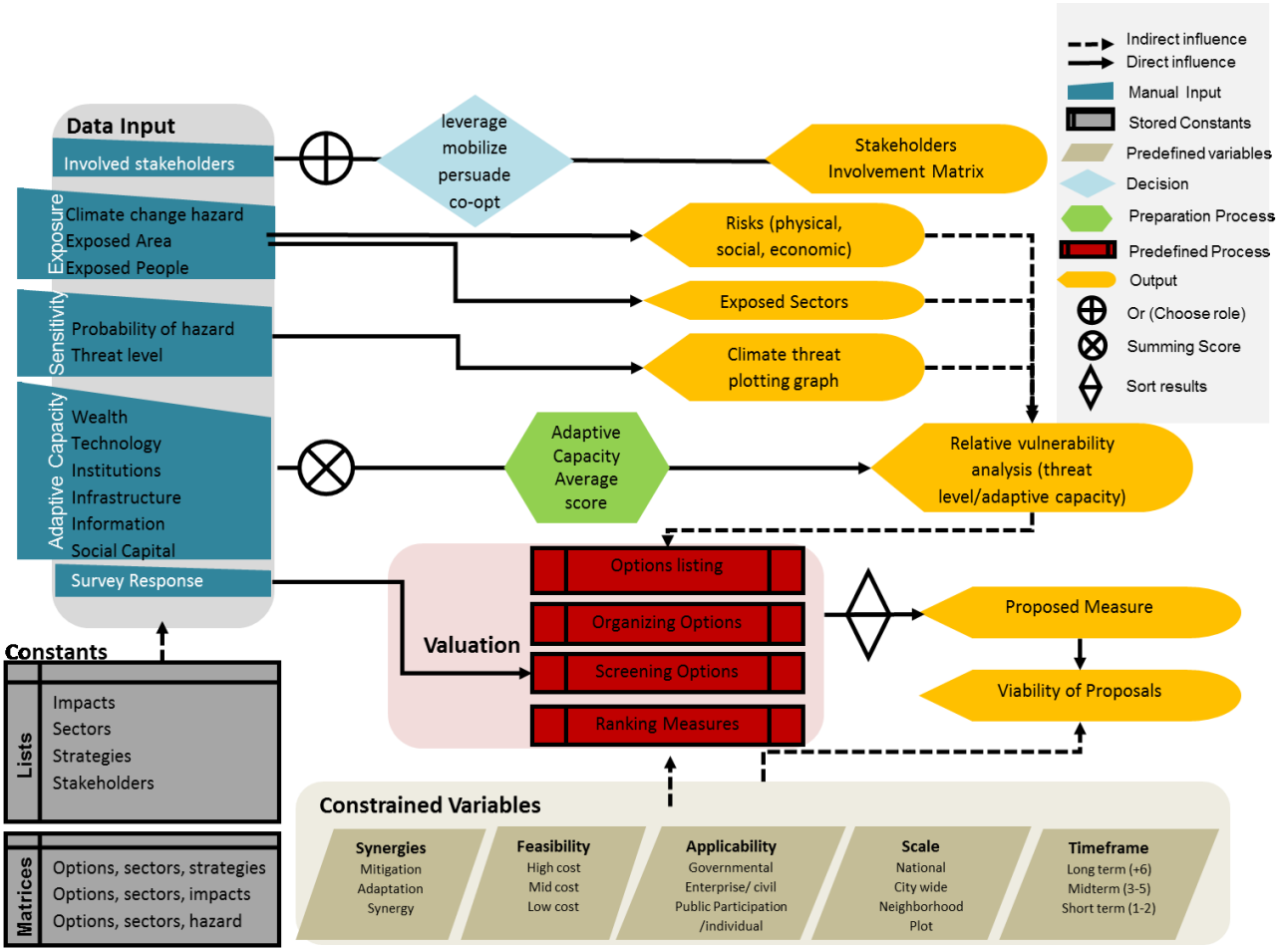


Figure 34 Flow Chart showing process behind algorithms of the ARM'D Tool. Source: Author.

The following table guides all users on a step by step path to the use of the tool by filling in the required input and data in each worksheet. This proves the applicability of the tool as all activities could be carried out in a short period of time and do not require any specific high

level expertise but a basic knowledge of Excel.

Table 31 Step, activities and input guide for excel application. Source: Author

Activity	Input	Responsible Entities	File
Check state of the art measures to keep inventory up to date	New mitigation measures	Tool Developers/ Market survey	Inventory
	New adaptation measures		
Check achievability of each measure	Synergies	Tool Developers/users	Options
	Feasibility		
	Applicability		
	Scale		
	Timeframe		
	Impact		
Check vulnerability of selected area	Stakeholders Analysis	Tool Developers/users	Analysis
	Exposure Analysis		
	Sensitivity Analysis		
	Adaptive Capacity Analysis		
Rank options	Timeframe	Tool Developers/users	Options
	Stakeholder Acceptability		
	Technical Feasibility		
	Ease of implementation		
	Urgency of implementation		
	Relative effectiveness		
Conduct interviews for social	Interview results (awareness)	Tool Developers/users	Options

satisfactoriness	Interview results (Satisfactoriness)	intellectuals	
Check all worksheets in all Files and ensure their consistency	Update Options sheet according to changes in inventory file (new measures)	Tool Developers	All
	Update achievability sheets according to updates in options sheet	Tool Developers	
	Redefine filtering parameters in screening and ranking file based on changes of achievability	Tool Developers	
Test the tool	Adjust the variables in all sheets to get the optimum results	Tool Developers	All

7.3.4 Testing the Model

Testing the tool was the final step in the procedure of developing it. Alexandria was chosen to validate the excel application and data was collected through field visits as well as interviews to be inserted in the excel worksheets. The tool validation was done over Alexandria but it is applicable to all MENA countries by adjusting a few variables in the excel worksheets which are defined in the previous scheme.

The Steps for using the tool could be summarized in the following section:

1. Open Analysis File
    - Navigate between worksheets
    - Update variable cells in each sheet according to current situation or location
    - Swap to final sheet for the summary analysis
2. Open Options file
    - Conduct the survey and insert results in the worksheet of survey responses

- Update variable cells in sheet ”Screening Options” according to acceptability of options

3. Open Proposal file
    - A list of proposed measures is automatically generated
    - Swap to final sheet for viability of measures

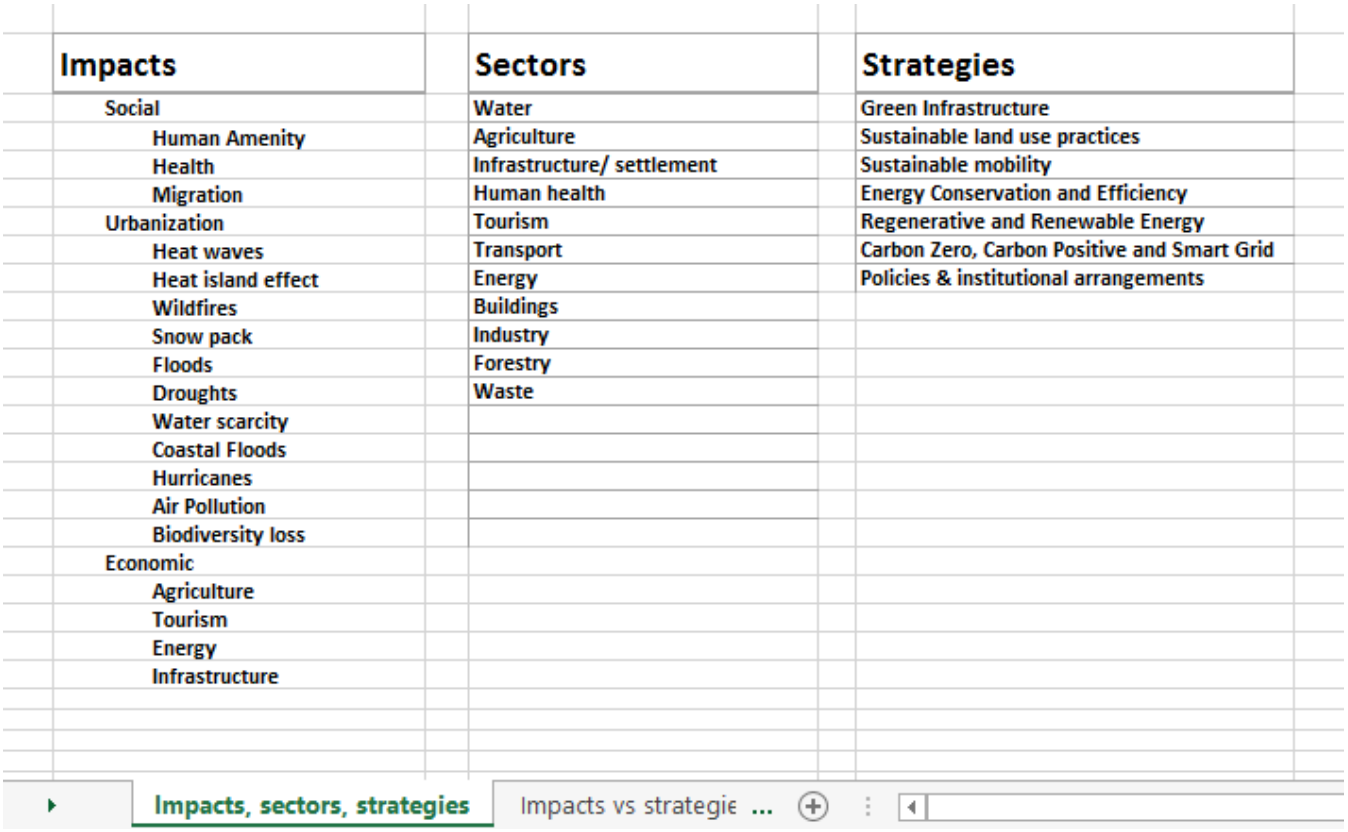
After comprehending the theory behind developing the application the next section is the detailed manual to use the software application. In order to get a grasp of the application the following charts show a visual clarification of the worksheets in each of the excel files designed. Each worksheet is presented with brief explanation of the columns forming it and the links between them as well as a clear specification of the fixed blocked cells and the variable cells that could be adjusted by the user of the application software.

7.3.4.1 Database file

The first file is the database file which could be considered the backend of the tool. It contains all the constants that feed in the rest of the files. It covers the general resilience data and stores it as fixed values that could only be modified by the tool architect and not by the user.

The file is composed of five worksheets illustrated in the following extracts from the Excel Tool:

The first worksheet in figure 35 is a listing of Impacts of climate change on people, urbanization and economy, involved sectors and proposed strategies. These were all derived from the extensive research in the previous chapters.



Impacts	Sectors	Strategies
Social	Water	Green Infrastructure
Human Amenity	Agriculture	Sustainable land use practices
Health	Infrastructure/ settlement	Sustainable mobility
Migration	Human health	Energy Conservation and Efficiency
Urbanization	Tourism	Regenerative and Renewable Energy
Heat waves	Transport	Carbon Zero, Carbon Positive and Smart Grid
Heat island effect	Energy	Policies & institutional arrangements
Wildfires	Buildings	
Snow pack	Industry	
Floods	Forestry	
Droughts	Waste	
Water scarcity		
Coastal Floods		
Hurricanes		
Air Pollution		
Biodiversity loss		
Economic		
Agriculture		
Tourism		
Energy		
Infrastructure		

Figure 35 Impacts, Sectors and Strategies Worksheet, Database File. Source: Author

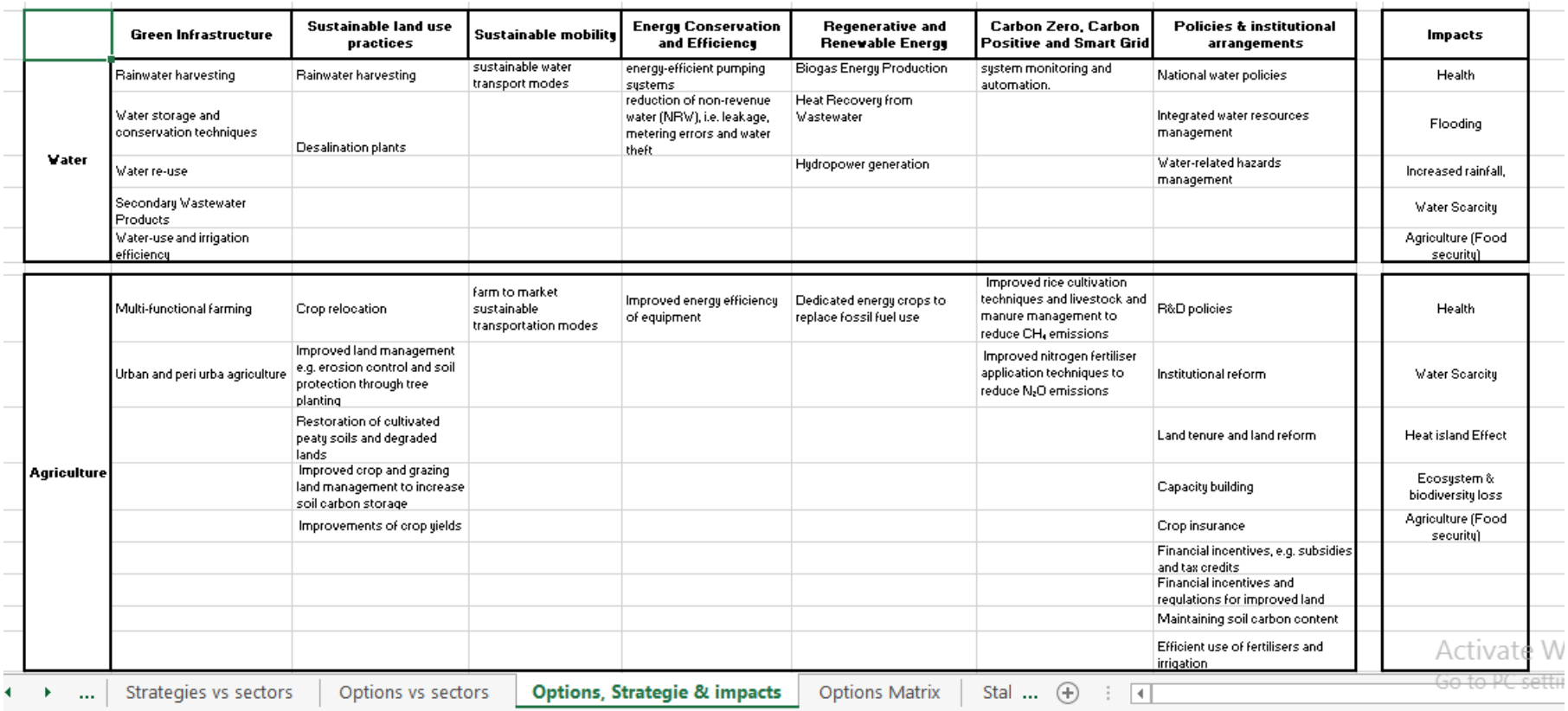
The second worksheet in figure 36 lists possible options for each sector categorized by the impact of the option whether mitigation or adaptation. The options were derived from previous literature review that was conducted in previous chapters.

	Adaptation	Mitigation
Water	Expanded rainwater harvesting	energy-efficient pumping systems
	Water storage and conservation techniques	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft
	Water re-use	system monitoring and automation.
	Desalination	Biogas Energy Production
	Water-use and irrigation efficiency	Heat Recovery from Wastewater
		Hydropower generation
		Secondary Wastewater Products
Agriculture	Adjustment of planting dates and crop variety	Improved crop and grazing land management to increase soil carbon storage
	Crop relocation	Restoration of cultivated peaty soils and degraded lands
	Improved land management e.g. erosion control and soil protection through tree planting	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions
	Urban and peri urba agriculture	Improved nitrogen fertiliser application techniques to reduce N_2O emissions
		Dedicated energy crops to replace fossil fuel use
		Improved energy efficiency
		Improvements of crop yields
Infrastructure/settlement (including coastal zones)	Relocation	hazard specific control activities such as flood levees or bushfire mitigation strategies
	Seawalls and storm surge barriers	design improvements to infrastructure or services
	Dune reinforcement	land use planning and design decisions that avoid developments and community infrastructure in areas prone to hazards
	Land acquisition and creation of wetlands as buffer against sea level rise and flooding	community awareness campaigns to increase knowledge of how to prepare for disaster events
	Protection of existing natural barriers	community education programs to build knowledge of the appropriate actions to prepare for and respond to

... | Strategies vs sectors | **Options vs sectors** | Options, Strategie & impacts | Options I

Figure 36Options vs Sectors Worksheet, Database File. Source: Author

The third worksheet in figure 37 lists the sectoral options against the strategies and the impacts. Options are similar to previous worksheet but with a different categorization.



	Green Infrastructure	Sustainable land use practices	Sustainable mobility	Energy Conservation and Efficiency	Regenerative and Renewable Energy	Carbon Zero, Carbon Positive and Smart Grid	Policies & institutional arrangements	Impacts
Water	Rainwater harvesting	Rainwater harvesting	sustainable water transport modes	energy-efficient pumping systems	Biogas Energy Production	system monitoring and automation.	National water policies	Health
	Water storage and conservation techniques	Desalination plants		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Heat Recovery from Wastewater		Integrated water resources management	Flooding
	Water re-use				Hydropower generation		Water-related hazards management	Increased rainfall,
	Secondary Wastewater Products							Water Scarcity
	Water-use and irrigation efficiency							Agriculture (Food security)
Agriculture	Multi-functional farming	Crop relocation	farm to market sustainable transportation modes	Improved energy efficiency of equipment	Dedicated energy crops to replace fossil fuel use	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions	R&D policies	Health
	Urban and peri urba agriculture	Improved land management e.g. erosion control and soil protection through tree planting				Improved nitrogen fertiliser application techniques to reduce N_2O emissions	Institutional reform	Water Scarcity
		Restoration of cultivated peaty soils and degraded lands					Land tenure and land reform	Heat island Effect
		Improved crop and grazing land management to increase soil carbon storage					Capacity building	Ecosystem & biodiversity loss
		Improvements of crop yields					Crop insurance	Agriculture (Food security)
							Financial incentives, e.g. subsidies and tax credits	
							Financial incentives and regulations for improved land	
							Maintaining soil carbon content	
							Efficient use of fertilisers and irrigation	

... | Strategies vs sectors | Options vs sectors | **Options, Strategie & impacts** | Options Matrix | Stal ...

Figure 37Options, Strategies & Impacts Worksheet, Database File. Source: Author

The fourth worksheet in figure 38 is another categorization for the sectoral options based on the climate hazard event that is occurring. Different colors reflect different sectors.

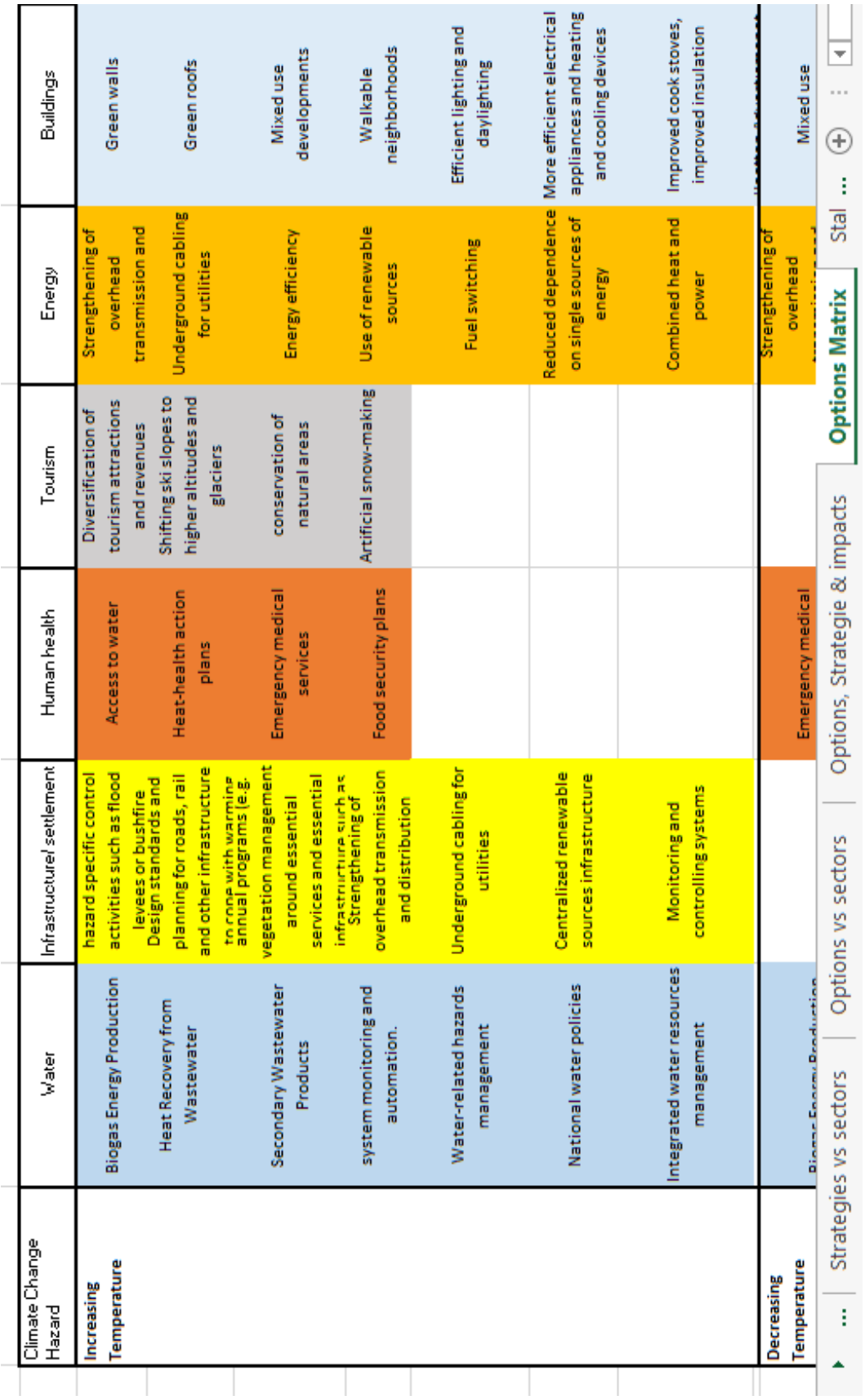


Figure 38 Options Matrix Worksheet, Database File. Source: Author

The final worksheet in the database file in figure 39 is the listing of stakeholders. The influence and interest are identified for each of the stakeholders. As a result the role of each stakeholder is stated. High influence and high interest state that the role is to mobilize which is the upper hand in any project. High influence but low interest state that the role is to co-opt, inform and consult only. High Interest and low influence is a leverage role by building capacities. Finally low interest and low influence is a persuade role depending on communication only.

Sector	Entity	Influence	Interest	Involvement
Government	• City departments (e.g. planning, engineering, transportation, finance, health)	High	High	**mobilize**
	• Local government elected Representatives	High	High	**mobilize**
	• Neighbouring local government representatives	High	Low	**co-opt**
	• District, regional and national governments	High	High	**mobilize**
Local Area and Non-Governmental	• Environmental groups	Low	High	**leverage**
	• Neighbourhood groups	Low	High	**leverage**
	• Local area leaders	Low	High	**leverage**
	• Local religious groups	Low	Low	**persuade**
	• Under-represented groups (e.g. women's and minority groups) & Individuals	Low	Low	**persuade**
Public Sector	• Sector boards and authorities (health, education, transport)	High	Low	**co-opt**
	• Educational institutions (technical schools, universities)	Low	High	**leverage**
	• International agencies	High	High	**mobilize**
Business and Labour	• Small and medium-sized businesses	High	High	**mobilize**
	• Trade and labour unions	Low	Low	**persuade**
	• Real estate developers	High	Low	**co-opt**
	• Banks, credit unions and other financial groups	High	Low	**co-opt**
	• Chambers of commerce and business groups	Low	Low	**persuade**
	• News media	High	Low	**co-opt**
	• Professional associations	Low	Low	**persuade**
	Privately owned / managed utilities	Low	High	**leverage**

Interest		
	leverage	**mobilize**
High	build capacity	Assign roles & coordinate
	persuad	**co-opt**
Low	communicate	inform & consult
	Low	High

Influence

... | Options vs sectors | Options, Strategie & impacts | Options Matrix | **Stakeholders**

Figure 39 Stakeholders Listing Worksheet, Database File. Source: Author

7.3.4.2 Analysis File

The second file is the analysis file. It is the initial user interface through which all inputs are variables entered by the user himself according to specifics of the case. This file is linked directly to the database file. It contains all the necessary analysis that need to be done prior to the decision making.

The file is composed of five worksheets illustrated in the following extracts from the Excel Tool:

The first worksheet in figure 40 is the stakeholder Advisory Group Worksheet. This is the first user interface in the tool. The user has to choose the competent stakeholders involved in the project. Based on the choice and based on the role defined for each in the database file, a stakeholder analysis matrix is generated.

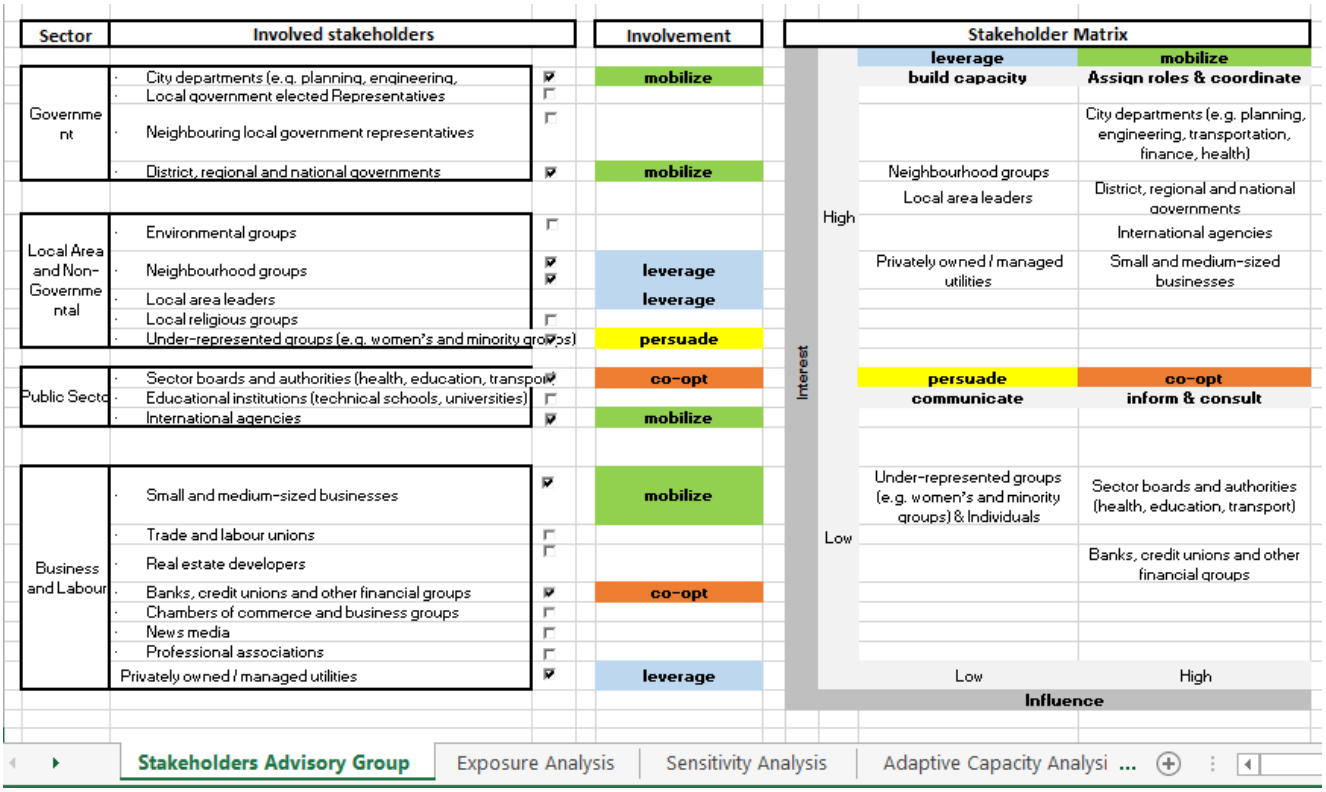
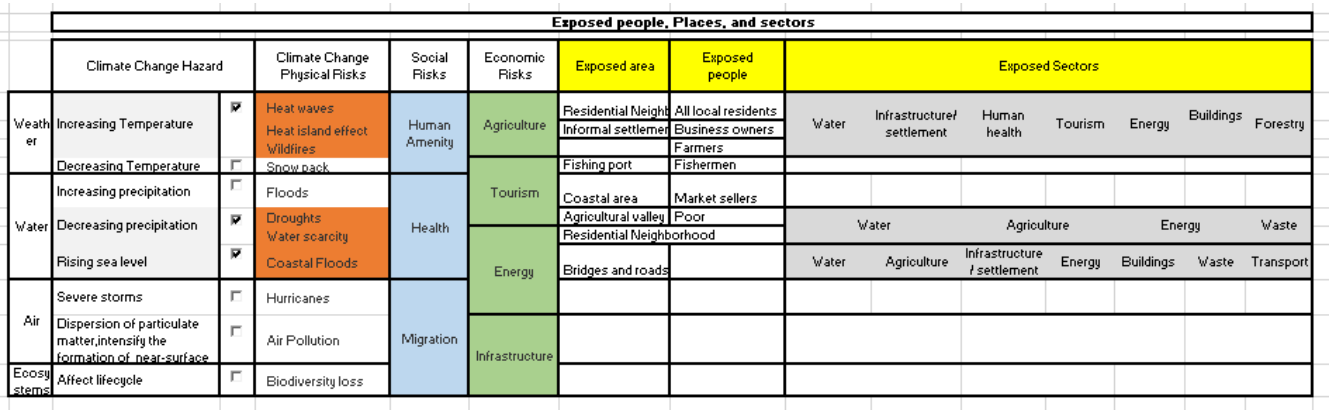


Figure 40 Stakeholder Advisory Group Worksheet, Analysis File. Source: Author

The second worksheet in figure 41 has also variables to be altered by users. By choosing the climate change hazard that is happening, physical, social, economic and sectoral risks are highlighted. Then the user gets to choose the exposed area and people from a drop down list.



	Exposed people, Places, and sectors														
	Climate Change Hazard		Climate Change Physical Risks	Social Risks	Economic Risks	Exposed area	Exposed people	Exposed Sectors							
Weather	Increasing Temperature	☑	Heat waves Heat island effect Wildfires	Human Amenity	Agriculture	Residential Neight	All local residents	Water	Infrastructure/ settlement	Human health	Tourism	Energy	Buildings	Forestry	
						Informal settlemer	Business owners								
	Decreasing Temperature	☐	Snow pack				Farmers								
Water	Increasing precipitation	☐	Floods	Health	Tourism	Fishing port	Fishermen								
	Decreasing precipitation	☑	Droughts Water scarcity			Coastal area	Market sellers								
						Agricultural valley	Poor	Water			Agriculture			Energy	Waste
	Rising sea level	☑	Coastal Floods		Energy	Residential Neighborhood									
						Bridges and roads		Water	Agriculture	Infrastructure / settlement	Energy	Buildings	Waste	Transport	
Air	Severe storms	☐	Hurricanes	Migration											
	Dispersion of particulate matter,intensify the formation of near-surface	☐	Air Pollution		Infrastructure										
Ecosystems	Affect lifecycle	☐	Biodiversity loss												

Figure 41 Exposure Analysis Worksheet, Analysis File. Source: Author

The third worksheet in figure 42 is the sensitivity analysis worksheet. Based on the choice of climate hazard, exposed areas and people, the potential impacts of each hazard are listed. The user then identifies the probability of the hazard and the threat level. The colors represent the values on a scale from 1 to 5. Based on this identification a graph between the magnitude of consequences and the probability of hazard is generated automatically to help prioritize the hazards.

Climate Change Physical threats	Potential Impacts	Probability of hazard	Threat level: Sensitivity of people, places and sectors to each hazard
Heat waves	Distress migration Decreased access to food/nutrition Spread pf diseases Increased energy demands for cooling Increased mortality during heat waves Livestock death and Decreased agriculture Ground water depletion	4	3
Heat island effect		5	4
Wildfires		1	2
Droughts	Distress migration Lack of water in reservoir Canot adequatey irrigate crops Power outages loss of jobs spread of diseases Livestock death and Decreased Agriculture	3	4
Water scarcity		4	4
Coastal Floods	Distress migration Salinization of soil/water Increased coastal erosion Infrastructure destruction Increased isolation (Cut-off roads, services) Loss of productive/residential land due to erosion	5	5

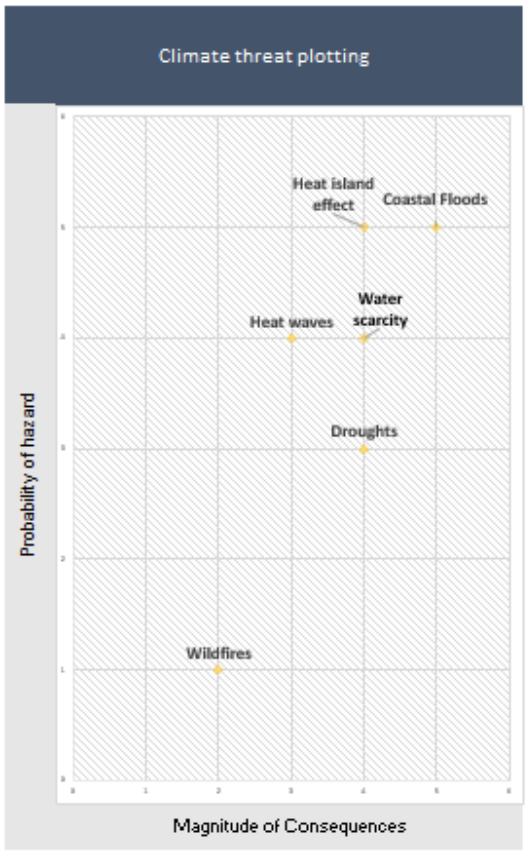


Figure 42 Sensitivity Analysis Worksheet, Analysis File. Source: Author

The adaptive capacity worksheet is based on a list of questions covering the issues of wealth, technology, institutions, infrastructure, information and social capital. By answering these questions an average score for each hazard is calculated. Different colors represent different issues.

Climate Change Physical Risks		Heat waves	Heat island	Wildfires			Droughts	Water scarcity	Coastal
Wealth:	Do you have access to adequate financial resources and funding?	1	2				3	3	5
	Do the people in the affected area have . access to basic transportation, adequate rations, ability to relocate temporarily, basic shelter)?	2	2				2	2	2
	Do you have adequate staff and allocated time to plan and implement adaptation actions?	1	1				3	3	5
	Average Score (total score/no. of questions)	1	2	0			3	3	4
Technology:	Is there an ability to communicate directly with the people/ sector affected (e.g. basic communication infrastructure, a designated key point of contact, regular interaction, radio service, etc.)?	4	4				4	4	4
	Average Score (total score/no. of questions)	4	4	0			4	4	4
Institutions	Is there political willingness to allocate resources to build adaptive capacity?	1	1				3	3	5
	Are there existing processes that you can integrate with?	1	1				1	1	4
	Are there any existing area/sectoral plans, including emergency response plans that can be referred to?	1	1				1	1	3
	Average Score (total score/no. of questions)	1	1	0			2	2	4
Infrastructure:	Is there adequate transport, water infrastructure, sanitation, energy supply and management?	3	3				3	3	3
	Are major infrastructure and/or facilities located in hazard prone areas?	2	3				3	3	5
	Do people in the affected area have access to safe, clean drinking water in the event of a hazard occurrence?	4	4				2	2	2
	Are there adequate medical services in close proximity?	2	2				2	2	2
	Average Score (total score/no. of questions)	3	3	0			3	3	3
Information:	Are decision-makers aware of a) climate change and b) potential impacts/risks in your jurisdiction?	2	2				4	4	5
	Are stakeholders in the area/sector aware there are current and/or potential impacts?	2	2				3	3	5
	Has this area/sector undertaken previous efforts to study or address the climate change driver and potential impact?	1	1				1	1	3
	Are there trained emergency response teams for this sector/ area?	1	1				1	1	1
	Average Score (total score/no. of questions)	2	2	0			2	2	4

... Exposure Analysis | Sensitivity Analysis | **Adaptive Capacity Analysis** | Summary Vulnerability Ana ...

Figure 43 Adaptive Capacity Analysis Worksheet, Analysis File. Source: Author

The final analysis worksheet in figure 44 is a summary of all previous analysis worksheets. It presents the vulnerability based on the threat level and the adaptive capacity scores. Different colors reflect the values in cells. The data is generated automatically in this worksheet.

	Exposure		Sensitivity	Adaptive Capacity	Vulnerability
	Climate Change Hazard	Climate Change Physical Risks	Threat level: Sensitivity of people, places and sectors to each hazard	Average Adaptive Capacity Score	Relative Vulnerability (Threat Level divided by Adaptive Capacity)
Weather	Increasing Temperature	Heat waves	3	2	1
		Heat island effect	4	2	2
		Wildfires	2		
Water					
	Decreasing precipitation	Droughts	4	3	1
		Water scarcity	4	3	1
	Rising sea level	Coastal Floods	5	4	1

... | Sensitivity Analysis | Adaptive Capacity Analysis | **Summary Vulnerability Analysis**

Figure 44 Summary Vulnerability Analysis Worksheet, Analysis File. Source: Author

7.3.4.3 Options File

The third file is the options file and could be considered as the subsequent user interface. This file is linked to the analysis file based on the input of the user which are constrained variables. It contains as well variables that could be tailored to each case by the user himself in order to be able to screen and rank the options.

The file is composed of eight worksheets illustrated in the following extracts from the Excel Tool:

Options are listed in this worksheet in figure 45 categorized by sector, strategy and synergies. The blue color highlights the mitigation options, the green color highlights the adaptation options and the grey color highlights synergy options that are able to mitigate and adapt.

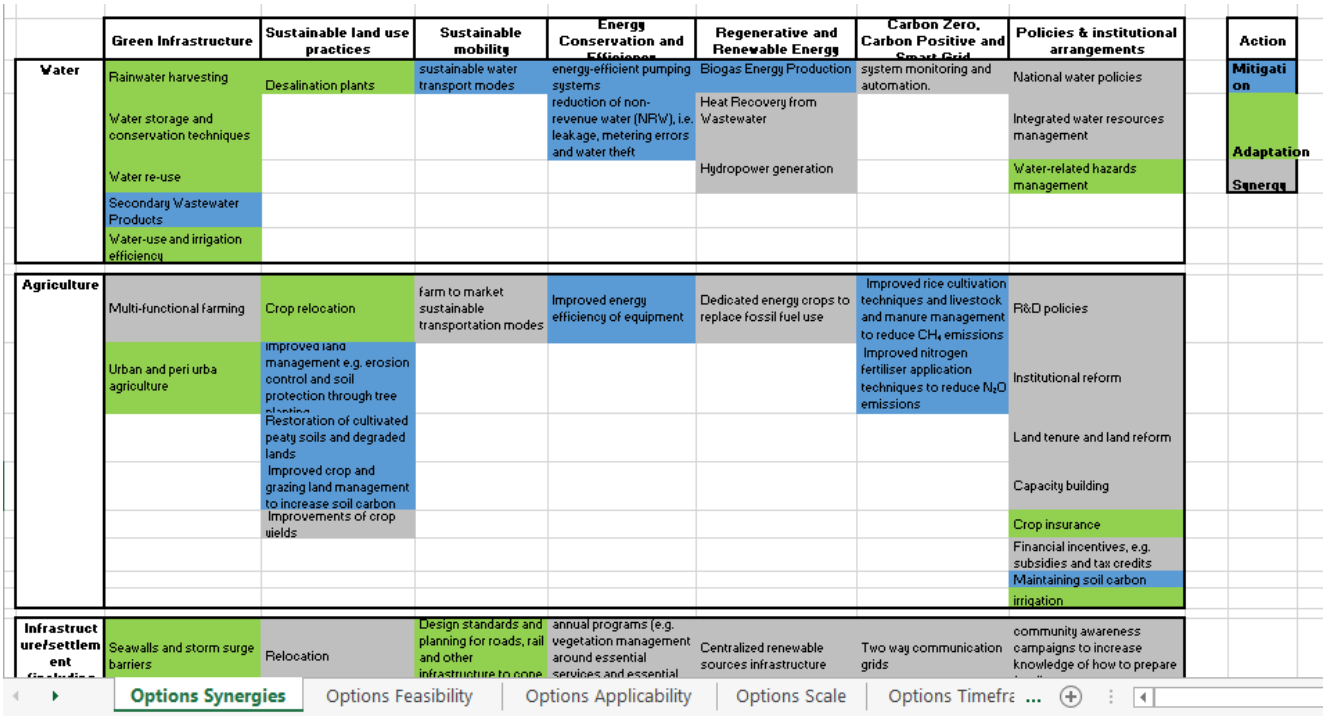


Figure 45 Options Synergies Worksheet, Options File. Source: Author

Options are listed in this worksheet in figure 46 categorized by sector, strategy and feasibility. The red color highlights the high cost options, the yellow color highlights the medium cost options and the green color highlights low cost options.

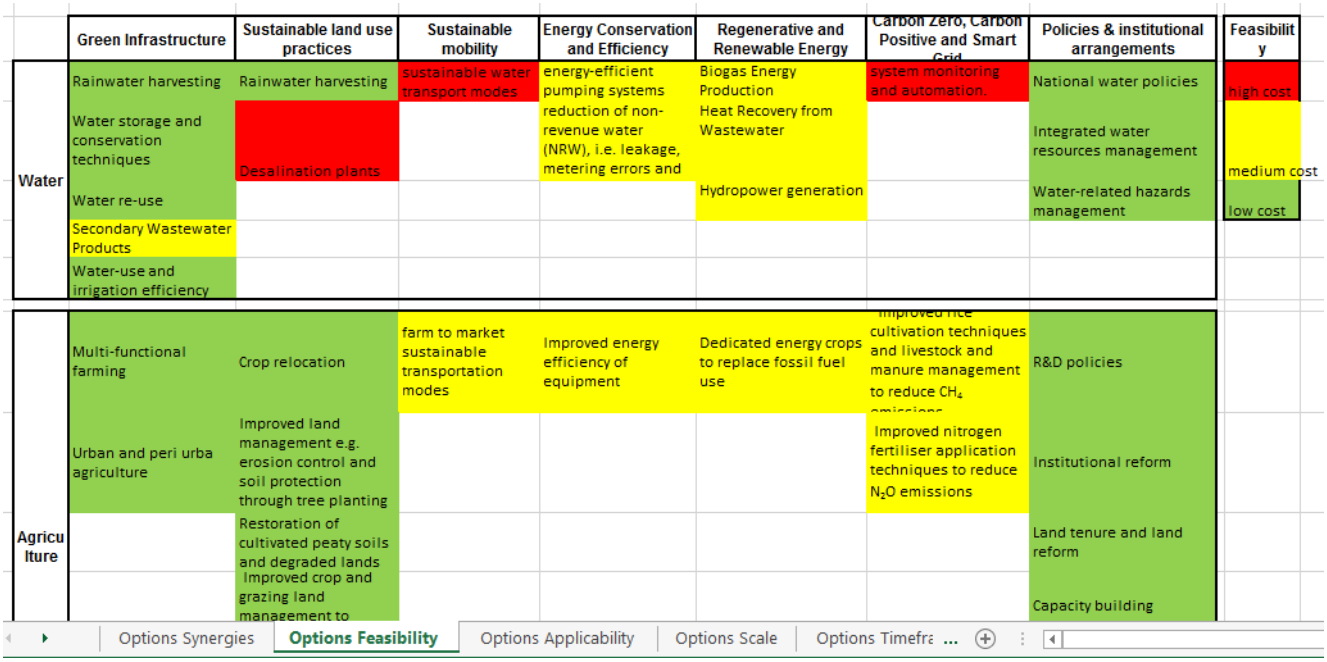


Figure 46 Options Feasibility Worksheet, Options File. Source: Author

Options are listed in this worksheet in figure 47 categorized by sector, strategy and applicability. The orange color highlights the governmental options, the yellow color highlights the enterprise/civil options and the blue color highlights public participation/individuals options.

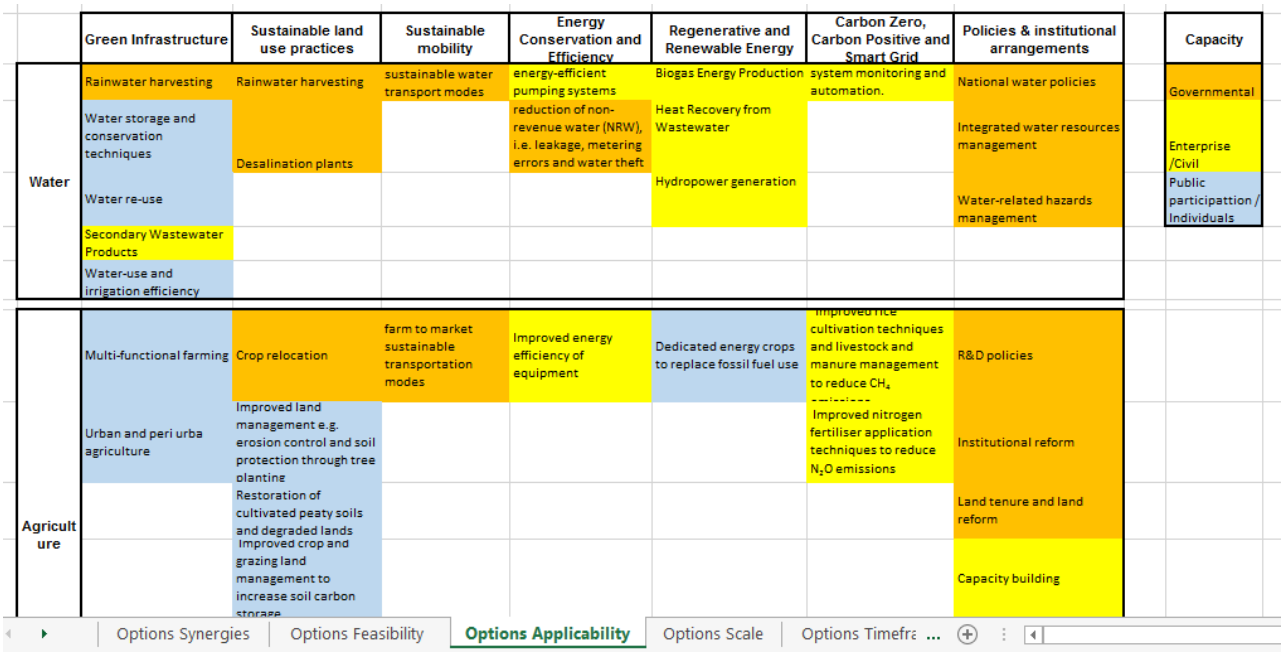


Figure 47 Options Applicability Worksheet, Options File. Source: Author

Options are listed in this worksheet in figure 48 are categorized by sector, strategy and scale. The grey color highlights the national plan options, the yellow color highlights the city-wide options and the blue color highlights neighborhood options and the green color highlights plot options.

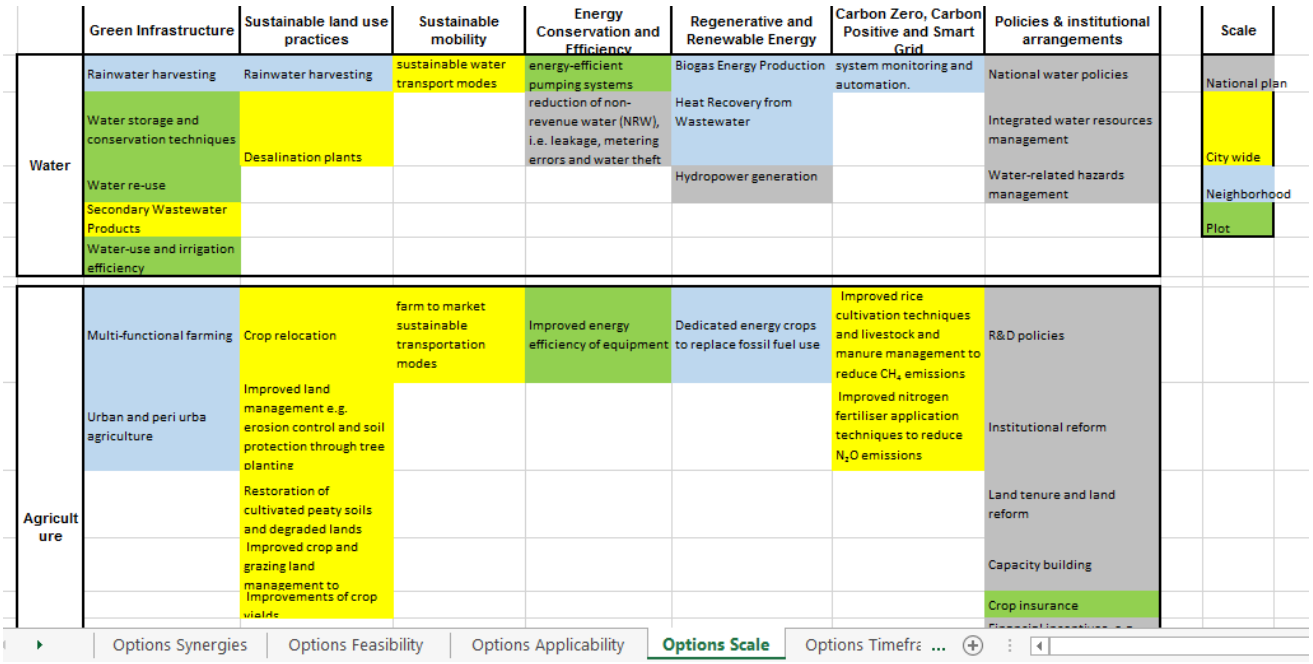
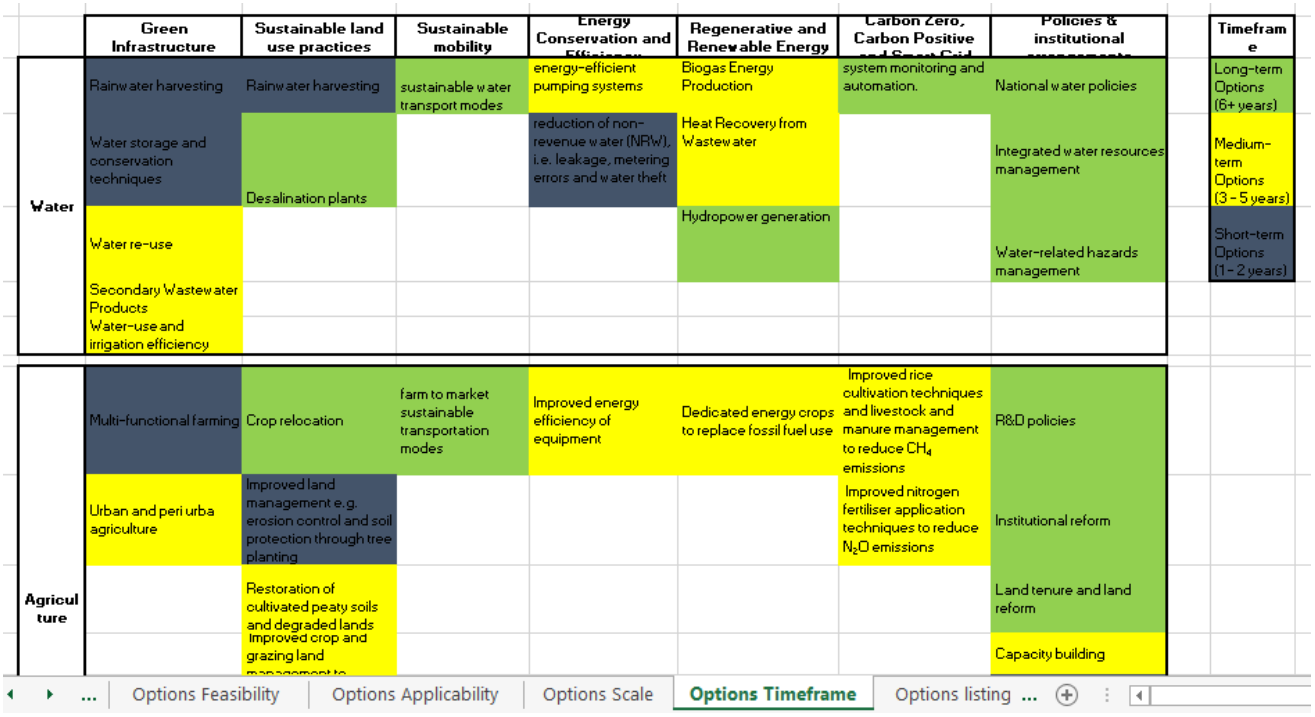


Figure 48 Options Scale, Options File. Source: Author

Options are listed in this worksheet in figure 49 categorized by sector, strategy and timeframe. The green color highlights the long term options, the yellow color highlights the midterm options and the blue color highlights short term options.

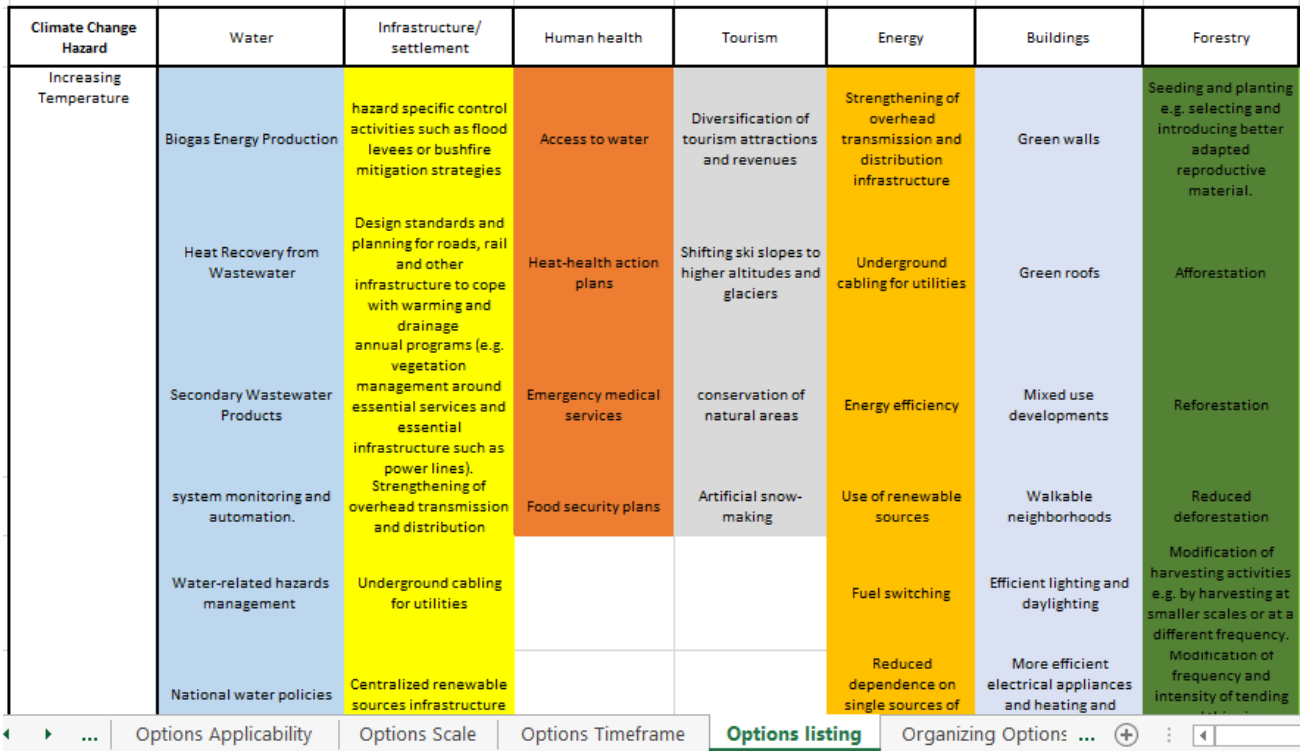


	Green Infrastructure	Sustainable land use practices	Sustainable mobility	Energy Conservation and Efficiency	Regenerative and Renewable Energy	Carbon Zero, Carbon Positive and Smart Grid	Policies & institutional arrangements	Timeframe
Water	Rainwater harvesting	Rainwater harvesting	sustainable water transport modes	energy-efficient pumping systems	Biogas Energy Production	system monitoring and automation.	National water policies	Long-term Options (6+ years)
	Water storage and conservation techniques	Desalination plants		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Heat Recovery from Wastewater		Integrated water resources management	Medium-term Options (3 - 5 years)
	Water re-use				Hydropower generation		Water-related hazards management	Short-term Options (1 - 2 years)
	Secondary Wastewater Products							
	Water-use and irrigation efficiency							
Agriculture	Multi-functional farming	Crop relocation	farm to market sustainable transportation modes	Improved energy efficiency of equipment	Dedicated energy crops to replace fossil fuel use	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions	R&D policies	
	Urban and peri urba agriculture	Improved land management e.g. erosion control and soil protection through tree planting				Improved nitrogen fertiliser application techniques to reduce N_2O emissions	Institutional reform	
		Restoration of cultivated peaty soils and degraded lands					Land tenure and land reform	
		Improved crop and grazing land					Capacity building	

Options Feasibility | Options Applicability | Options Scale | **Options Timeframe** | Options listing ...

Figure 49 Options Timeframe Worksheet, Options File. Source: Author

The options listing worksheet in figure 50 only shows the possible sectoral options based on the climate hazard chosen in previous analysis files. Different colors reflect different sectors.

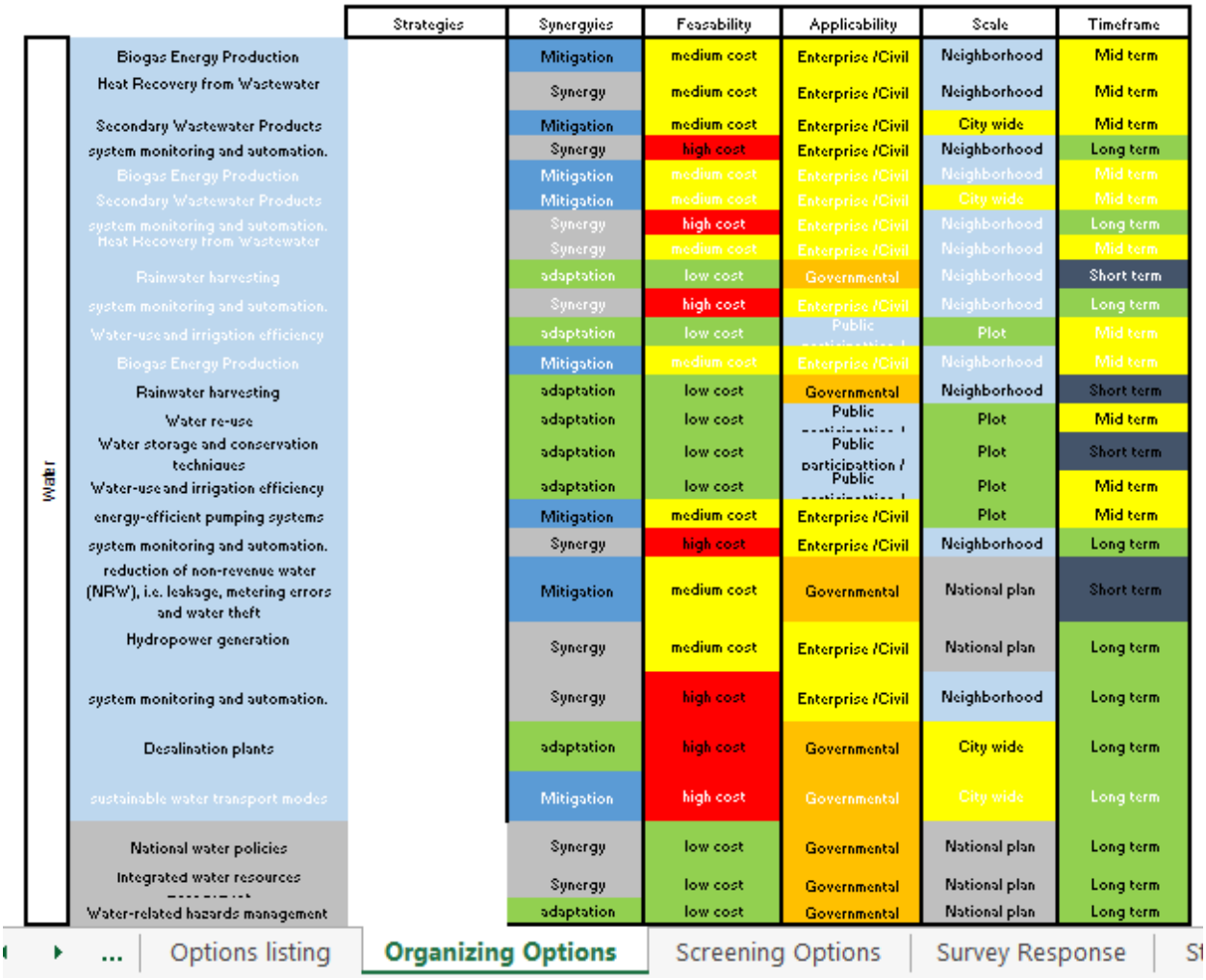


Climate Change Hazard	Water	Infrastructure/ settlement	Human health	Tourism	Energy	Buildings	Forestry
Increasing Temperature	Biogas Energy Production	hazard specific control activities such as flood levees or bushfire mitigation strategies	Access to water	Diversification of tourism attractions and revenues	Strengthening of overhead transmission and distribution infrastructure	Green walls	Seeding and planting e.g. selecting and introducing better adapted reproductive material.
	Heat Recovery from Wastewater	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Heat-health action plans	Shifting ski slopes to higher altitudes and glaciers	Underground cabling for utilities	Green roofs	Afforestation
	Secondary Wastewater Products	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Emergency medical services	conservation of natural areas	Energy efficiency	Mixed use developments	Reforestation
	system monitoring and automation.	Strengthening of overhead transmission and distribution	Food security plans	Artificial snow-making	Use of renewable sources	Walkable neighborhoods	Reduced deforestation
	Water-related hazards management	Underground cabling for utilities			Fuel switching	Efficient lighting and daylighting	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.
	National water policies	Centralized renewable sources infrastructure			Reduced dependence on single sources of	More efficient electrical appliances and heating and	Modification of frequency and intensity of tending

Options Applicability | Options Scale | Options Timeframe | **Options listing** | Organizing Options ...

Figure 50 Options Listing Worksheet, Options File. Source: Author

The organizing options worksheet in figure 51 highlight the achievability of sectoral options based on data from previous options worksheets which are: Synergies, Feasibility, Applicability, Scale and Timeframe.



	Strategies	Synergyies	Feasability	Applicability	Scale	Timeframe
Water	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Heat Recovery from Wastewater	Synergy	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Secondary Wastewater Products	Mitigation	medium cost	Enterprise /Civil	City wide	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Secondary Wastewater Products	Mitigation	medium cost	Enterprise /Civil	City wide	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Heat Recovery from Wastewater	Synergy	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Rainwater harvesting	adaptation	low cost	Governmental	Neighborhood	Short term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Water-use and irrigation efficiency	adaptation	low cost	Public	Plot	Mid term
	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Rainwater harvesting	adaptation	low cost	Governmental	Neighborhood	Short term
	Water re-use	adaptation	low cost	Public	Plot	Mid term
	Water storage and conservation techniques	adaptation	low cost	Public participattion /	Plot	Short term
	Water-use and irrigation efficiency	adaptation	low cost	Public	Plot	Mid term
	energy-efficient pumping systems	Mitigation	medium cost	Enterprise /Civil	Plot	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Mitigation	medium cost	Governmental	National plan	Short term
	Hydropower generation	Synergy	medium cost	Enterprise /Civil	National plan	Long term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Desalination plants	adaptation	high cost	Governmental	City wide	Long term
	sustainable water transport modes	Mitigation	high cost	Governmental	City wide	Long term
	National water policies	Synergy	low cost	Governmental	National plan	Long term
	Integrated water resources	Synergy	low cost	Governmental	National plan	Long term
	Water-related hazards management	adaptation	low cost	Governmental	National plan	Long term

... | Options listing | **Organizing Options** | Screening Options | Survey Response | St

Figure 51 Organizing Options Worksheet, Options File. Source: Author

The final worksheet in the options file in figure 52 is the screening of options worksheet which interprets the previous achievability of sectoral options into numeric values for scoring. Relative effectiveness, Economic feasibility, Ease of implementation, Mainstreaming potential, Urgency of implementation, Multi objective, and Stakeholder Acceptability are all automatically scored to calculate an average score for each of the options.

		Relative effectiveness	Economic feasibility	Ease of implementati	Mainstreaming potential	Urgency of implementatio	Multi objectiv	Stakeholder Acceptability	Score
Water	Biogas Energy Production	2	2	2	3	2	3	3.41176471	17.412
	Heat Recovery from wastewater	3	2	2	3	2	2	3.35294118	17.353
	Secondary Wastewater Products	2	2	2	2	2	2	3.11764706	15.118
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	Rainwater harvesting	1	3	1	3	3	2	3.16176471	16.162
	Water re-use	1	3	3	4	2	1	3.17647059	17.176
	Water storage and conservation techniques	1	3	3	4	3	1	3.17647059	18.176
	Water-use and irrigation efficiency	1	3	3	4	2	2	3.19117647	18.191
	energy-efficient pumping systems	2	2	2	4	2	1	3.30882353	16.309
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	2	2	1	1	3	1	3.19117647	13.191
	Hydropower generation	3	2	2	1	1	1	3.57352941	13.574
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	Desalination plants	1	1	1	2	1	1	3.5	10.5
	National water policies	3	3	1	1	1	1	3.11764706	13.118
	Integrated water resources management	3	3	1	1	1	1	3.13235294	13.132
	Water-related hazards management	1	3	1	1	1	1	3.17647059	11.176
Infrastructure/ settlement	hazard specific control activities such as flood levees or bushfire mitigation strategies	3	2	1	2	2	3	3.63235294	16.632
	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	1	2	1	1	1	5	3.76470588	14.765
	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power	3	3	1	2	2	2	3.5	16.5
	Strengthening of overhead transmission and distribution infrastructure	2	2	1	2	2	3	3.11764706	15.118

... | Options listing | Organizing Options | **Screening Options** | Survey Response

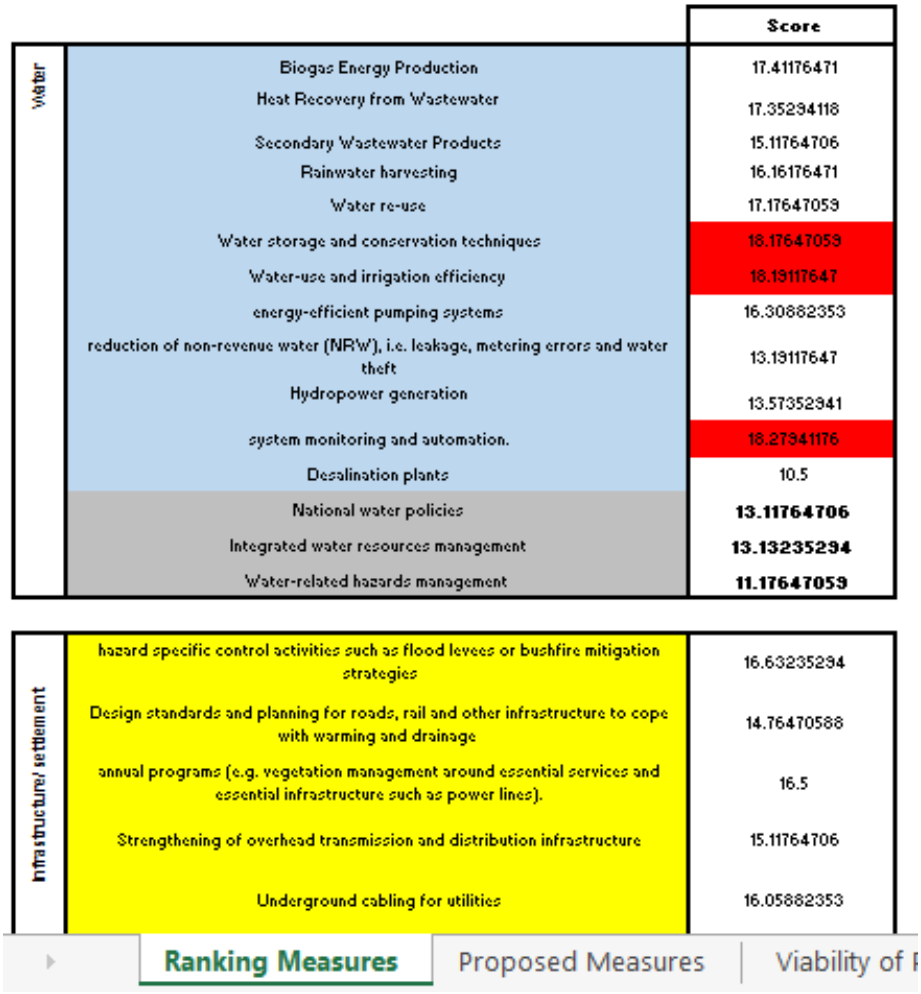
Figure 52 Screening Options Worksheet, Options File. Source: Author

7.3.4.4 Proposal File

The last file is the proposal file. It is the resultant of all the algorithms and processed performed in this tool. It automatically generates a list of possible measures that could be applied to the specific case study based on the users' input and helps in deriving an action plan as well to assure the ease of implementation. The action plan is prepared by input from the tool architect for each case as data and resources could vary from a case to another.

The file is composed of three worksheets illustrated in the following extracts from the Excel Tool:

The ranking measures worksheet in figure 53 automatically highlights the highest three options in each sector in red color based on score from the screening worksheet in the options file.



		Score
Water	Biogas Energy Production	17.41176471
	Heat Recovery from Wastewater	17.35294118
	Secondary Wastewater Products	15.11764706
	Rainwater harvesting	16.16176471
	Water re-use	17.17647059
	Water storage and conservation techniques	18.17647059
	Water-use and irrigation efficiency	18.13117647
	energy-efficient pumping systems	16.30882353
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	13.13117647
	Hydropower generation	13.57352941
	system monitoring and automation.	18.27941176
	Desalination plants	10.5
	National water policies	**13.11764706**
	Integrated water resources management	**13.13235294**
	Water-related hazards management	**11.17647059**
Infrastructure/ settlement	hazard specific control activities such as flood levees or bushfire mitigation strategies	16.63235294
	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	14.76470588
	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	16.5
	Strengthening of overhead transmission and distribution infrastructure	15.11764706
	Underground cabling for utilities	16.05882353

Ranking Measures | Proposed Measures | Viability of F

Figure 53 Ranking Measures Worksheet, Proposal File. Source: Author

The proposed measures worksheet in figure 54 lists the highest ranked options for each sector. Different colors reflect the different sectors.

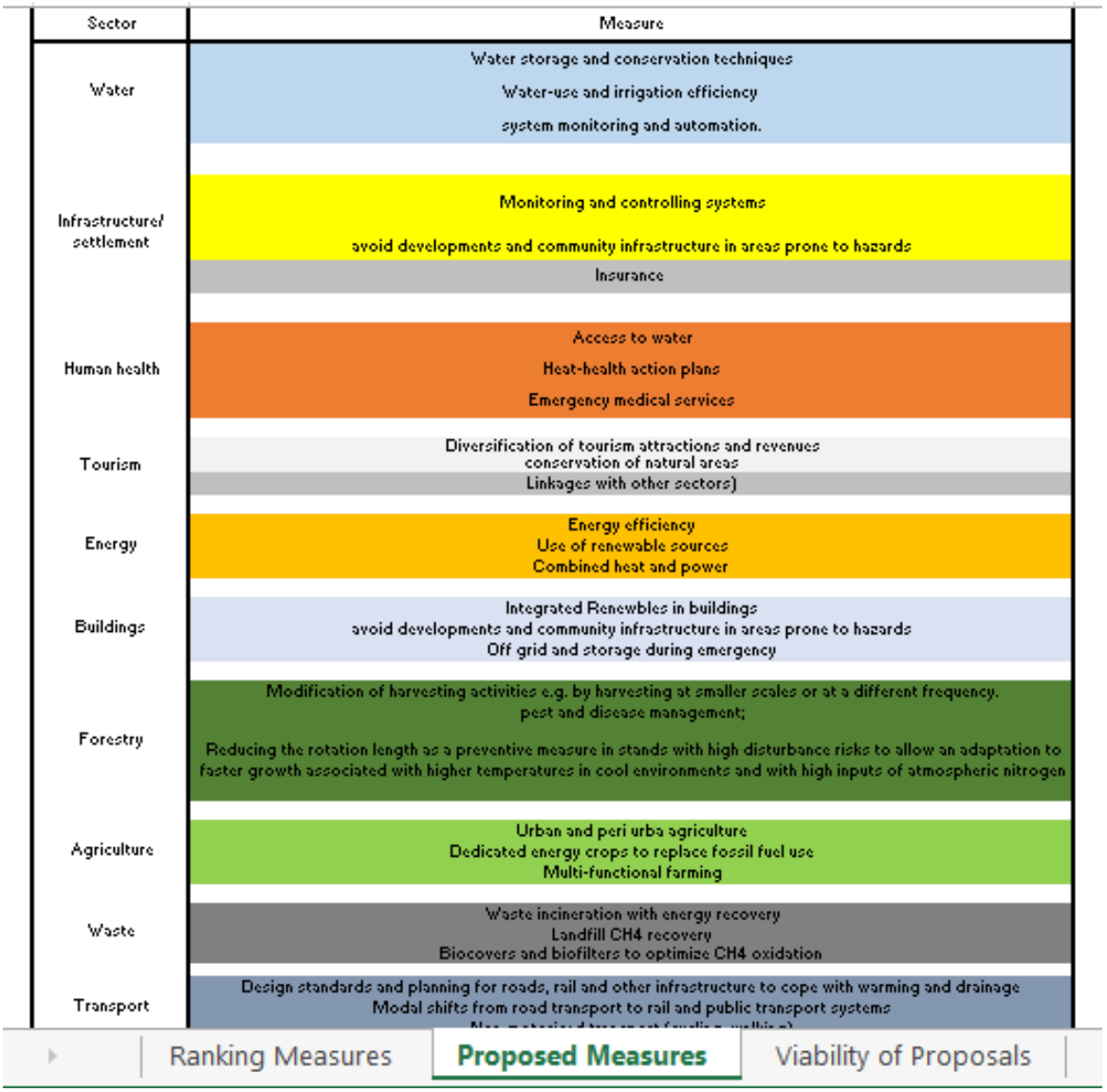


Figure 54 Proposed Measures Worksheet, Proposal File. Source: Author

The final worksheet in figure 55 is the viability of proposals worksheet. This is generated based on the proposed measures worksheet. It categorized the options based on the strategy adopted which were the core of this research in previous chapters. For each option the achievability factors are listed as well for a clear understanding of each option proposed.

Strategy	Sector	Measure	Relative effectiveness	Economic feasibility	Ease of implementation	Mainstreaming potential	Urgency of implementation
Green Infrastructure	Water	Water storage and conservation techniques	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		Water-use and irrigation efficiency	adaptation	low cost	Public participattion / Individuals	Plot	Mid term
	Human Health	Access to water	Synergy	medium cost	Governmental	Neighborhood	Mid term
	Agriculture	Urban and peri urba agriculture	adaptation	low cost	Public participattion / Individuals	Neighborhood	Mid term
		Multi-functional farming	Synergy	low cost	Public participattion / Individuals	Neighborhood	Short term
	Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	adaptation	medium cost	Governmental	National plan	Mid term
Sustainable land use practices	Infrastructure/ Settlement	avoid developments and community infrastructure in areas prone to hazards	Synergy	low cost	Governmental	City wide	Short term
	Human Health	Heat-health action plans	Synergy	medium cost	Governmenta	Neighborhood	Mid term
		Emergency medical services	Mitigation	medium cost	Governmenta	Neighborhood	Short term
	Tourism	Diversification of tourism attractions and revenues	Synergy	medium cost	Enterprise /Civil	City wide	Mid term
		conservation of natural areas	adaptation	low cost	Governmenta	National plan	Short term
	Buildings	avoid developments and community infrastructure in areas prone to	Synergy	low cost	Governmental	City wide	Short term
	Forestry	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		pest and disease management;	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		Reducing the rotation length as a					

Ranking Measures | Proposed Measures | **Viability of Proposals**

Figure 55 Viability of Proposals Worksheet, Proposal File. Source: Author

8 The Pilot ARM'D City

8.1 Egypt's Status Quo

8.1.1 Climate Situation

In general Egypt's climate is considered hot and dry. The average temperature ranges from 17 to 20C along the northern Mediterranean coast to more than 25C in Upper Egypt. Precipitation is highest along the coast as well with an average of more than 200 mm/year. The rest of Egypt has about 2 mm of yearly precipitation, therefore Egypt can be classified as an arid are with the exception of the Mediterranean coast as a semi-arid area (Wagg, 2015).

Egypt is one of the most vulnerable countries to climate change but is listed as one of the least active when it comes to taking adaptation measures. There has been a significant increase in the number of extreme weather events leading to economic losses in Egypt over the last ten years. These events have flooded major cities, destroyed infrastructure and distressed economic activities. Not only cities and urban areas were affected but also in the countryside it has destroyed fertile agricultural lands and disrupted development initiatives (Batisha, 2012). Egypt should realize the threats from the impacts of climate change and develop policies to minimize the risks. Adaptation to climate change is a pivotal issue from the perspectives of water resources development, food production, and rural population stabilization (UNDP, 2019).

The following map shows the change in precipitation 2010-2040 based on the average output of 7 GCM models under Greenhouse Gas Emission Scenario A2. The map shows a high decrease in precipitation along the Mediterranean Northern Coast and on the other hand a mild increase in precipitation in Upper Egypt (Goebel & De Pauw, 2010).

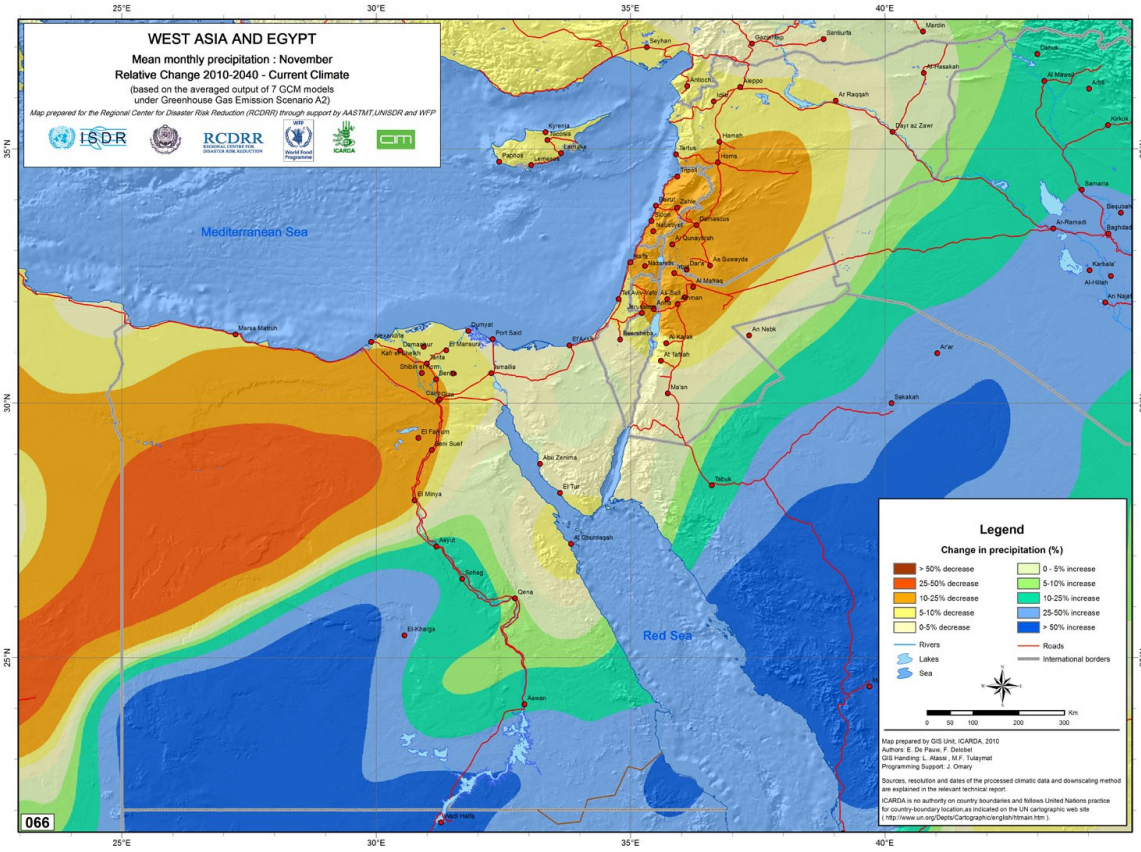


Figure 56 Change in Precipitation 2010-2040. Source: ICARDA, 2010

The next map shows the absolute change of annul aridity index 2010-2040 based on the averaged output of 7 GCM models under Greenhouse Ga Emission Scenario based on GHG scenario A1b. The map shows a higher change in aridity in the northern Mediterranean coast more than the remaining parts of the country (Goebel & De Pauw, 2010).

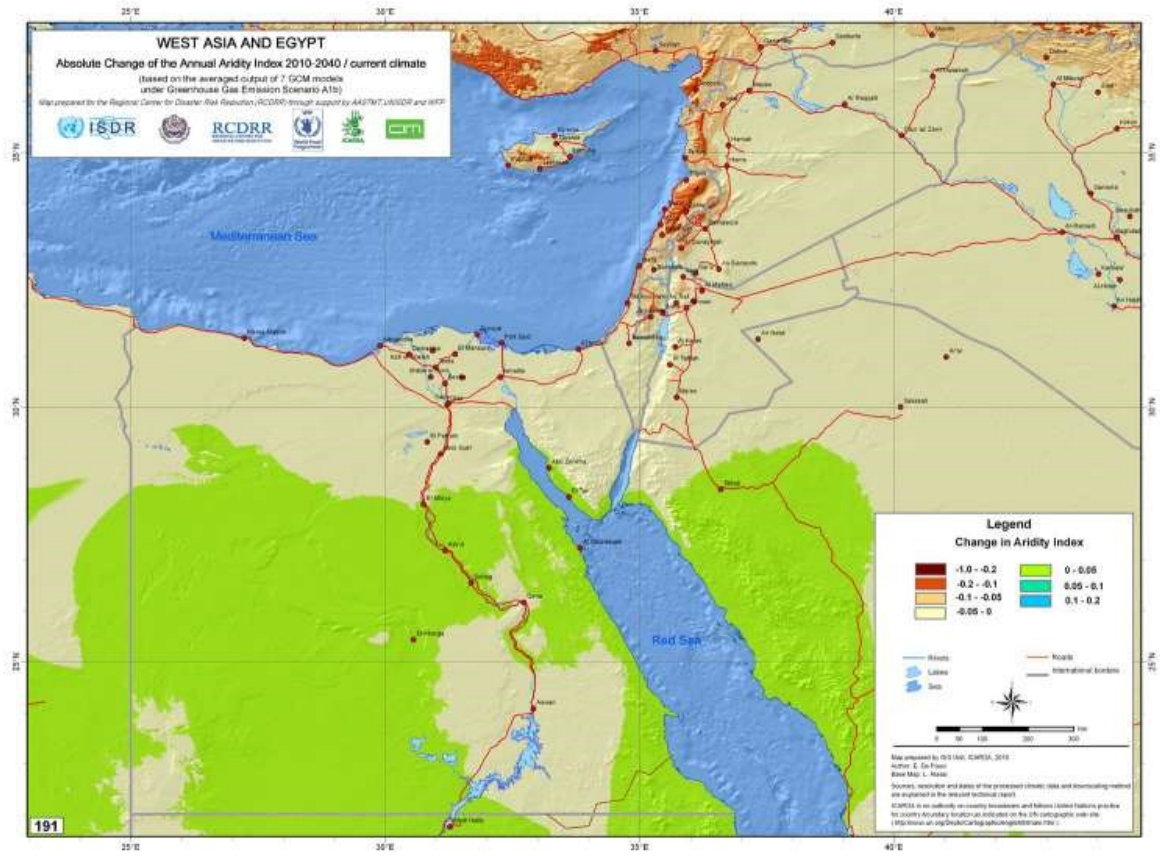


Figure 57 absolute change of annul aridity index 2010-2040. Source: ICARDA, 2010

The subsequent map illustrates the annual mean potential evapotranspiration 2010-2040 based on GHG scenario A1b. By observing the map it is clear that temperature is increasing all over the country but specifically the higher temperature will hit the southern region of Egypt which means that evapotranspiration will increase in the Upper Egypt region more than coastal areas (Goebel & De Pauw, 2010).

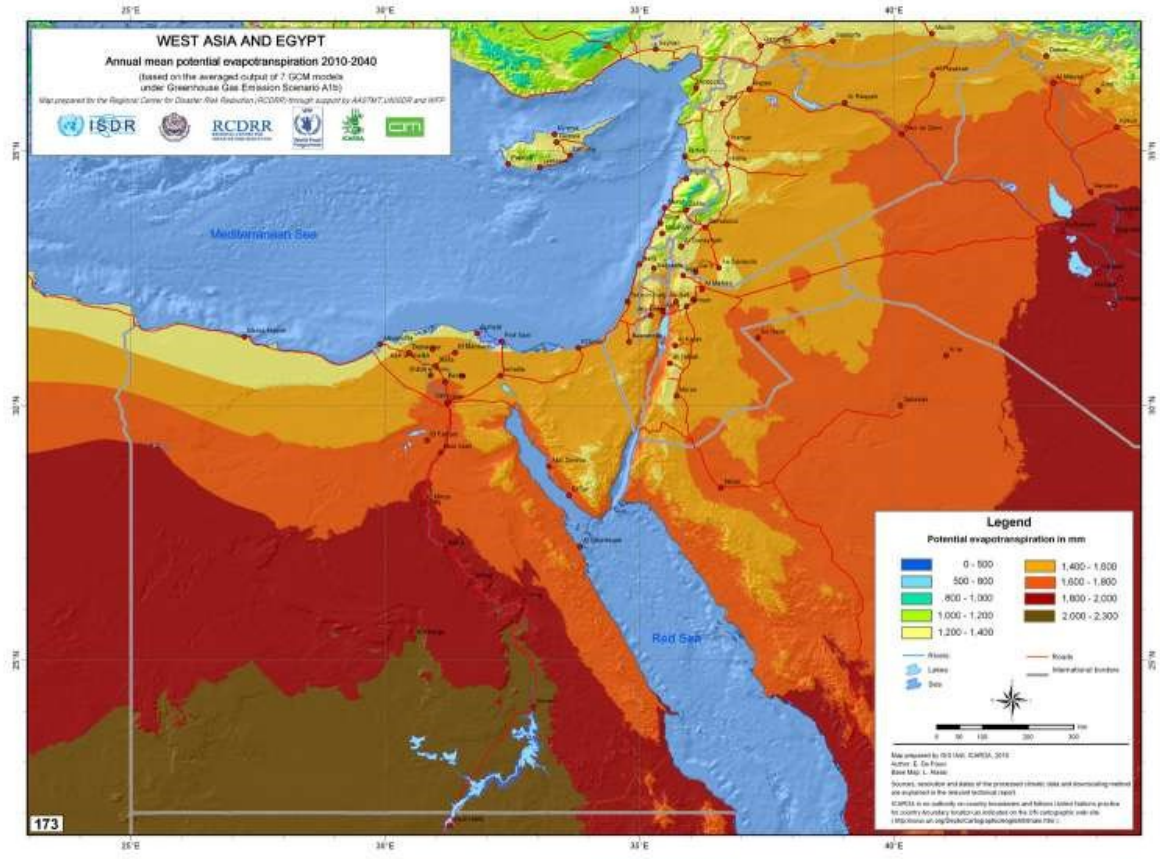


Figure 58 Annual mean potential evapotranspiration 2010-2040. Source: ICARDA, 2010

Increasing temperature and sea level rise are the two crucial aspects that are likely to hit Egypt hard. An increase in the temperature would cause a rise in evaporation levels which in turn will reduce the Nile water and soil moisture. This could threaten Egypt's water supply, reduce crop yields and decrease tourism leading to a massive loss of employment. Sea Level Rise is another key impact that Egypt is facing. A rise of sea levels would flood vast areas of the low lying coastal delta which will influence the movement of people from their houses and will cause the loss of fertile agriculture lands, impact on the water quality and affect most fresh water fish. The increased evaporation resulting from the sea level rise will probably increase the ground water salinity as well. Some studies claim that a one-meter rise in sea level will entirely inundate the Nile delta. Coastal installations in the cities of Alexandria and Port Said would be endangered. Recreational tourism facilities would be threatened. Dykes and protective measures would prevent flooding up to a 50 cm sea level rise. However, it might cause serious groundwater salinity and increase the impact of wave action (Batisha, 2012) (Smith, et al., 2013) .

The impacts of this change is devastating to the Egyptian Economy, the graph below shows the estimated economic impacts in 2030 and 2060 if no further action is taken in regards to agriculture, buildings, human health and mortality and tourism (Smith, et al., 2013).

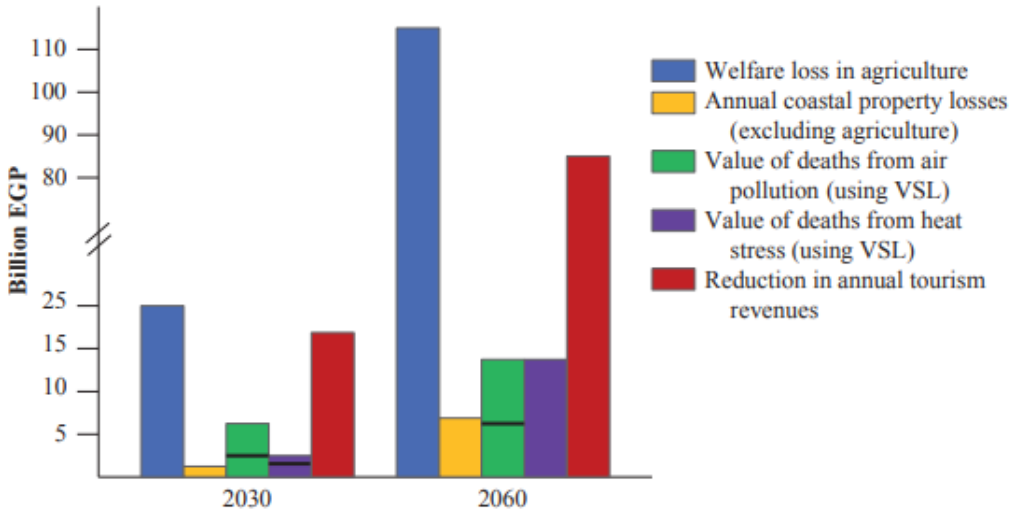


Figure 59 Estimated economic impacts by sector in 2030 and 2060 assuming low reduction in Nile flow, a pessimistic socioeconomic scenario, unprotected coastal areas, and high SLR. Source: (Smith, et al., 2013)

Currently the "Enhancing Climate Change Adaptation in the North Coast of Egypt" project aims to protect the highly populated low-lying lands in the Mediterranean Coast and Nile Delta, which have been identified as an extremely vulnerable to sea-level rise. The project will be implemented by the Ministry of Water Resources and Irrigation with a total budget of US$ 31.4 million over seven years. The GCF-financed project will expand the use of low-cost dikes system to prevent the flooding during extreme weather events. The project will also fund the development of an Integrated Coastal Zone Management Plan (ICZM) for the North Coast of Egypt which will be linked with the creation of a systematic observation system to monitor Oceanographic parameters changes as well as the impacts on the coastal erosion and shore stability (UNDP, 2019).

8.1.2 Pioneering Initiatives

In Egypt a little bit of action has started to kick off in the past couple of years towards the whole climate change matter. International organizations were the first to push the boundaries and initiate projects that help deal with the inevitable impacts posed by the changing climate.

The currently ongoing initiatives are supported by the different ministries in Egypt after realizing the magnitude of vulnerability of the people, sectors and structures to the changing climate.

Auspiciously the current projects have a wide array of target groups and objectives that cover different aspects of facing the climate change dilemma as shown in table 32. Some are fully concerned with the long term mitigation strategies, others focus on adaptation activities that are short term or mid-term, a few target capacity building, raising awareness and communication and finally one project emphasizes on monitoring and evaluation.

Despite the prodigious effort exerted in these projects, only a few have actually succeeded in leaving an impact like the Energy Efficiency for lighting and Appliances project which was supported highly by the government, also the Renewable Energy projects are now a major investment area in the Egyptian context. Other projects are still paving the way for their activities to have the expected impacts. The main drawback in these approaches is the dispersed scopes by directing at either mitigation or adaptation and none of them was alarmed with finding the synergies between both to come up with an integrated plan.

Table 32 Ongoing programs and projects in Egypt to face Climate Change. Source: Author

Projects	Partners	Status	Scope
Egypt NAMA Nationally appropriate mitigation actions	**LECB** Program, UNDP EC German Ministry of Environment AusAID	Ongoing	**Mitigation**
Industrial Energy Efficiency Project (IEE)	UNIDO EOS IDA IMC FEI GEF	2013 - Ongoing	

Egyptian CDM Projects	UNEP EEAA	2004 - Ongoing	
Improving Energy Efficiency for Lighting & Building Appliances	GEF UNDP MOEE EEHC EOS NREA	2011 - Ongoing	
Grid Connected Small-Scale Photovoltaic Systems Project	GEF UNDP MTI	2014 - Ongoing	
Egyptian Solar PV Feed-in-Tariff scheme for Small Scale Projects less than 500 kWp	GIZ RCREE	2014 - Ongoing	
Supporting Egypt to advance their NAP process	**UNDP UN Environment GEF**	**2015 - Ongoing**	**Adaptation**
Supporting Egypt to advance their NAP process	**UNDP UN Environment GEF**	**2015 - Ongoing**	
Enhancing Climate Change Adaptation in the North Coast of Egypt	**UNDP Ministry of Water Resources and Irrigation**	**2019-2025**	

The Participatory Development Programme in Urban Areas (PDP)	**GIZ**	**2013 - Ongoing**
Raising Climate Change Awareness in Alexandria, Red Sea, Daqahlia, Menia)	**FRIEDRICH EBERT STIFTUNG**	**2013 - Ongoing**
Building Resilient Food Security Systems to Benefit the Southern Egypt Region	**WFP**	**2012 - Ongoing**
Assessment and Strategy Development to respond to the impacts of sea-level rise on human mobility in Egypt	**International Organization for Migration (IOM) Ministry of Manpower and Immigration and Ministry of Environment Coastal Research Institute**	**Ongoing**

Adaptation to Climate Change in the Nile Delta Through Integrated Coastal Zone Management	**UNDP GEF DFID/IDRC**	**2009 - Ongoing**	**Capacity Building**
Low Emission Capacity Building Programme (Egypt).	**Low Emission Capacity Building (LECB) Program, UNDP EEAA**	**2016 - Ongoing**	
Egypt - Fourth National Communication to UNFCCC Project (NC4Egypt).	**UNDP GEF EEAA**	**2019 –2023**	**Communication**
Advisory Board for Climate Change in Cities (AB-CCC)	**GIZ EEAA**	**2014 - Ongoig**	
Strengthening the Monitoring & Reporting System for Multilateral Environmental Agreements in Egypt	**UNDP GEF**		**Monitoring & Evaluation**

8.2 Mediterranean Coast threats

Egypt's Northern coastal area features the low lying Nile delta with its urban cities, industrial zones, agriculture lands and touristic locations. The Nile delta represents 5.5% of the total area of Egypt but comprises over 95% of the population. The northern coast and delta area include 30-40% of Egypt's agricultural production, half of Egypt's industrial production, three large agglomerations mainly Alexandria, Damietta and Port Said, three main Delta lagoons Idku, Burullus and Manzala which produce over 60% Egypt's fish catch. Approximately 15% of Egypt's GDP is generated in these low elevation coastal zones (Roushdi, 2012).

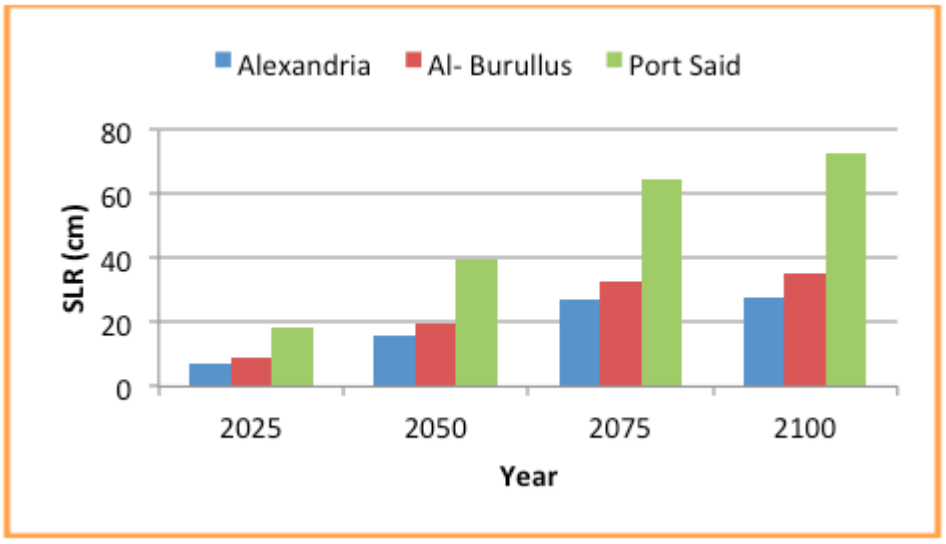


Figure 60 Predicted SLR values at several locations in 2025, 2050, 2075 and 2100 using optimistic scenario. Source: (Roushdi, 2012)

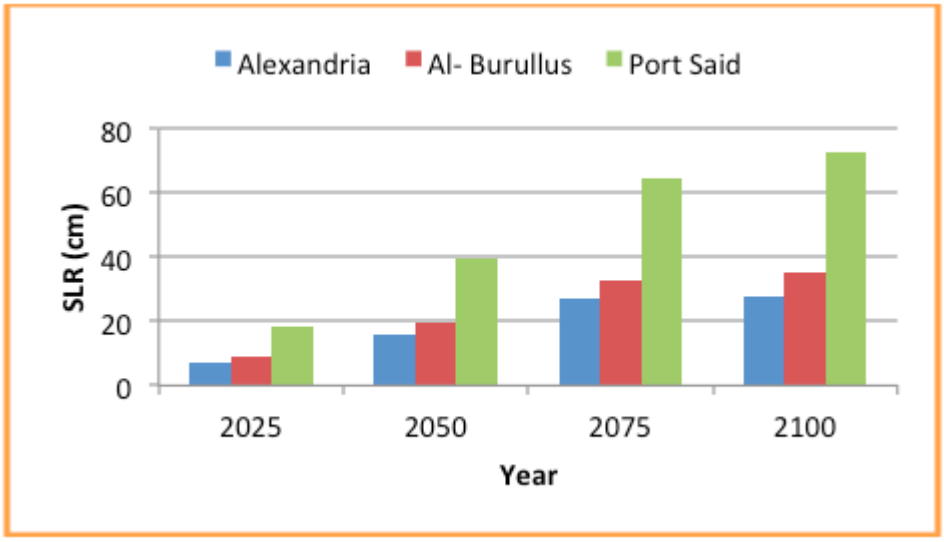


Figure 61 Predicted SLR values at several locations in 2025, 2050, 2075 and 2100 using pessimistic scenario. Source: (Roushdi, 2012

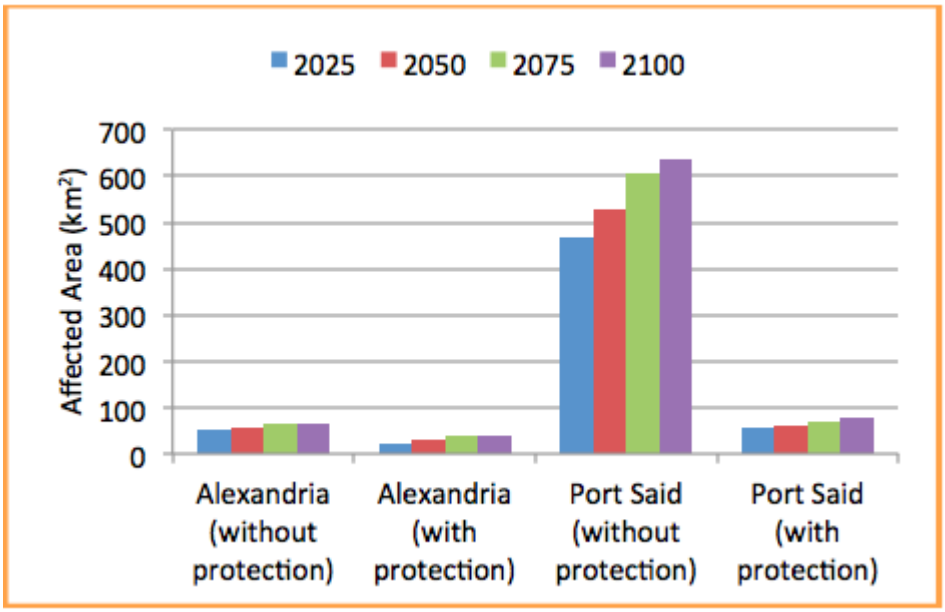


Figure 62 Predicted Inundated areas of Alexandria and Port Said (with and without protection. Source: (Roushdi, 2012)

Declining levels of silt build-up in the Nile Delta mean the coastal foundations on which Alexandria is built are wearing away. Seawater and flooding destabilizes the soil and the foundations of buildings and infrastructure. Building subsidence and collapse is then a regular occurrence. According to the IPCC the Alexandria lowlands are vulnerable to increased flooding, waterlogging and salinization under accelerated sea level rise. It also calculates and assumes the losses of agricultural yields, tourism and industry to reach more than $30 billion if seal levels rise by half a meter (Eldeberky, 2011, p. 43) (Cooke, 2018).

The next maps show the threat of flooding of the low lying land of the northern coast and Nile

Delta region in Egypt due to Sea Level Rise. The first one shows projections if the seal level rises by 1 meter while the second shows the scenario of a 2 meters rise. If sea level rises by 0.5 meters only 4 million people will be affected and 1800 square km land area will be submerged, while an increase of 1.5 meter will cause 8 million people to be affected and 5700 square Km land area to be submerged (ICARDA, 2008) (Schuttenhelm, 2015).

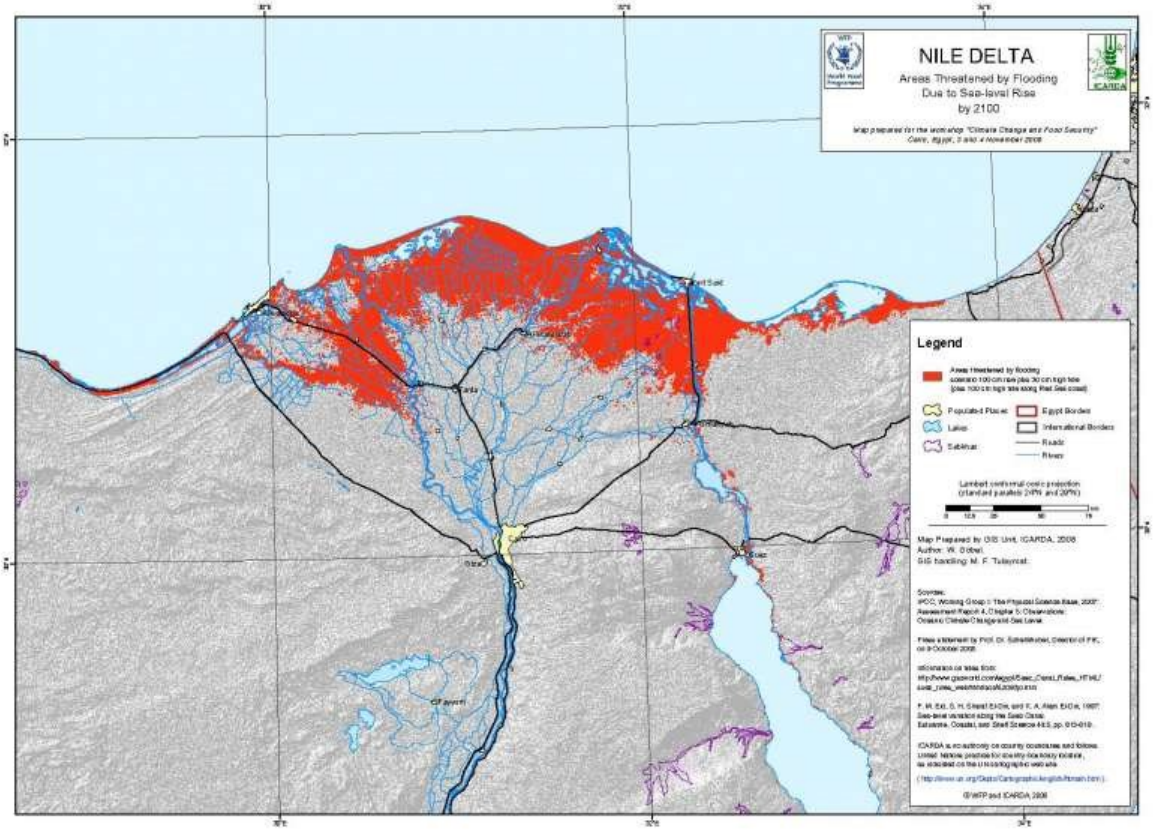


Figure 63 Northern Mediterranean Coast threatened by flooding in 2100 with 130 cm rise. Source: ICARDA, 2008

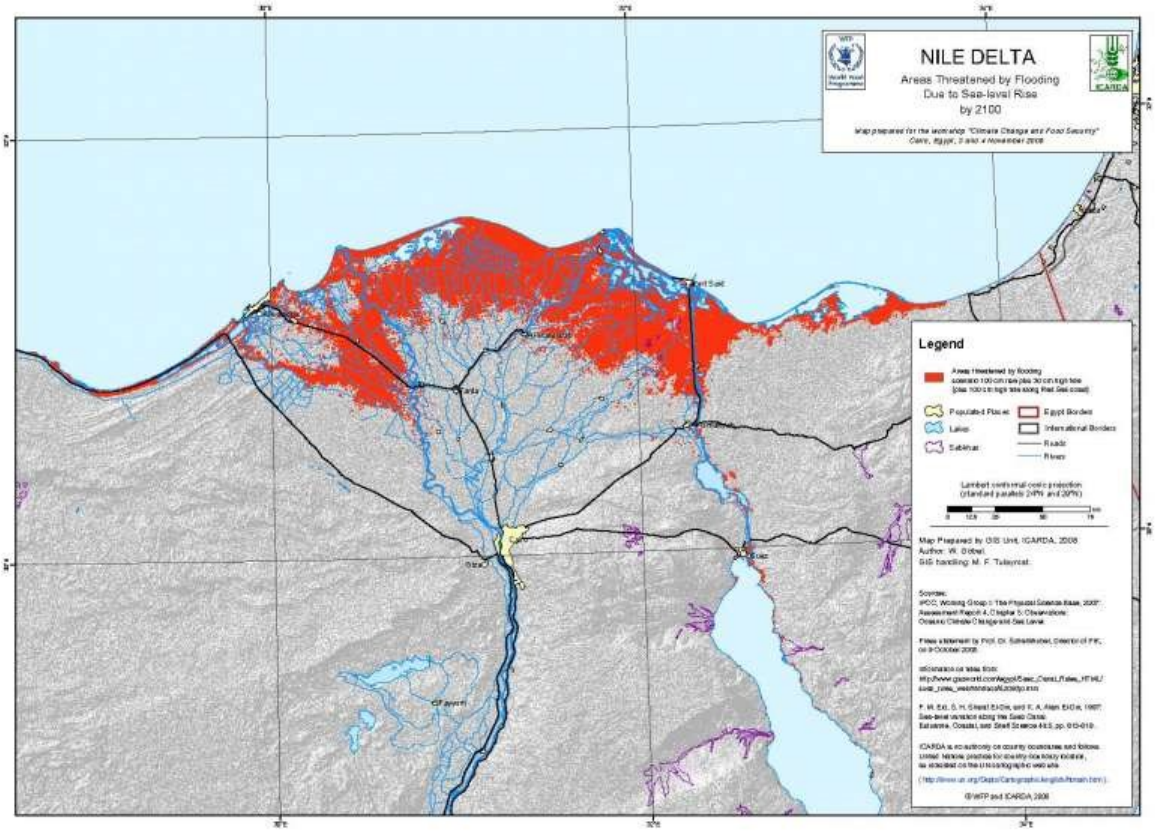


Figure 64 Northern Mediterranean Coast threatened by flooding in 2100 with 200 cm rise. Source: ICARDA, 2008

As mentioned earlier this northern area is home to a vast percentage of the Egyptian population. The below map pinpoints the population in the threatened area. From this mapping one can derive that the densest areas are the three cities of Alexandria, Port Said and Damietta with several million inhabitants. The areas in between are mostly agriculture lands with an average population of a few hundred thousand (El-Hattab, 2015, p. 297).

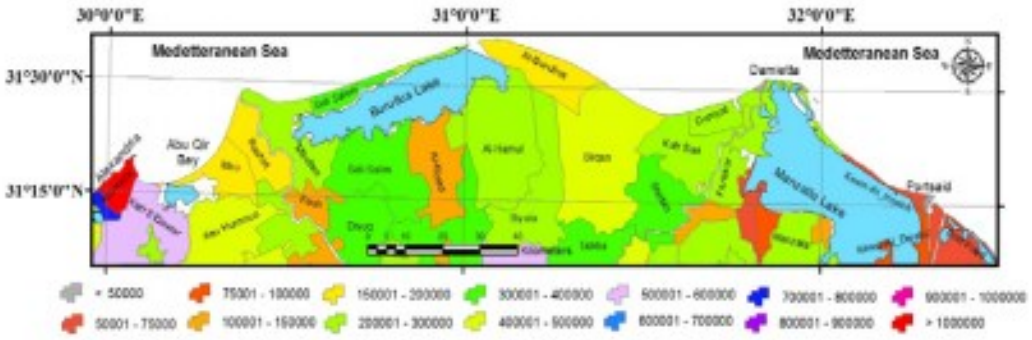


Figure 65 Population density distribution along North Mediterranean Coast. Source: El-Hattab, 2015

Most of the inhabitants of the area are farmers and fishermen. The second major professionals are craftsmen and related workers and in the major three cities are professional workers providing tertiary services and technicians with a few unskilled workers scattered

around the area (El-Hattab, 2015, p. 297).

Figure 10: Occupation status in different districts of study area.

Figure 66 Occupation status in districts of North Mediterranean Coast. Source: El-Hattab, 2015

The below figures highlight the vulnerability of the Mediterranean coast to the climate change risks. This area needs rapid action to mitigate the change and adapt to its inevitable impacts. This could be considered the most exposed are in Egypt to the impacts of climate change. Policies and actions need to be developed in order to increase the adaptive capacity of the areas and the inhabitants to be able to withstand extreme weather events and emergency strikes. The area is exposed to high coastal erosion and submerging of its land, mild slope risks, subsidence and home collapsing risks and finally but most important are socioeconomic risks accompanying the primary impacts of climate change which will put stress on the human factor due to forced immigration, welfare and health issues based on the occupation of the family members and their ability to adapt to this change (El-Hattab, 2015, p. 298).

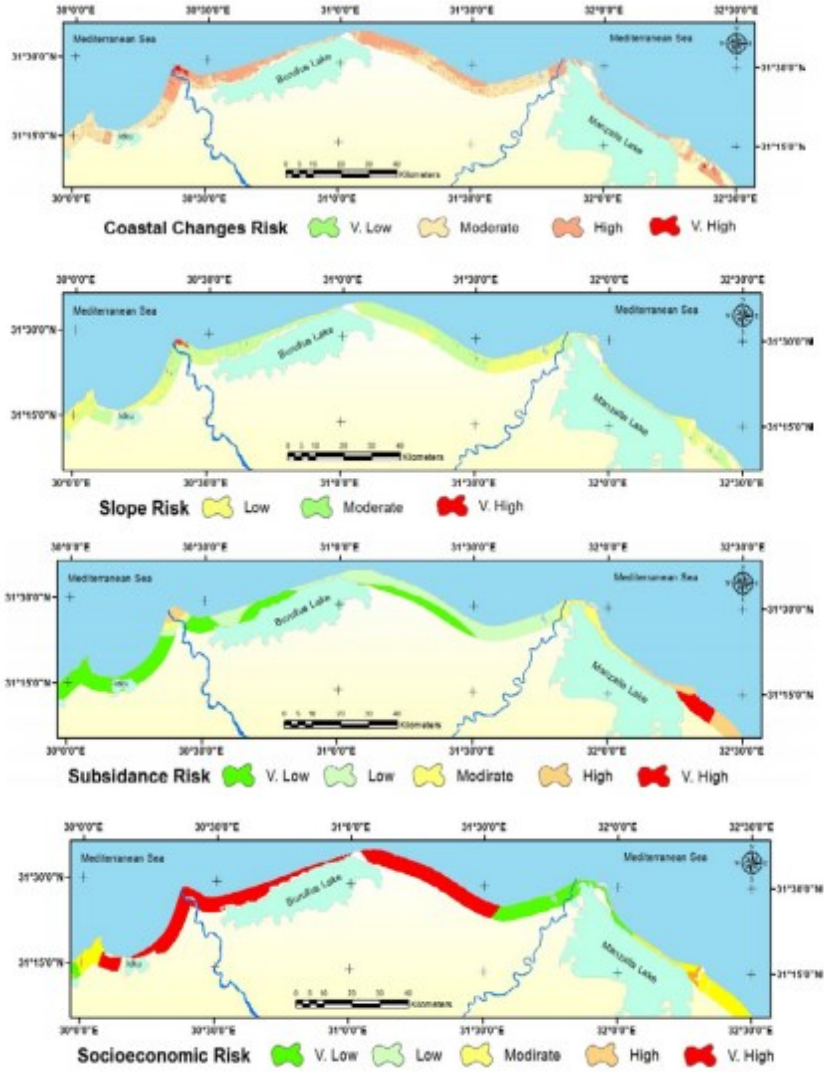


Figure 67 Vulnerability levels of North Mediterranean Coast. Source: El-Hattab, 2015

8.3 ARM'D Model Application

8.3.1 Mapping the City of Alexandria

It is decidedly arguable that the coastal city of Alexandria, the second largest city in Egypt, is at risk of being submerged due to rising sea levels. According to a report published by the IPCC, Alexandria's coastal shores would be submerged with a 0.5-metre sea-level rise, while approximately 8 million people would be displaced due to flooding in Alexandria and the Nile Delta if no defensive measures are taken (Link, Link, & Scheffran, 2013, p. 84) (Egyptian Streets, 2018) (The Egyptian Cabinet- Information & Decision Support Center, 2011, p. 21).

The following set of maps were created by GIS to analyze the condition of Alexandria before applying the ARM'D city tool on it. The aim was to highlight the most exposed and vulnerable areas based on location, average income and measures implemented. The maps were based on a rapid observatory assessment with some assumptions and approximations to fulfill as a case study for applying the ARM'D City Tool.

The first map illustrated in figure 68 highlights the coastal neighborhoods in Alexandria in yellow to show the ones at higher risk of being impacted by the climate change and especially the sea level rising.

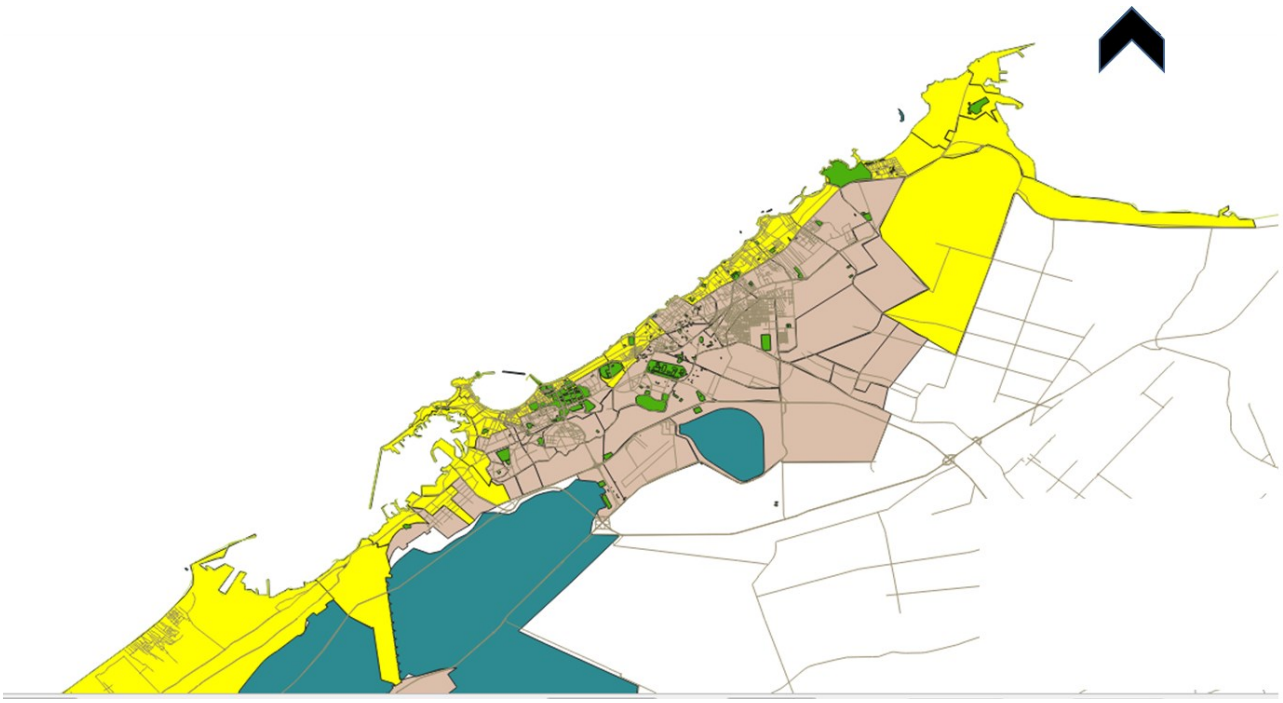


Figure 68 Coastal Neighborhoods in Alexandria (Source: Author)

The second map in figure 69 shows the different distribution of population across the neighborhoods of Alexandria in order to demonstrate the densest areas that will be affected by any climate hazards that occur. These areas with the highest density are closer to the coastal shore more than other areas with less inhabitants.

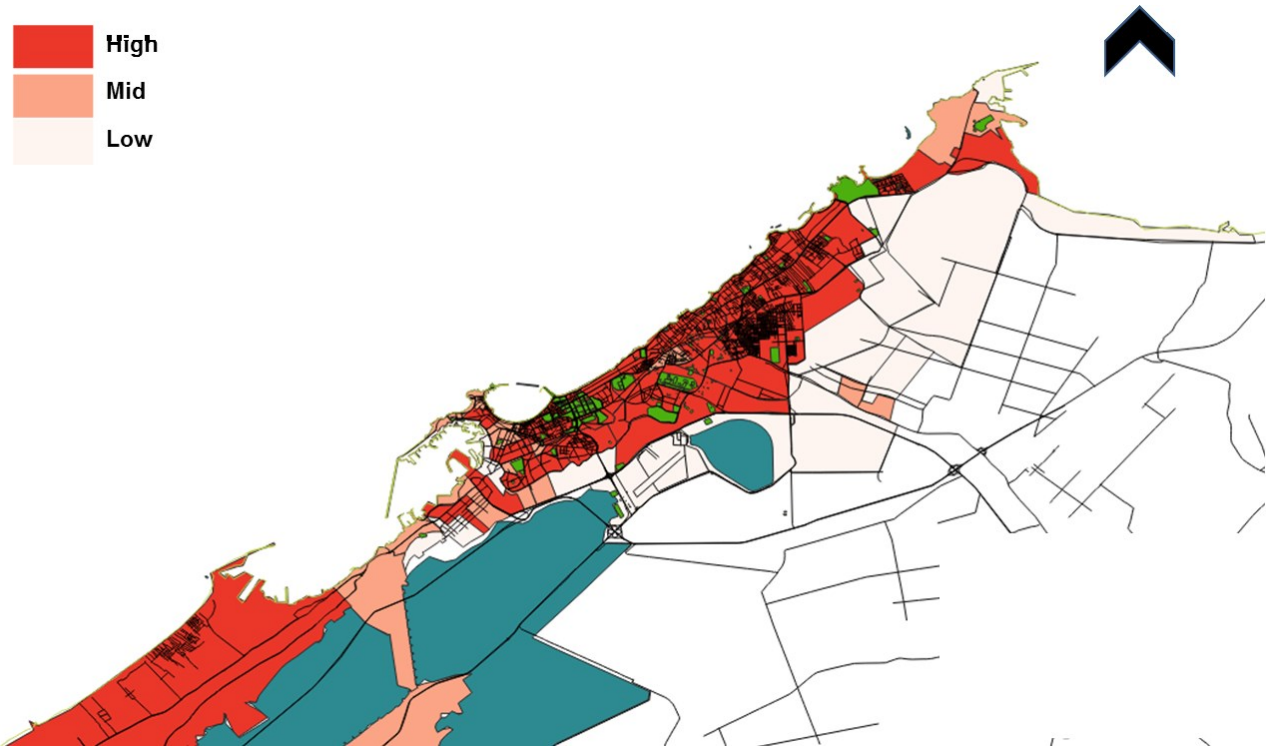


Figure 69 Average Population in Alexandria. Source: Author

The third map is shown in figure 70 below and it shows the economic vulnerability of different neighborhoods in Alexandria based on the income range assumed for different districts based on rapid observation. However most of the neighborhoods overlooking the coast have a higher income range.

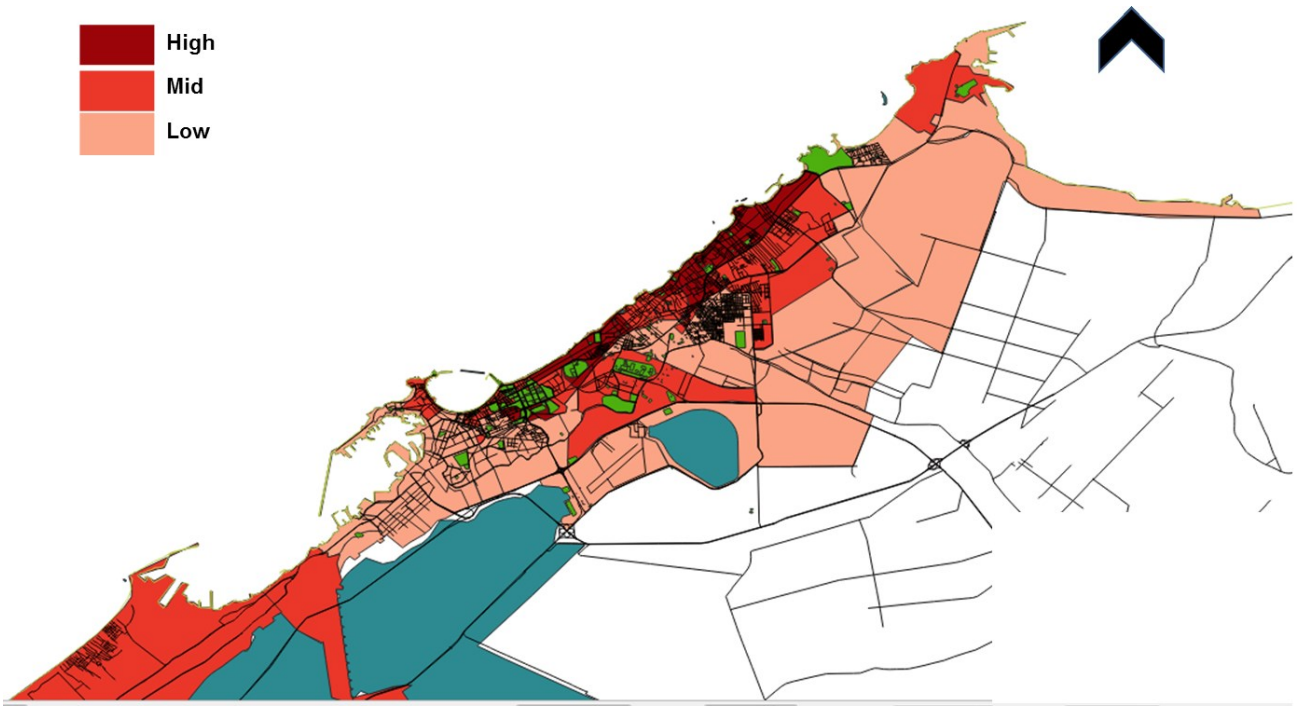


Figure 70 Average Income Range of Alexandria. Source: Author

The fourth map shown in figure 71 is an attempt to pinpoint the neighborhoods that have any applied measures to withstand climate change. The area highlighted in light brown are the areas that received some attention in regards to coastal protection. The same scheme was applied for the highlighted neighborhoods which is the blocks-barrier as shown in the picture below.

Figure 71 Coastal Protection in Alexandria. Source: Author

The fifth map illustrated in figure 72 below reflects the different activities and land-uses in the neighborhoods of Alexandria based on the most dominant land-use in each neighborhood after on site observation. This serves as a basis for knowing the types of economic sectors that will be impacted by the changing climate. In this map the most vulnerable areas are mostly residential and commercial areas.

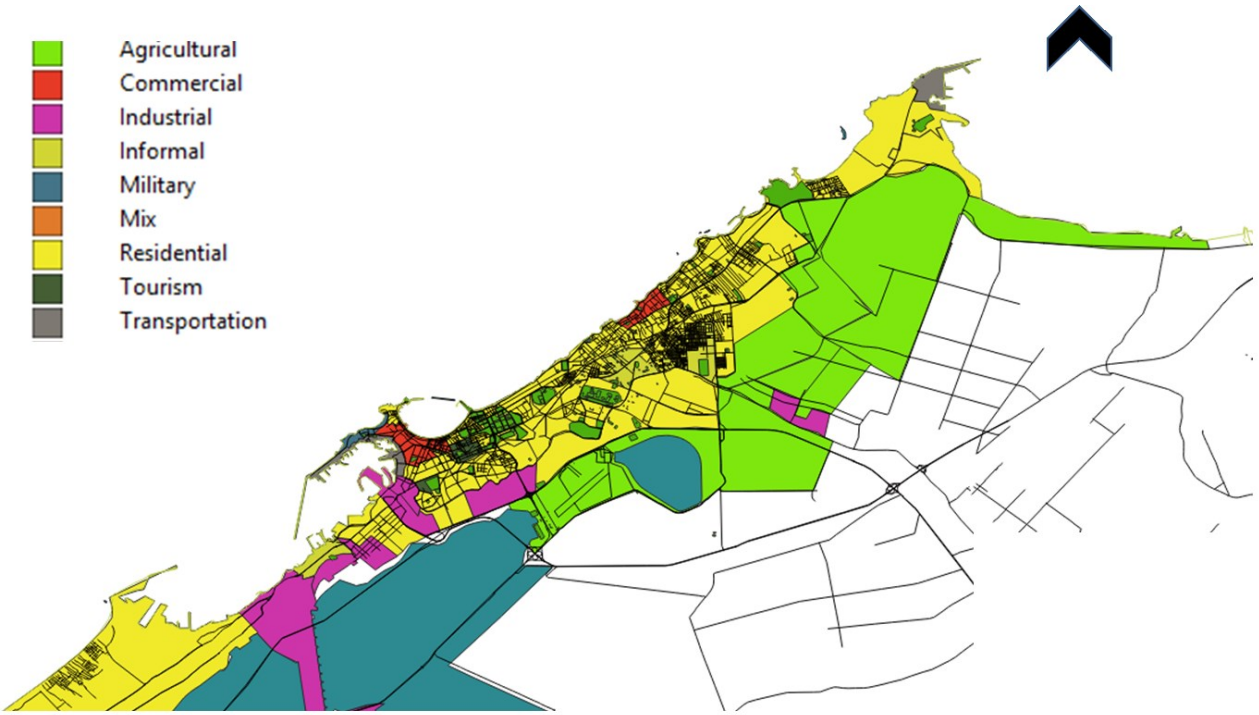


Figure 72 Land-use in Alexandria. Source: Author

Based on the previous layers of maps and the data inserted in the attribute tables in GIS the following map in figure 73 was created to highlight the neighborhoods with the highest exposure and sensitivity towards to the changing climate. This was done by comparing the location whether near coast or distant, the density of the area and if relocating would be easier or not, the range of income of the inhabitants and how they could overcome the financial burdens of any occurring change, the presence of existing measures in the neighborhood and the adaptive capacity of the neighborhood. This comparison and assessment was conducted based on data collected from field through observations and subjective interpretation of the surroundings. The highlighted area in yellow in the below map are the neighborhoods that were taken into deliberation as a case study for applying the ARM'D City Tool.

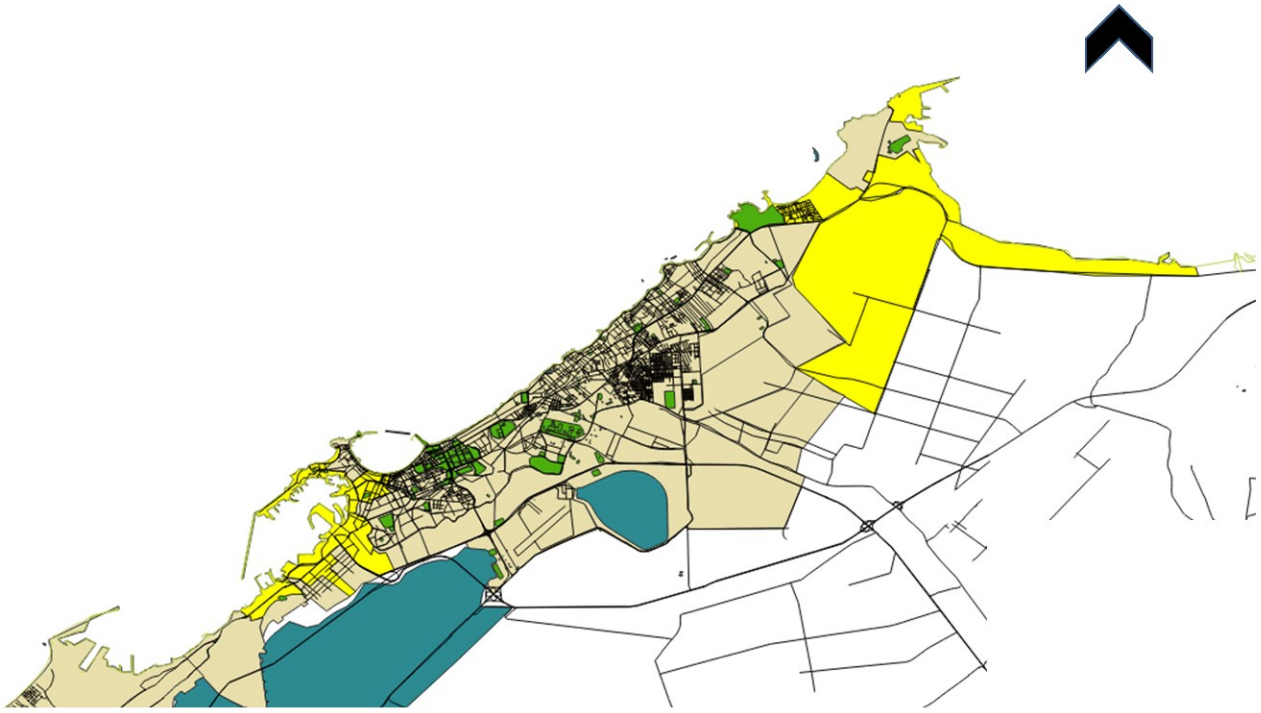


Figure 73 Vulnerable neighborhoods in Alexandria. Source: Author

8.3.2 Declaring parameters

Based on the analysis explained in the last section, the northern coast of Egypt was chosen to validate the developed model. It was chosen to be a pilot area for applying the ARM'D City model against climate change impacts. The expected result is a set of recommendations that could be put in action to help mitigate the predicted changes, adapt to the inevitable changes to become resilient to climate change. The tool will arm the case study with the weapons needed to withstand extreme weather events and pattern changes by providing an easy to apply decision making tool as an integral part of the planning process.

8.3.2.1 Stakeholder Analysis

The first step in the application is the analysis of the area. This includes stakeholder analysis, exposure analysis, sensitivity analysis, adaptive capacity analysis, and vulnerability analysis. To enter the required data, the second workbook under the name of "Analysis_File" needs to be activated.

The Stakeholder Advisory group is the first worksheet in the "Analysis_File". In column D, the involved stakeholders need to be chosen. In the case of the Mediterranean Coast and Nile Delta the involved stakeholders are:

- City departments (e.g. planning, engineering, transportation, finance, health)
- District, regional and national governments
- Neighborhood groups
- Local area leaders
- Under-represented groups (e.g. women's and minority groups) & Individuals
- Sector boards and authorities (health, education, transport)
- International agencies
- Small and medium-sized businesses
- Banks, credit unions and other financial groups
- Privately owned / managed utilities

Sector	Involved stakeholders		Involvement
Government	· City departments (e.g. planning, engineering,	☑	mobilize
	· Local government elected Representatives	☐	
	· Neighbouring local government representatives	☐	
	· District, regional and national governments	☑	mobilize
Local Area and Non-Governmental	· Environmental groups	☐	
	· Neighbourhood groups	☑	leverage
	· Local area leaders	☑	leverage
	· Local religious groups	☐	
	· Under-represented groups (e.g. women's and minority groups)	☑	persuade
Public Secto	· Sector boards and authorities (health, education, transpo	☑	co-opt
	· Educational institutions (technical schools, universities)	☐	
	· International agencies	☑	mobilize
Business and Labour	· Small and medium-sized businesses	☑	mobilize
	· Trade and labour unions	☐	
	· Real estate developers	☐	
	· Banks, credit unions and other financial groups	☑	co-opt
	· Chambers of commerce and business groups	☐	
	· News media	☐	
	· Professional associations	☐	
	Privately owned / managed utilities	☑	leverage

Figure 74 Stakeholders Advisory Group, Case of Alexandria. Source: Author

After entering the data in the worksheet, the stakeholder involvement matrix is automatically generated with the chosen stakeholder groups to reflect the level of interest against the level of influence.

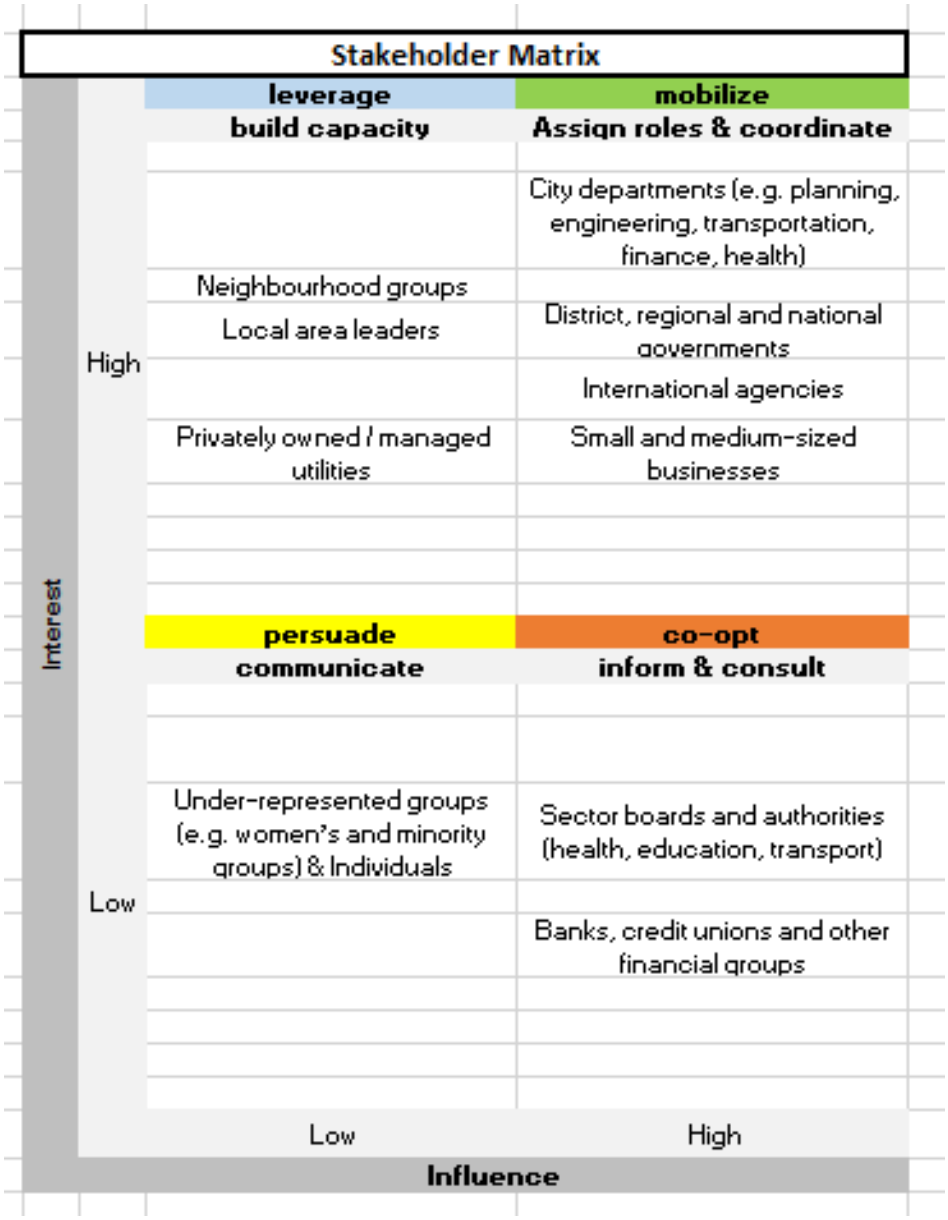


Figure 75 Stakeholder analysis matrix, the case of Alexandria. Source: Author

8.3.2.2 Exposure Analysis

After the identification of the stakeholders and their role in the process, the next step is the vulnerability assessment. By entering variables data in the exposure analysis worksheet, the sensitivity analysis worksheet and the adaptive capacity analysis worksheet a summary for the vulnerability assessment is automatically generated.

In the Exposure analysis worksheet, the climate change hazard that is expected to hit the region is chosen, in the case of North Mediterranean Coast of Egypt the chosen hazards are, Increasing temperature, decreasing precipitation and sea level rise. By choosing the relevant hazard in column D, the physical, social and economic risks related to the hazard are highlighted as well as the exposed sectors. The associated physical risk are Heat waves, Heat

island effect, wildfires, Droughts, Water scarcity and Coastal Floods. The social risks that will result from the chosen hazards are human amenity, health and migration while the economy will suffer due to risks in agriculture, tourism, energy and infrastructure. The exposed sectors for each climate hazard are then listed. For the increasing temperature the sectors are Water, Infrastructure/ settlement, Human health, Tourism, Energy, Buildings, and Forestry. For the decreasing precipitation the sectors are Water, Agriculture, Energy and Waste. For the sea level rise the exposed sectors are Water, Agriculture, Infrastructure/ settlement, Energy, Buildings, Waste and Transport.

From a drop down list, the exposed areas and exposed people are then picked. In this case the exposed areas are Residential Neighborhoods, Informal settlements, Fishing ports, Coastal area, Agricultural valley, Bridges and roads while the exposed people are local residents including the elderly, youths, children and women, Business owners, Farmers, Fishermen, Market sellers and the Poor in general.

	Exposed people, Places, and sectors																
	Climate Change Hazard		Climate Change Physical Risks	Social Risks	Economic Risks	Exposed area	Exposed people	Exposed Sectors									
Weather	Increasing Temperature	☑	Heat waves Heat island effect Wildfires	Human Amenity	Agriculture	Residential Neighb	All local residents	Water	Infrastructure/ settlement	Human health	Tourism	Energy	Buildings	Forestry			
						Informal settlemer	Business owners										
							Farmers										
	Decreasing Temperature	☐	Snow pack		Tourism	Fishing port	Fishermen										
Water	Increasing precipitation	☐	Floods	Health		Coastal area	Market sellers										
	Decreasing precipitation	☑	Droughts Water scarcity			Agricultural valley	Poor	Water		Agriculture			Energy		Waste		
						Residential Neighborhood											
	Rising sea level	☑	Coastal Floods		Energy	Bridges and roads		Water	Agriculture	Infrastructure / settlement	Energy	Buildings	Waste	Transport			
Air	Severe storms	☐	Hurricanes	Migration													
	Dispersion of particulate matter,intensify the formation of near-surface	☐	Air Pollution		Infrastructure												
Ecosystems	Affect lifecycle	☐	Biodiversity loss														

Figure 76 Exposure Analysis, the case of Alexandria. Source: Author

8.3.2.3 Sensitivity Analysis

The next analysis is the sensitivity analysis. By swiping to the worksheet the chosen hazards will appear along with a list of the expected primary and secondary impacts. In the case of increased temperature the expected impacts are Distress migration, Decreased access to food/nutrition, Spread of diseases, increased energy demands for cooling, increased mortality during heat waves, Livestock death and Decreased agriculture, Ground water depletion and water shortages. In the case of decreased precipitation the impacts are Distress migration, Lack of water in reservoir, Cannot adequately irrigate crops, Power outages, loss of jobs, spread of diseases, livestock death, and decreased Agriculture. While the sea level rise will lead to Distress migration, Salinization of soil/water, Increased coastal erosion, Infrastructure destruction, Increased isolation (Cut-off roads, services), and Loss of

productive/residential land due to erosion.

The following input is the probability of the physical hazard occurring and its threat level. In the sensitivity analysis worksheet on a scale from 1 to 5 where 5 is the highest the probability of occurrence and threat are chosen. The heat waves, heat island effect and wild fires.

Climate Change Physical threats	Potential Impacts	Probability of hazard	Threat level: Sensitivity of people, places and sectors to each hazard
Heat waves	Distress migration Decreased access to food/nutrition Spread pf diseases Increased energy demands for cooling Increased mortality during heat waves Livestock death and Decreased agriculture Ground water depletion	4	3
Heat island effect		5	4
Wildfires		1	2
Droughts	Distress migration Lack of water in reservoir Canot adequatey irrigate crops Power outages loss of jobs spread of diseases Livestock death and Decreased Agriculture	3	4
Water scarcity		4	4
Coastal Floods	Distress migration Salinization of soil/water Increased coastal erosion Infrastructure destruction Increased isolation (Cut-off roads, services) Loss of productive/residential land due to erosion	5	5

Figure 77 Sensitivity Analysis, the case of Alexandria. Source: Author

After entering the values in the columns D and E, a climate threat plotting graph is automatically generated. The graph plots the probability of the hazard against the magnitude of consequences to give a clear image for the prioritized hazard.

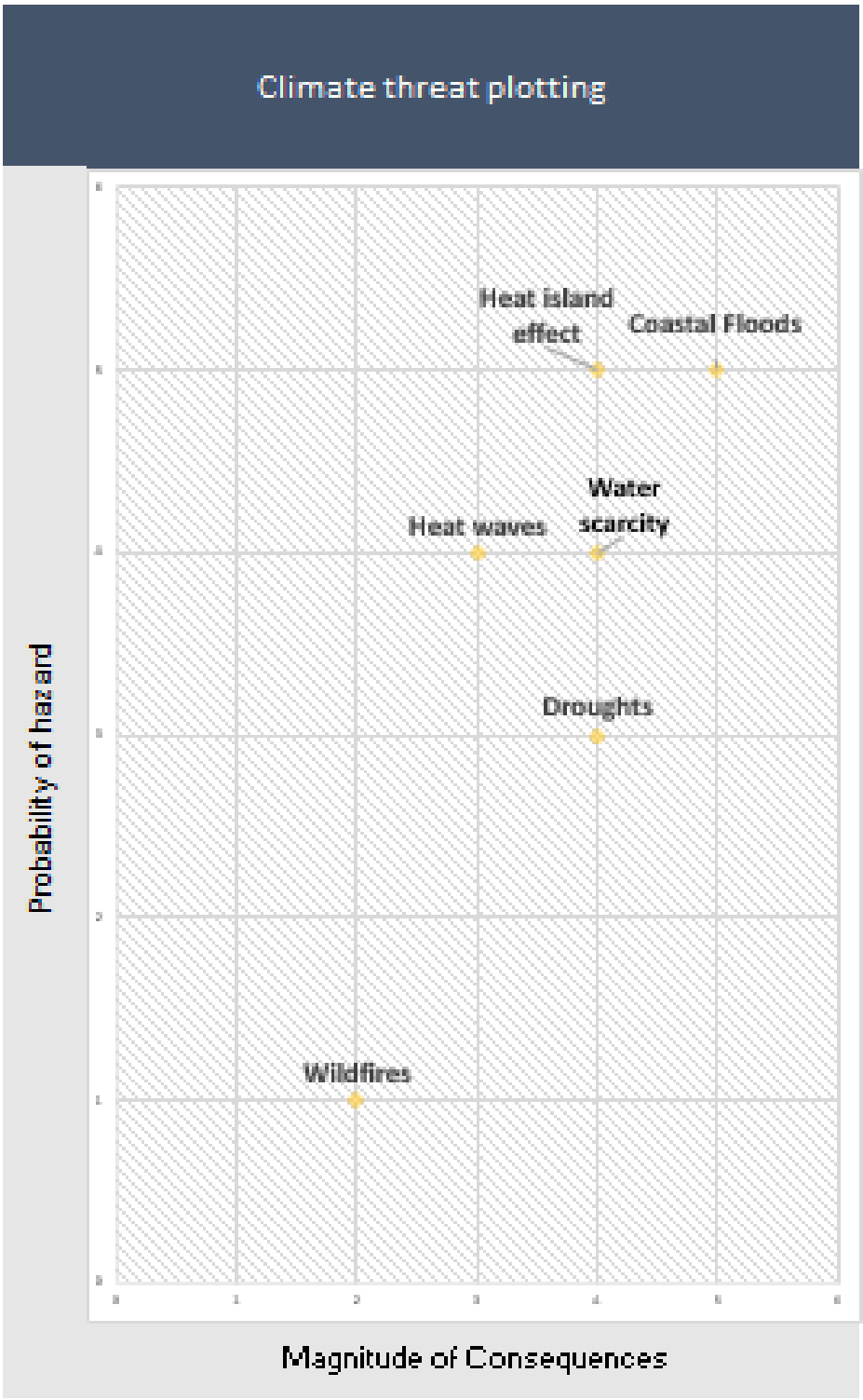


Figure 78 Climate threat Plotting graph, the case of Alexandria. Source: Author

8.3.2.4 Adaptive Capacity Analysis

The consecutive analysis is the adaptive capacity worksheet. In this worksheet the adaptive capacity is measured against Wealth, Technology, Institutions, Infrastructure, Information, and Social Capital. A score is entered manually for each climate hazard against questions under each of the previous sections mentioned.

The wealth section covers questions related to financial resources and funding, access to basic transportation and basic shelter, adequate staff and allocated time to plan and implement adaptation actions. The technology section covers the ability to communicate directly with the people/ sector affected. The institutions section questions are related to the political willingness to allocate resources, the existing processes and plans to integrate with. The infrastructure part is concerned with adequate transport, water infrastructure, sanitation, energy supply and management and access to safe, clean drinking water and medical services in close proximity. The information section is related to the awareness of stakeholders about climate change and impacts, previous efforts to study or address the climate change driver and potential impact in the area, and the existence of trained emergency response teams for this sector/ area. The final section is the social capital and questions cover the availability of notable community leaders and groups, specific agencies, and NGOs that have the mandate and skills to focus on the specific sector/area.

By entering a score from 1 to 5 where 5 is the highest the tool calculates an average score for each section and then calculates an overall score for the adaptive capacity related to each climate hazard.

Climate Change Physical Risks		Heat waves	Heat island	Wildfires			Droughts	Water scarcity	Coastal
Wealth:	Do you have access to adequate financial resources and funding?	1	2				3	3	5
	Do the people in the affected area have . access to basic transportation, adequate rations, ability to relocate temporarily, basic shelter)?	2	2				2	2	2
	Do you have adequate staff and allocated time to plan and implement adaptation actions?	1	1				3	3	5
	Average Score (total score/no. of questions)	1	2	0			3	3	4
Technology:	Is there an ability to communicate directly with the people/ sector affected (e.g. basic communication infrastructure, a designated key point of contact, regular interaction, radio service, etc.)?	4	4				4	4	4
	Average Score (total score/no. of questions)	4	4	0			4	4	4
Institutions	Is there political willingness to allocate resources to build adaptive capacity?	1	1				3	3	5
	Are there existing processes that you can integrate with?	1	1				1	1	4
	Are there any existing area/sectoral plans, including emergency response plans that can be referred to?	1	1				1	1	3
	Average Score (total score/no. of questions)	1	1	0			2	2	4
Infrastructure:	Is there adequate transport, water infrastructure, sanitation, energy supply and management?	3	3				3	3	3
	Are major infrastructure and/or facilities located in hazard prone areas?	2	3				3	3	5
	Do people in the affected area have access to safe, clean drinking water in the event of a hazard occurrence?	4	4				2	2	2
	Are there adequate medical services in close proximity?	2	2				2	2	2
	Average Score (total score/no. of questions)	3	3	0			3	3	3
Information:	Are decision-makers aware of a) climate change and b) potential impacts/risks in your jurisdiction?	2	2				4	4	5
	Are stakeholders in the area/sector aware there are current and/or potential impacts?	2	2				3	3	5
	Has this area/sector undertaken previous efforts to study or address the climate change driver and potential impact?	1	1				1	1	3
	Are there trained emergency response teams for this sector/ area?	1	1				1	1	1
	Average Score (total score/no. of questions)	2	2	0			2	2	4

Figure 79 Adaptive Capacity, the case of Alexandria. Source: Author

8.3.2.5 Vulnerability Assessment

The final worksheet is generated automatically as a summary to the previous analysis worksheets. The worksheet shows the chosen climate hazard and the associated risk, the threat level of each hazard, the capacity to adapt to it and the relative vulnerability is calculated by dividing threat level by adaptive capacity scores.

	Exposure		Sensitivity	Adaptive Capacity	Vulnerability
	Climate Change Hazard	Climate Change Physical Risks	Threat level: Sensitivity of people, places and sectors to each hazard	Average Adaptive Capacity Score	Relative Vulnerability (Threat Level divided by Adaptive Capacity)
Weather	Increasing Temperature	Heat waves	3	2	1
		Heat island effect	4	2	2
		Wildfires	2		
Water					
	Decreasing precipitation	Droughts	4	3	1
		Water scarcity	4	3	1
	Rising sea level	Coastal Floods	5	4	1

Figure 80 Vulnerability Assessment, the case of Alexandria. Source: Author

8.3.3 Scenarios generation

8.3.3.1 Options listing

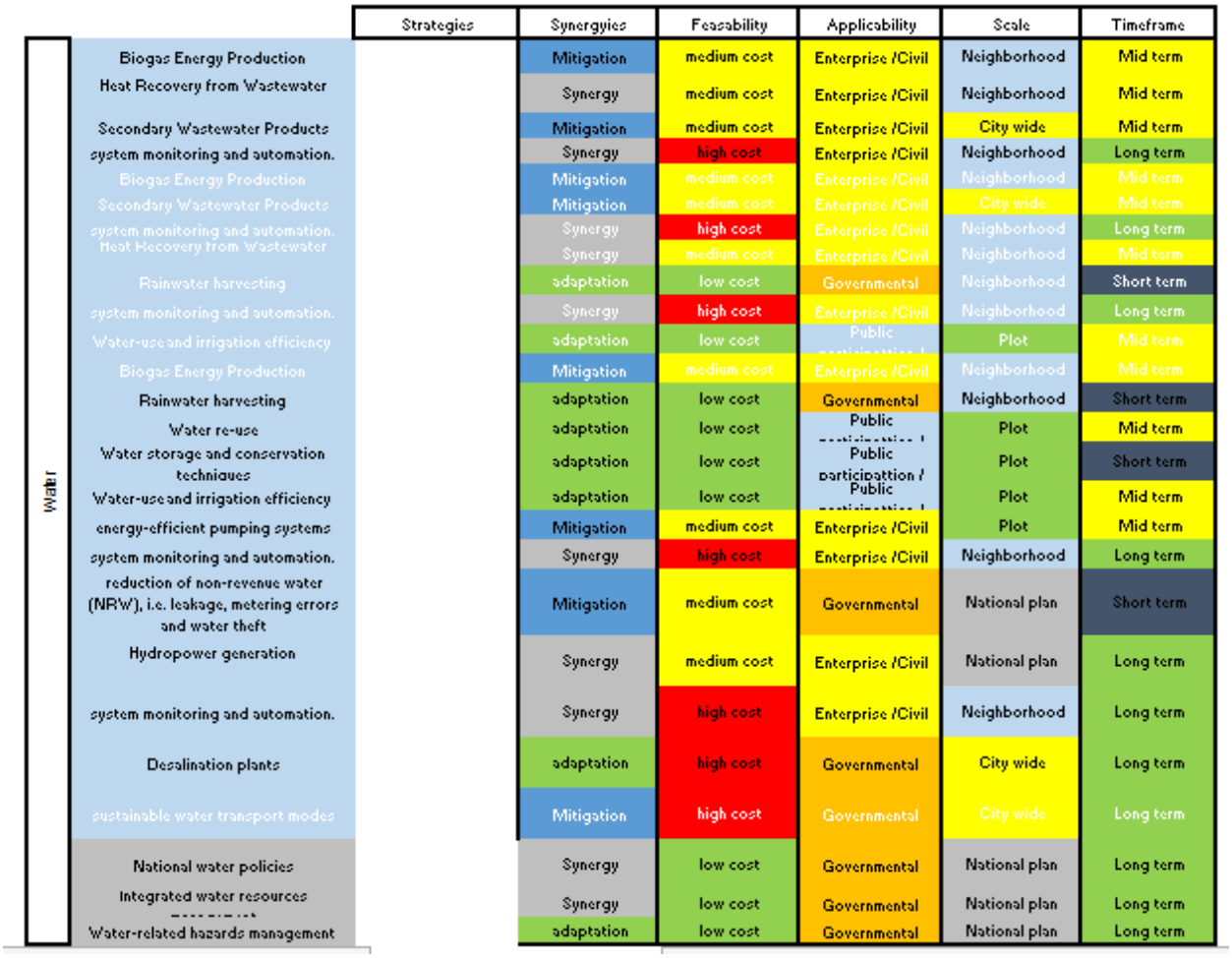
After conducting the analysis, generation of alternatives is the subsequent step. Based on the information entered in the variables cells in the previous workbook, competent options are listed. By shifting to the "Options_File" workbook, the options listing worksheet will highlight all available options for each hazard and in each specific sector impacted by the hazard. The data is derived from the database and linked directly to the conducted analysis.

Climate Change Hazard	Water	Infrastructure/ settlement	Human health	Tourism	Energy	Buildings	Forestry
Increasing Temperature	Biogas Energy Production	hazard specific control activities such as flood levees or bushfire mitigation strategies	Access to water	Diversification of tourism attractions and revenues	Strengthening of overhead transmission and distribution infrastructure	Green walls	Seeding and planting e.g. selecting and introducing better adapted reproductive material.
	Heat Recovery from Wastewater	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Heat-health action plans	Shifting ski slopes to higher altitudes and glaciers	Underground cabling for utilities	Green roofs	Afforestation
	Secondary Wastewater Products	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Emergency medical services	conservation of natural areas	Energy efficiency	Mixed use developments	Reforestation
	system monitoring and automation.	Strengthening of overhead transmission and distribution	Food security plans	Artificial snow-making	Use of renewable sources	Walkable neighborhoods	Reduced deforestation
	Water-related hazards management	Underground cabling for utilities			Fuel switching	Efficient lighting and daylighting	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.
	National water policies	Centralized renewable sources infrastructure			Reduced dependence on single sources of	More efficient electrical appliances and heating and	Modification of frequency and intensity of tending

Figure 81 Options listing, the case of Alexandria. Source: Author

8.3.3.2 Organizing Options

Moving to the next worksheet which is organizing options, the options listed earlier are then evaluated automatically according to their achievability. First the options are categorized by synergies, if they could mitigate, adapt or act as a common strategy. Second the categorization is according to feasibility, high cost, medium cost or low cost options. Third, the applicability is listed, if the level of application is the responsibility of the governmental, Enterprise /Civil or Public participation / Individuals. Fourth, the options are categorized according to scale, national plan, citywide, neighborhood or plot. Finally the options are categorized according to timeframe, long term options, midterm options and short term options. This data is extracted from the first worksheets in the "Options_File".



	Strategies	Synergyies	Feasability	Applicability	Scale	Timeframe
Water	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Heat Recovery from Wastewater	Synergy	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Secondary Wastewater Products	Mitigation	medium cost	Enterprise /Civil	City wide	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Secondary Wastewater Products	Mitigation	medium cost	Enterprise /Civil	City wide	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Heat Recovery from Wastewater	Synergy	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Rainwater harvesting	adaptation	low cost	Governmental	Neighborhood	Short term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Water-use and irrigation efficiency	adaptation	low cost	Public	Plot	Mid term
	Biogas Energy Production	Mitigation	medium cost	Enterprise /Civil	Neighborhood	Mid term
	Rainwater harvesting	adaptation	low cost	Governmental	Neighborhood	Short term
	Water re-use	adaptation	low cost	Public	Plot	Mid term
	Water storage and conservation techniques	adaptation	low cost	Public participattion /	Plot	Short term
	Water-use and irrigation efficiency	adaptation	low cost	Public	Plot	Mid term
	energy-efficient pumping systems	Mitigation	medium cost	Enterprise /Civil	Plot	Mid term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Mitigation	medium cost	Governmental	National plan	Short term
	Hydropower generation	Synergy	medium cost	Enterprise /Civil	National plan	Long term
	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Desalination plants	adaptation	high cost	Governmental	City wide	Long term
	sustainable water transport modes	Mitigation	high cost	Governmental	City wide	Long term
	National water policies	Synergy	low cost	Governmental	National plan	Long term
	Integrated water resources	Synergy	low cost	Governmental	National plan	Long term
	Water-related hazards management	adaptation	low cost	Governmental	National plan	Long term

Figure 82 Organizing Options, the case of Alexandria. Source: Author

8.3.3.3 Screening Options

The last worksheet in the "Options_File" is the screening worksheet. In this file scores are automatically calculated for each option according to the categorization in the organizing options worksheet. The synergies is reflected here as the Relative effectiveness, the cost is scored as the Economic feasibility, the applicability is scored as the Ease of implementation, the scale is the Mainstreaming potential, the timeframe is the Urgency of implementation, and the options that are repeated to serve several issues is the Multi objective. The average total score is the sum of the listed individual scores for each measure.

		Relative effectiveness	Economic feasibility	Ease of implementati	Mainstreaming potential	Urgency of implementatio	Multi objectiv	Stakeholder Acceptability	Score
Water	Biogas Energy Production	2	2	2	3	2	3	3.41176471	17.412
	Heat Recovery from Wastewater	3	2	2	3	2	2	3.35294118	17.353
	Secondary Wastewater Products	2	2	2	2	2	2	3.11764706	15.118
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	Rainwater harvesting	1	3	1	3	3	2	3.16176471	16.162
	Water re-use	1	3	3	4	2	1	3.17647059	17.176
	Water storage and conservation techniques	1	3	3	4	3	1	3.17647059	18.176
	Water-use and irrigation efficiency	1	3	3	4	2	2	3.19117647	18.191
	energy-efficient pumping systems	2	2	2	4	2	1	3.30882353	16.309
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	2	2	1	1	3	1	3.19117647	13.191
	Hydropower generation	3	2	2	1	1	1	3.57352941	13.574
	system monitoring and automation.	3	1	2	3	1	5	3.27941176	18.279
	Desalination plants	1	1	1	2	1	1	3.5	10.5
	National water policies	3	3	1	1	1	1	3.11764706	13.118
	Integrated water resources management	3	3	1	1	1	1	3.13235294	13.132
	Water-related hazards management	1	3	1	1	1	1	3.17647059	11.176
Infrastructure/ settlement	hazard specific control activities such as flood levees or bushfire mitigation strategies	3	2	1	2	2	3	3.63235294	16.632
	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	1	2	1	1	1	5	3.76470588	14.765
	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power	3	3	1	2	2	2	3.5	16.5
	Strengthening of overhead transmission and distribution infrastructure	2	2	1	2	2	3	3.11764706	15.118

Figure 83 Screening Options, the case of Alexandria. Source: Author

8.3.4 Achievability of scenarios

8.3.4.1 Satisfactoriness of measures

The Stakeholder Acceptability is the last input in the tool before proposing the most appropriate measures that could be implemented. In the "Options_File" and under the same worksheet of screening options, the acceptability of involved and interested stakeholders is entered on a scale from 1 to 5 where 5 is the highest. The stakeholders were listed previously in the "Analysis_File" under the Stakeholders Advisory Group sheet. Based on the generated matrix the role of stakeholders could be determined.

To measure the satisfactoriness of the measures from the stakeholders' point of view a questionnaire was prepared. The questionnaire constituted the following sections:

- **Socio-demographic:** The first section included personal information and description of the participants, including their age, gender, education, and employment status

- **Involvement:** The second section states the level of interest vs the level of influence of the stakeholders by identifying their role.
- **Perception:** The third section identifies the level of awareness to current drivers and challenges in the topic of climate change. It aims at collecting data regarding the sources of the information they acquired and their observations related to a possible changes of the climate.
- **Satisfactoriness:** Measures the acceptability and outreach of proposed options

8.3.4.1.1 **ARM'D Neighborhood Survey**

A. Socio-demographic

Gender	□Male	□Female		
Age	□till 18	□18 - 35	□35 - 50	□More than 50
Educational background	□Average qualification	□High qualification	□able to read and write	□illiterate
Employment Status	□Employed	□ Unemployed		
Sector of Employment	□Governmental/ Public Institution	□Private Sector	□Academia	□NGO

B. Involvement

Government	□City departments (e.g. planning, engineering, transportation, finance, health) □District, regional and national governments
Local Area and Non-Governmental	□Neighborhood groups □Local area leaders □Under-represented groups (e.g. women's and minority groups) & Individuals

Public Sector	□Sector boards and authorities (health, education, transport) □International agencies
Business and Labor	□Small and medium-sized businesses □Banks, credit unions and other financial groups □Privately owned / managed utilities

C. Perception

Have you noticed some particular changes in the environment or climate in the past 10 years?

□Rain	□Temperature	□Season Shift	□Floods	□Droughts	□No

Are you aware of the global policies or initiatives taken by various organizations to reduce climate change/global warming?

□Yes	□No

Are you aware about the environmental policies in your country?

□Yes	□No

How would you describe your knowledge about the following:

Causes of Climate Change	□Broad	□Moderate	□Slight	□None
Consequences of Climate change	□Broad	□Moderate	□Slight	□None
Mitigation strategies	□Broad	□Moderate	□Slight	□None

Adaptation Strategies	□Broad	□Moderate	□Slight	□None
Resilience	□Broad	□Moderate	□Slight	□None

Do you think enough is being done for climate change by the following:

Government	□Yes	□No	□To some extent
Local authorities	□Yes	□No	□To some extent
Corporations and Industry	□Yes	□No	□To some extent
International Agencies/NGOs	□Yes	□No	□To some extent
Citizens	□Yes	□No	□To some extent

D. Satisfactoriness

To what extent do you agree that the following proposed options will help face the climate change threat?

	Highly Disagree	Disagree	Neutral	Agree	Highly Agree
Water Sector					
Biogas Energy Production					
Heat Recovery from Wastewater					
Secondary Wastewater Products					
Rainwater harvesting					
Water re-use					
Water storage and conservation techniques					
Water-use and irrigation efficiency					
energy-efficient pumping systems					
reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft					

Hydropower generation					
System monitoring and automation.					
Desalination plants					
National water policies					
Integrated water resources management					
Water-related hazards management					
Infrastructure/ settlement					
hazard specific control activities such as flood levees or bushfire mitigation strategies					
Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage					
Annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).					
Strengthening of overhead transmission and distribution infrastructure					
Underground cabling for utilities					
Centralized renewable sources infrastructure					
Seawalls and storm surge barriers					
Dune reinforcement					
Land acquisition and creation of wetlands as buffer against sea level rise and flooding					
Protection of existing natural barriers					
avoid developments and community infrastructure in areas prone to hazards					
Monitoring and controlling systems					
Relocation					
community awareness campaigns to increase knowledge of how to prepare for					

disaster events					
Standards and regulations to integrate climate change considerations into design					
Land-use policies					
Insurance					
Human Health					
Access to water					
Heat-health action plans					
Emergency medical services					
Food security plans					
Public health policies that recognize climate risk					
Regional and international cooperation					
Tourism					
Diversification of tourism attractions and revenues					
Shifting ski slopes to higher altitudes and glaciers					
conservation of natural areas					
Artificial snow-making					
Integrated planning (e.g. carrying capacity					
Linkages with other sectors)					
Financial incentives, e.g. subsidies and tax credits					
Energy					
Strengthening of overhead transmission and distribution infrastructure					
Underground cabling for utilities					
Energy efficiency					
Use of renewable sources					
Fuel switching					
Reduced dependence on single sources of energy					

Combined heat and power					
Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)					
Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics					
Carbon Capture and Storage CCS					
Carbon Capture and Reuse CCR					
Carbon Capture and Utilization CCU					
Carbon Offsets					
Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas					
National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources					
Incorporating climate change in design standards					
Reduction of fossil fuel subsidies					
Taxes or carbon charges on fossil fuels					
Feed-in tariffs for renewable energy technologies					
Renewable energy obligations; producer subsidies					
Buildings					
Green walls					
Green roofs					
Mixed use developments					
Walkable neighborhoods					
Efficient lighting and daylighting					
More efficient electrical appliances and					

heating and cooling devices					
Improved cook stoves, improved insulation					
Passive and active solar design for heating and cooling					
Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;					
Climate proofing of new buildings					
climate proofing of old buildings					
Alternative refrigeration fluids, recovery and recycling of fluorinated gases					
Solar photovoltaics integrated in buildings					
Integrated Renewables in buildings					
Feed in energy supply to grid					
Rooftop Advertisement usage for renewable devices					
avoid developments and community infrastructure in areas prone to hazards					
Off grid and storage during emergency					
Development of early warning systems					
Standards and regulations to integrate climate change considerations into design					
Land-use policies					
Building codes					
Insurance					
Appliance standards and labelling					
Building codes and certification					
Demand-side management programs					
Public sector leadership programs, including procurement					
Incentives for energy service companies (ESCOs)					
Forestry					

Seeding and planting e.g. selecting and introducing better adapted reproductive material.					
Afforestation					
Reforestation					
Reduced deforestation					
Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.					
Modification of frequency and intensity of tending and thinning practices.					
Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen					
pest and disease management;					
pest and disease management;					
forest fire protection					
Reduction of the forest fragmentation					
Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change					
Tree species improvement to increase biomass productivity and carbon sequestration					
Use of forestry products for bioenergy to replace fossil fuel use					
Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and					

manage forests					
Land-use regulation and enforcement					
Agriculture					
farm to market sustainable transportation modes					
Urban and peri-urba agriculture					
Improved energy efficiency of equipment					
Dedicated energy crops to replace fossil fuel use					
Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions					
Improved nitrogen fertilizer application techniques to reduce N_2O emissions					
Multi-functional farming					
Urban and peri-urba agriculture					
Crop relocation					
Restoration of cultivated peaty soils and degraded lands					
Improved crop and grazing land management to increase soil carbon storage					
Improvements of crop yields					
Improved land management e.g. erosion control and soil protection through tree planting					
R&D policies					
Institutional reform					
Land tenure and land reform					
Capacity building					
Crop insurance					
Financial incentives, e.g. subsidies and tax credits					

Financial incentives and regulations for improved land management					
Maintaining soil carbon content					
Efficient use of fertilizers and irrigation					
Waste					
Controlled wastewater treatment					
Waste incineration with energy recovery					
Landfill CH_4 recovery					
Bio covers and bio filters to optimize CH_4 oxidation					
Controlled wastewater treatment					
Financial incentives for improved waste and wastewater management					
Renewable energy incentives or obligations					
Waste management regulations					
Transport					
Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage					
More fuel-efficient vehicles					
Hybrid vehicles					
Cleaner diesel vehicles					
Biofuels					
Modal shifts from road transport to rail and public transport systems					
Non-motorized transport (cycling, walking)					
Higher efficiency aircraft					
Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage					
Realignment/relocation					

Integrating climate change considerations into national transport policy					
Investment in R&D for special situations, e.g. permafrost areas					
Mandatory fuel economy; biofuel blending and CO_2 standards for road transport					
Taxes on vehicle purchase, registration, use and motor fuels;					
Road and parking pricing					
Influence mobility needs through land-use regulations and infrastructure planning					
Investment in attractive public transport facilities and non-motorized					
Industry					
More efficient end-use electrical equipment					
Advanced energy efficiency					
Heat and power recovery					
Off grid and storage during emergency					
Provision of benchmark information; performance standards; subsidies; tax credits					
Tradable permits					
Insurance plans					
Share losses with public funds					
change in operating practices					
Voluntary agreements					

8.3.4.1.2 ARM'D Neighborhood Survey Results

This analysis is based on a sample of 68 results received from both online and personal questionnaire for the residents of the governorate of Alexandria the largest city in the Northern Mediterranean Coast of Egypt. The sample was calculated based on the population of Alexandria which is 5,200,000 inhabitants according to the UN data. The error margin is

10% and the confidence level is 90%.

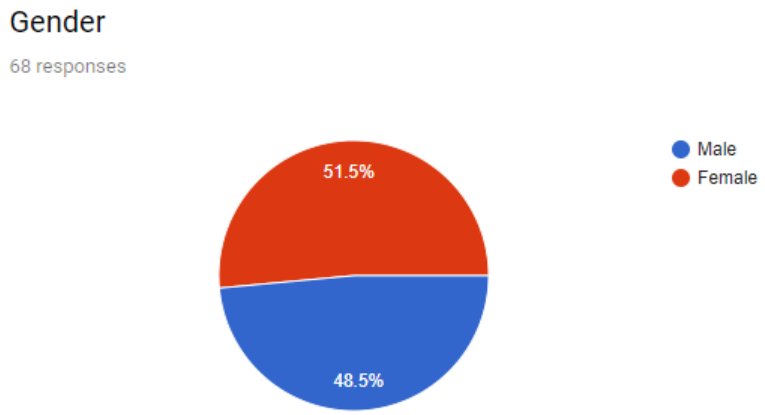


Figure 84 Percentage of Gender Survey Responses, the case of Alexandria. Source: Author

The number of males and females interviewed were almost equal in order to get a clear overview of both perspectives.

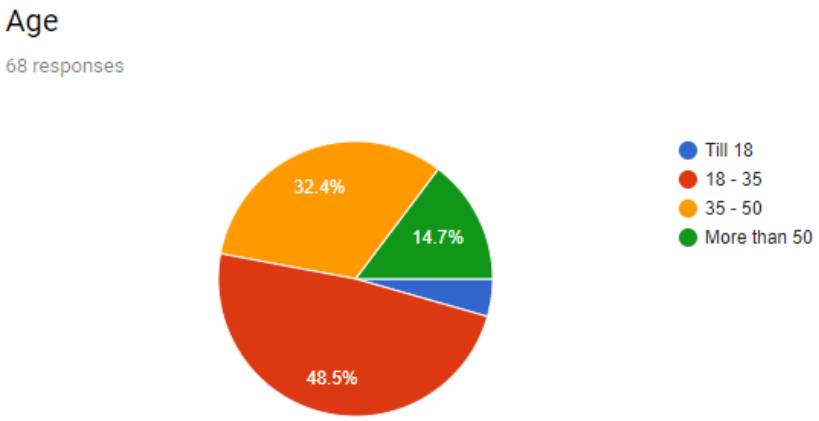


Figure 85 Percentage of Age Groups Survey Responses, the case of Alexandria. Source: Author

Almost half of interviewees were between 18 and 35 years. Third of the interviewees belonged to the age group between 35 and 50 years.

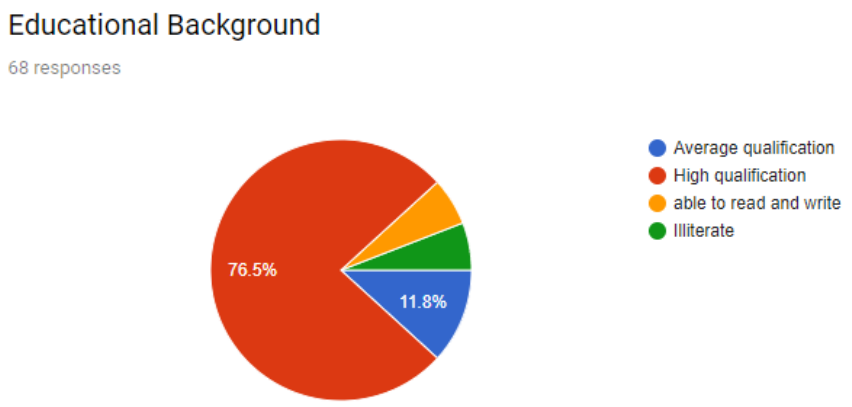


Figure 86 Percentage of Educational Background Survey Responses, the case of Alexandria. Source: Author

The majority of the interviewees have a high qualification degree and almost 10% are illiterate or are only able to read and write.

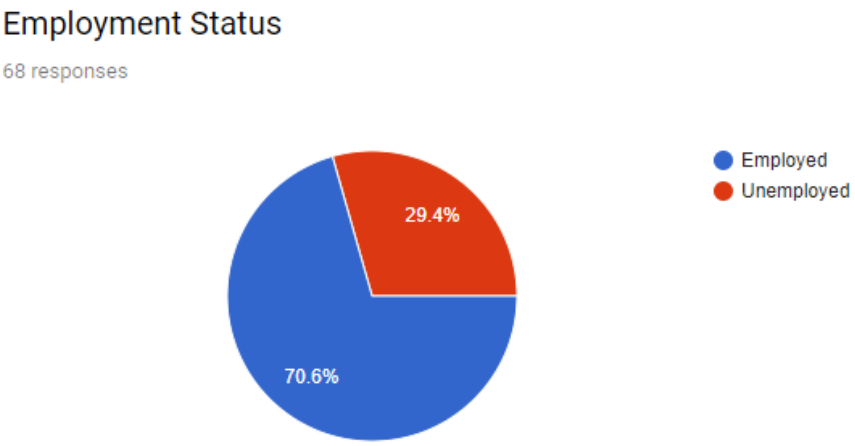


Figure 87 Percentage of Employment Status Survey Responses, the case of Alexandria. Source: Author

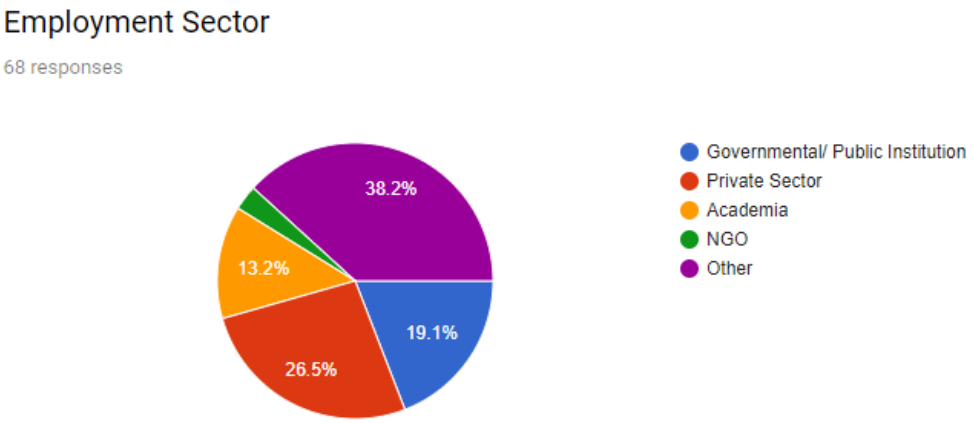


Figure 88Percentage of Employment Sector Survey Responses, the case of Alexandria. Source: Author

More than 70% percent of the interviewees are employed. They are almost equally distributed among private sector, public sector and Academia.

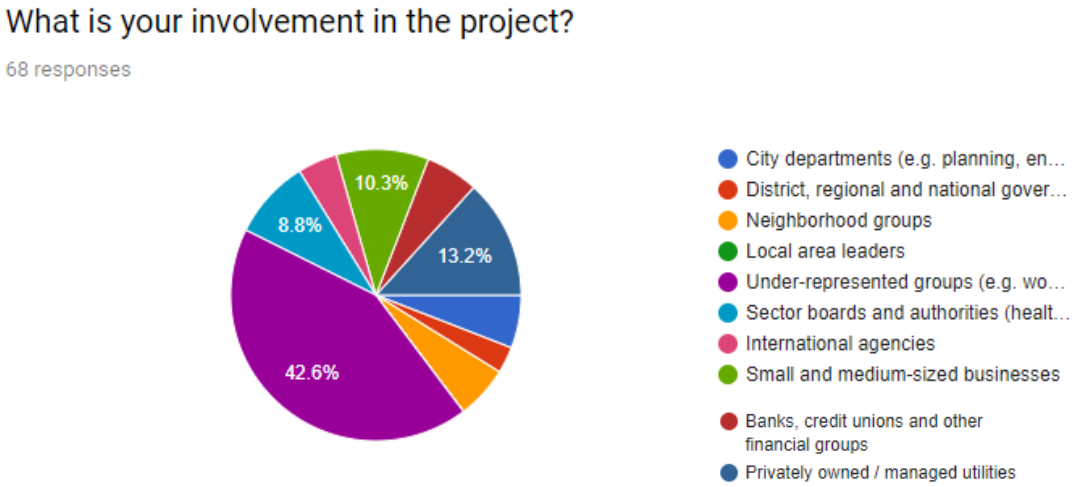


Figure 89 Percentage of Stakeholders Survey Responses, the case of Alexandria. Source: Author

Almost half of the interviewees belong to the underrepresented groups and individuals. Others are distributed between city departments, government and authorities, community based groups, International agencies, enterprises, financial entities and privately owned entities.

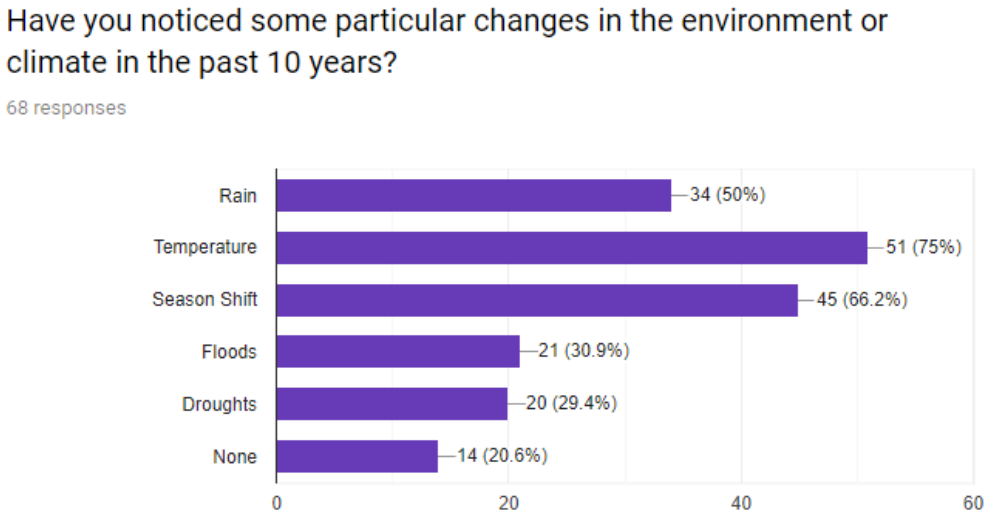


Figure 90 Climate Change Awareness Survey Responses, the case of Alexandria. Source: Author

80% of the interviewees noticed changes in the climate over the past years. The majority agreed upon temperature changes, rain pattern changes and shifts in seasons.

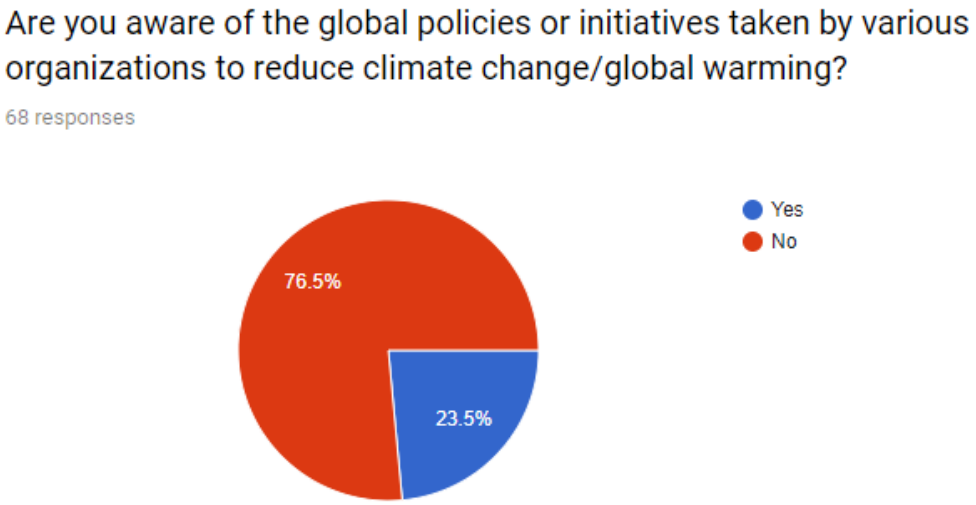


Figure 91 Global Policies Awareness Survey Responses, the case of Alexandria. Source: Author

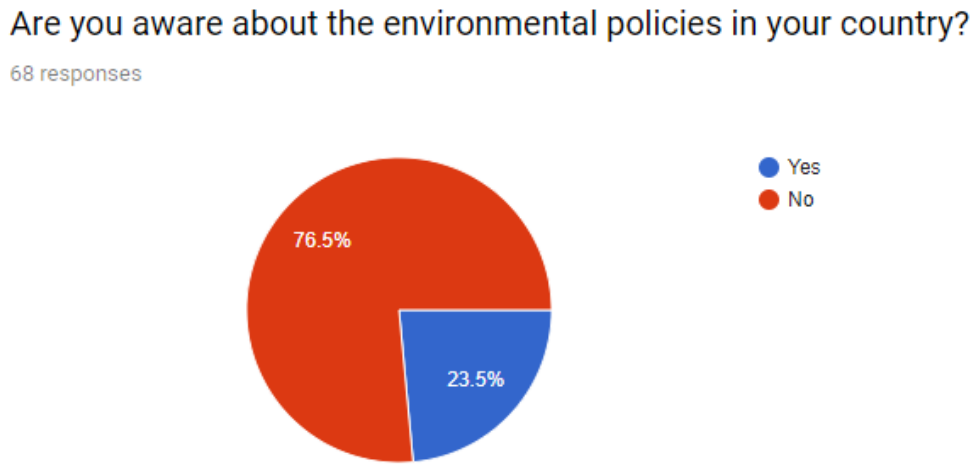


Figure 92 National Policies Awareness Survey Responses, the case of Alexandria. Source: Author

The majority of responses agreed on being aware of some policies on the global scale and the national scale as well. This is reflected probably due to the percentage of higher educated interviewees.

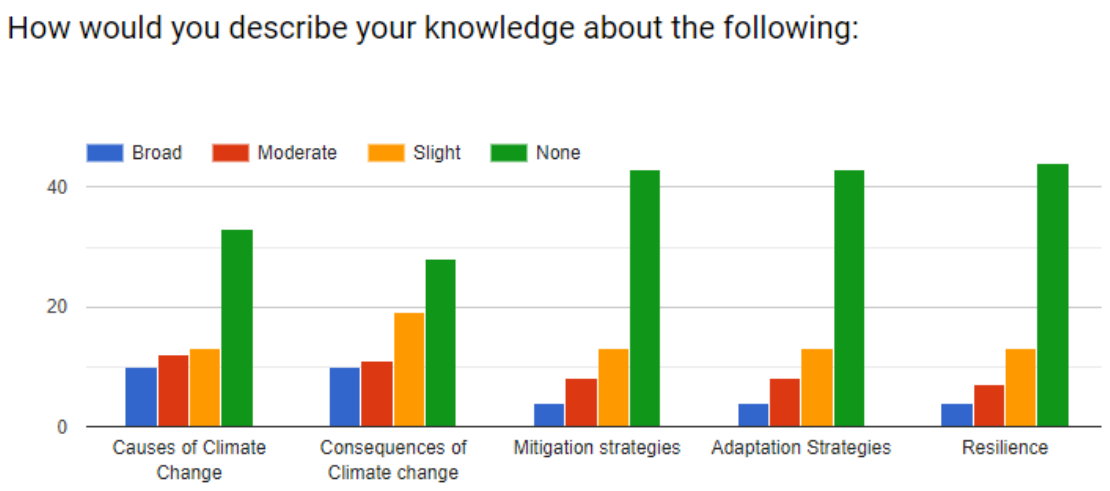


Figure 93 Climate Change Knowledge Survey Responses, the case of Alexandria. Source: Author

Most of respondents have no information about climate change details other that some of the causes and consequences. However Mitigation strategies, Adaptation strategies and resilience are not common terminologies that the interviewees know of.

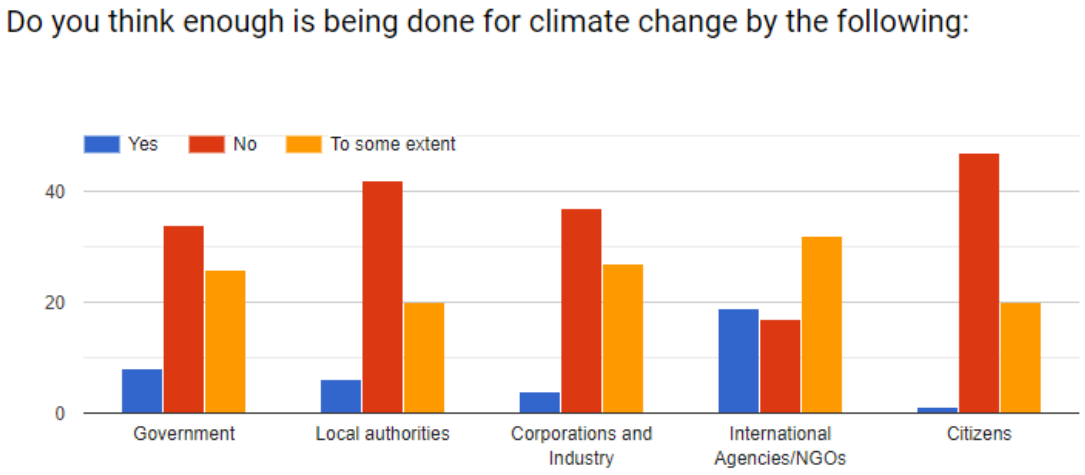


Figure 94 Climate Change Stakeholders Action Survey Responses, the case of Alexandria. Source: Author

The interviewees believe that international agencies and NGOs are the most active parties in facing the changing climate. Most of them agreed that citizens are the least active and local authorities as well.

The last section of the survey was concerned with the opinion of the stakeholders about the proposed options and their aptitude to face climate change. The average score for each measure is then calculated by taking the mean value of the opinions of stakeholders by adding the values entered and dividing it by the number of participants. The data collected from the survey is then inserted in the "Options_File" under the worksheet screening options. The

input is chosen from a drop down list on a scale of (10, 20, 30, 40, and 50) based on the level of agreement in the questionnaire. The total scoring is then automatically calculated by adding all previous cells for each measure which are: Relative effectiveness, Economic feasibility, Ease of implementation, Mainstreaming potential, Urgency of implementation, Multi objective, and Stakeholder Acceptability.

8.3.4.2 Ranking Measures

Data from the "Options_File" is linked to the "Proposal_File" through worksheets screening options and ranking measures. In the ranking measures sheet the measures with the highest two scores are highlighted in each sector automatically to serve as the base for the final proposals.

		Score
Water	Biogas Energy Production	17.41176471
	Heat Recovery from Wastewater	17.35294118
	Secondary Wastewater Products	15.11764706
	Rainwater harvesting	16.16176471
	Water re-use	17.17647059
	Water storage and conservation techniques	18.17647059
	Water-use and irrigation efficiency	18.13117647
	energy-efficient pumping systems	16.30882353
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	13.13117647
	Hydropower generation	13.57352941
	system monitoring and automation.	18.27941176
	Desalination plants	10.5
	National water policies	**13.11764706**
	Integrated water resources management	**13.13235294**
	Water-related hazards management	**11.17647059**
Infrastructure/ settlement	hazard specific control activities such as flood levees or bushfire mitigation strategies	16.63235294
	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	14.76470588
	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	16.5
	Strengthening of overhead transmission and distribution infrastructure	15.11764706
	Underground cabling for utilities	16.05882353

Figure 95 Ranking Measures, the case of Alexandria, Source: Author

8.3.4.3 Proposed Measures

The worksheet proposed measures is directly linked to the ranking measures worksheet, where highlighted measures are automatically copied in this worksheet presenting the highest ranked proposals for each sector.

Table 33 Proposed Measures, the case of Alexandria. Source: Author

Sector	Measure
Water	Water storage and conservation techniques Water-use and irrigation efficiency System monitoring and automation.
Infrastructure/ settlement	Monitoring and controlling systems avoid developments and community infrastructure in areas prone to hazards Insurance
Human health	Access to water Heat-health action plans Emergency medical services
Tourism	Diversification of tourism attractions and revenues conservation of natural areas Linkages with other sectors)
Energy	Energy efficiency Use of renewable sources Combined heat and power
Buildings	Integrated Renewables in buildings avoid developments and community infrastructure in areas prone to hazards Off grid and storage during emergency
Forestry	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.

	pest and disease management; Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen
Agriculture	Urban and peri-urban agriculture Dedicated energy crops to replace fossil fuel use Multi-functional farming
Waste	Waste incineration with energy recovery Landfill CH_4 recovery Bio covers and bio filters to optimize CH_4 oxidation
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage Modal shifts from road transport to rail and public transport systems Non-motorized transport (cycling, walking)
Industry	Heat and power recovery Off grid and storage during emergency Voluntary agreements

Subsequently to the listing of different proposals in the previous table, a link was made through GIS to the maps of Alexandria that were presented previously. The maps on GIS highlighted the most vulnerable areas and the proposals were linked manually to their interrelated neighborhood. The proposals were linked based on the type of activity or land-use of the neighborhood in the attribute table and the expected damages and impacts that might occur due to the foreseen changes in the climate. The aim of this mapping in figure 96 is to provide a spatial underpinning to the proposed measures and solutions, and to highlight the most opportune proposals for each neighborhood.

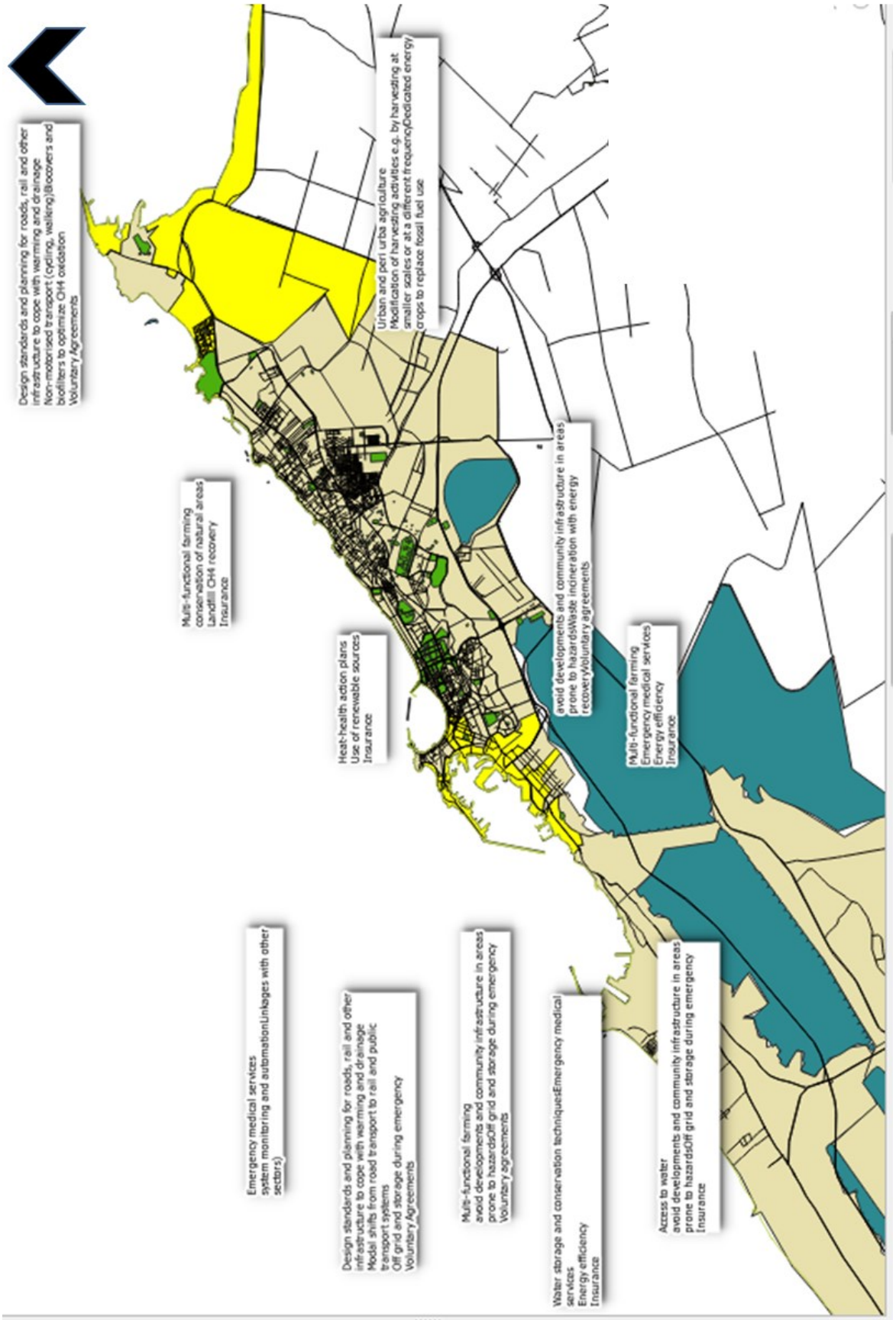


Figure 96 Mapping proposed measures for the city of Alexandria. Source: Author

8.3.4.4 Viability of Proposals

The final worksheet is the viability of proposals. In this worksheet the final proposed measures are listed for all sectors impacted by climate change hazards chosen in the first analysis worksheets. Next to each measure is the achievability of this measure, showing the impact of putting it to action, the assumed cost range, the responsible entity for implementation, the scale of application and the timeframe needed for the action.

The options are categorized according to the strategies listed previously in this study which are: Green Infrastructure, Sustainable land use practices, sustainable mobility, Energy Conservation and Efficiency, Regenerative and Renewable Energy, Carbon Zero, Carbon Positive and Smart Grid and Policies & institutional arrangements.

Table 34 Viability of Proposals, the case of Alexandria. Source: Author

Strategy	Sector	Measure	Relative effectiveness	Economic feasibility	Ease of implementation	Mainstreaming potential	Urgency of implementation
Green Infrastructure	Water	Water storage and conservation techniques	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		Water-use and irrigation efficiency	adaptation	low cost	Public participattion / Individuals	Plot	Mid term
	Human Health	Access to water	Synergy	medium cost	Governmental	Neighborhood	Mid term
	Agriculture	Urban and peri urba agriculture	adaptation	low cost	Public participattion / Individuals	Neighborhood	Mid term
		Multi-functional farming	Synergy	low cost	Public participattion / Individuals	Neighborhood	Short term
	Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	adaptation	medium cost	Governmental	National plan	Mid term
Sustainable land use practices	Infrastructure/ Settlement	avoid developments and community infrastructure in areas prone to hazards	Synergy	low cost	Governmental	City wide	Short term
	Human Health	Heat-health action plans	Synergy	medium cost	Governmental	Neighborhood	Mid term
		Emergency medical services	Mitigation	medium cost	Governmental	Neighborhood	Short term
	Tourism	Diversification of tourism attractions and revenues	Synergy	medium cost	Enterprise /Civil	City wide	Mid term
		conservation of natural areas	adaptation	low cost	Governmental	National plan	Short term
	Buildings	avoid developments and community infrastructure in areas prone to hazards	Synergy	low cost	Governmental	City wide	Short term
	Forestry	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		pest and disease management;	adaptation	low cost	Public participattion / Individuals	Plot	Short term
		Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen	adaptation	low cost	Public participattion / Individuals	Plot	Short term

Table 35 Cont. Viability of Proposals, the case of Alexandria. Source: Author

Sustainable mobility	Transport	Modal shifts from road transport to rail and public transport systems	Synergy	medium cost	Public participation / Individuals	Neighborhood	Short term
		Non-motorised transport (cycling, walking)	Synergy	low cost	Public participation / Individuals	Neighborhood	Short term
Energy Conservation and Efficiency	Energy	Energy efficiency	Mitigation	medium cost	Public participation / Individuals	Plot	Short term
		Combined heat and power	Synergy	medium cost	Enterprise /Civil	Plot	Mid term
Regenerative and Renewable Energy	Energy	Use of renewable sources	Synergy	high cost	Enterprise /Civil	Plot	Short term
	Buildings	Integrated Renewbles in buildings	Synergy	medium cost	Enterprise /Civil	Plot	Short term
		Off grid and storage during emergency	Synergy	medium cost	Enterprise /Civil	Plot	Mid term
	Agriculture	Dedicated energy crops to replace fossil fuel use	Synergy	medium cost	Public participation / Individuals	Neighborhood	Mid term
	Waste	Waste incineration with energy recovery	Mitigation	medium cost	Enterprise /Civil	City wide	Mid term
	Industry	Heat and power recovery	Synergy	medium cost	Enterprise /Civil	Plot	Mid term
		Off grid and storage during emergency	Synergy	high cost	Enterprise /Civil	Plot	Mid term
Carbon Zero, Carbon Positive and Smart Grid	Water	system monitoring and automation.	Synergy	high cost	Enterprise /Civil	Neighborhood	Long term
	Infrastructure/ Settlement	Monitoring and controlling systems	Synergy	high cost	Governmental	Neighborhood	Long term
	Waste	Landfill CH4 recovery	Synergy	medium cost	Enterprise /Civil	City wide	Mid term
		Biocovers and biofilters to optimize CH4 oxidation	Synergy	medium cost	Enterprise /Civil	City wide	Mid term
Policies & institutional arrangements	Infrastructure/ Settlement	Insurance	adaptation	medium cost	Enterprise /Civil	Plot	Short term
	Tourism	Linkages with other sectors)	Synergy	low cost	Governmental	National plan	Long term
	Industry	Voluntary agreements	Synergy	low cost	Enterprise /Civil	Plot	Short term

Green Infrastructure measures proposed are Water storage and conservation techniques, Water-use and irrigation efficiency, Access to water, Urban and peri-urban agriculture, Multi-functional farming and Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage. Sustainable land use policies measures are to avoid developments and community infrastructure in areas prone to hazards, Heat-health action plans, Emergency medical services, Diversification of tourism attractions and revenues, conservation of natural areas, Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency, pest and disease management; Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen. Sustainable mobility measures include Modal shifts from road transport to rail and public transport systems and Non-motorized transport (cycling, walking). Energy conservation measures include Energy efficiency in all sectors and combined heat and power. Regenerative and Renewable energy measures include Use of renewable sources, Integrated Renewables in buildings, off grid and storage during emergency, dedicated energy crops to replace fossil fuel use, Waste incineration with energy recovery and Heat and power recovery. Carbon zero, carbon positive and smart grid strategies include system automation, Monitoring and controlling systems, Landfill CH_4 recovery, Bio covers and bio filters to optimize CH_4 oxidation. Policies and institutional arrangements include Insurance, Linkages with other sectors and Voluntary agreements.

8.3.4.5 Magnitudes of Proposals

The proposed options if applied will have a considerable influence on the vulnerability of the environment, the economy and the people of the North Mediterranean Coast in Egypt and specifically the city of Alexandria as demonstrated in figure 97.

10% of the proposed options will help in mitigating the changes and reduce the expected sea level rise, increasing temperature and decreasing precipitation. 30% of the proposals will work on increasing the adaptive capacity to be able to adapt to the inevitable changes that will definitely occur no matter what. 60% of the proposals will act as a common ground for both mitigation and adaptation by providing synergies that will make the city more resilient.

40% of the proposals are considered low cost, 50% are medium cost and 10% are high cost. 30% of the proposed measures should be implemented by the government, 40% could implemented by enterprises or civil society organizations, while 30% could be implemented by individuals as public participation. The proposals vary in scale of implementation from national plan to single plot size; 10% national initiatives, 20% citywide proposals, 30% neighborhood proposals and 40% could be applied to single buildings and single land plots. Finally concerning the timeframe, 50% of the proposals are short term and could be applied right away with direct impacts, 40% midterm and 10% are long term options.

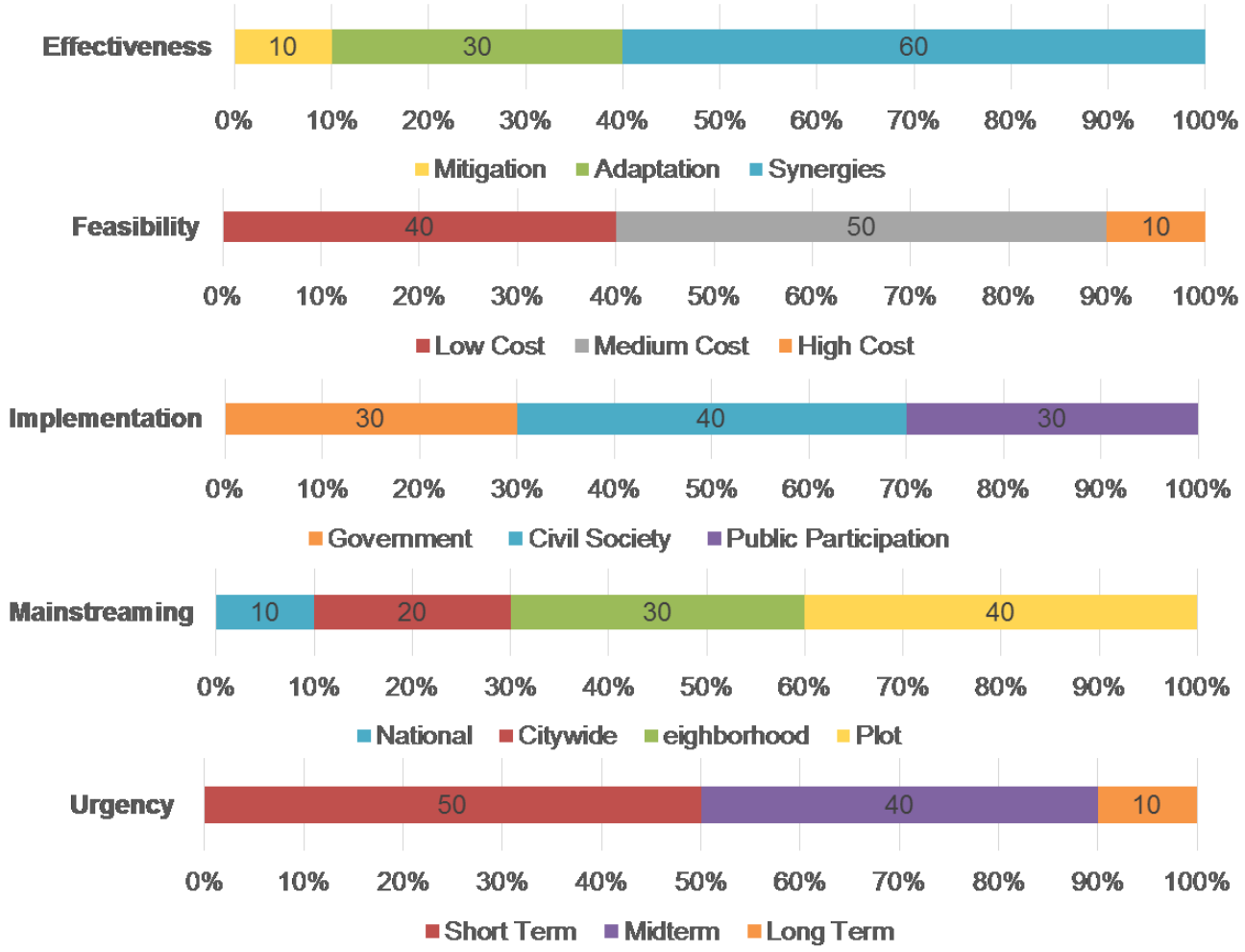


Figure 97 Magnitude of proposals. Source: Author

The proposed ARM'D City proposals are a set of recommended strategies that could help create a model for an Adaptive, Resilient and Mitigated development of the city. A city that is armed with all required approaches to have resilient communities and institutions, robust systems, adaptive planning capacity, flexible, resources oriented and integrated.

9 Results

9.1 Conclusion

The climate change is inevitable however there are many actions that could be done to mitigate this change and improve the vulnerability index. The impacts of climate change will not differentiate between the countries who caused the most damage or least, it will affect all countries regardless of their development level.

The long discussed dichotomy of mitigation and adaptation strategies must come to an end and focus on possible synergies should commence. By emphasizing on synergies the resilience index would increase for the people, places, environment and institutions. Synergies between the mitigation and adaptation strategies are mostly concerned with two dominant segments which are the spatial segment and the energy segment. Both segments are an integral part of all sectors and have the upmost influence. Strategies that are all-encompassing to mitigation, adaptation and resilience are Green Infrastructure, Sustainable land use practices, sustainable mobility, Energy Conservation and Efficiency, Regenerative and Renewable Energy, Carbon Zero, Carbon Positive and Smart Grid and Policies & institutional arrangements.

The ARM'D City is the epitome of resilient cities. It merges the qualities of resilience along with mitigation and adaptation features to create an inclusive model. The ARM'D City model is a replicable model that could be applied all over the MENA region by changing the variables. By adopting this model integrating climate change into the planning process will be facilitated. Decision makers could have a clear understanding of the expected impacts due to climate hazards. The model also provides a set of tools to act against this change and gives the chance to compare and asses each of them based on technical and socioeconomic feasibility.

After analyzing the vulnerability of Egypt to the changing climate the most exposed region was the Northern Mediterranean Coast. Sea level rise, increasing temperature and decreasing precipitation are the major climate hazards that will hit the coastal shore of Egypt. This will have a tremendous impact on the built environment, agriculture lands and economy of the region which will be reflected on Egypt as a whole. It is obvious that taking action to mitigate and adapt to the climate change is mandatory.

By applying the ARM'D City model to the city of Alexandria, it was shown that there are several measures that could be implemented not only by the government but by the public themselves, however the survey showed that more awareness raising is needed in order to inform the local residents and decision makers as well about the threat imposed by climate change. Linking the resultant model to a GIS platform helped in connecting the spatial data to the findings of the tool and the survey results, and mapping the alternative scenarios.

In summary, opportunities and prospects offered by the ARM'D City tool, introduce a novel way of thinking in which focus is shifted towards co-relating different dimensions at the urban scale. Applying parametric approaches resulted in the creation of a tool that is applied on the scale of a city, focusing on chosen urban parameters and climate parameters only for simplification, as the main aim is illustrating the reciprocal impact of various urban data on changing climate. The tool proves that the parametric approach to urbanism could assist in generating alternatives for the mitigation, adaptation and resilience strategies and asses them which could facilitate reaching a more responsive and resilient city able to withstand the changing climate.

Benefits of climate resilient cities that are presented in figure 98 appear in different categories: health and well-being improvements, industrial productivity, infrastructure and buildings responsiveness, agriculture yields, stimulating innovation and investment in renewable and regenerative energy, safeguarding forests, accelerating low-carbon development in the world's cities and making long term investments in the low carbon economy.

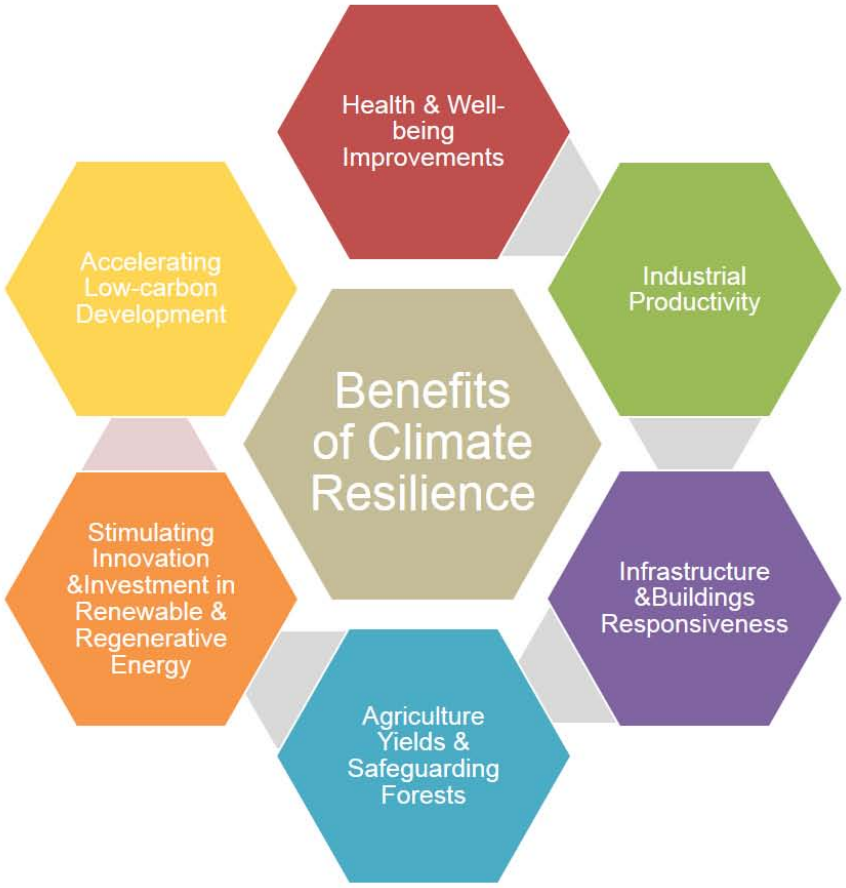


Figure 98 Benefits of Climate Resilience. Source: Author

9.2 Further implications

This research aimed at producing a guideline for planning for a changing climate as well as creating a simplified tool co-relating the reciprocal impact between spatial, energy and climate parameters. By changing the input parameters and adding more urban parameters into the tool excel tool, a more extensive model which takes into consideration all involved parameters and all complex relations could be generated. The major possible drawbacks of this trend could be categorized the technicalities, which lies in the difficulty of updating the database and adding state of the art strategies to the inventory.

The focus is on the digitally generated systems regarding city patterns and not only its connection with climatic aspects but also with economic aspects. By establishing a set of basic principles and equations through digital mediums, the result is a city capable of responding to the influence of relational fields between these forces, creating not a static form of urban planning, but rather an adaptive form.

Possible fields of research that could be integrated based on this research's findings which are explained in figure 99, could be focusing on the detailed relation between each climate hazard and the detailed reciprocal impact between urban, people and economy. Also creating a more detailed database with specific measures would allow for a more comprehensive approach.

Linking the resultant model to a GIS platform with more detailed mapping and attribute tables is another further step that should be studied. This will provide endless possibilities for analysis and scenario generation. When connecting the spatial data to the findings of the tool and the survey results, mapping the scenarios is possible. This GIS link would give the opportunity to visualize the impacts of climate change without taking further action as well the impacts of applying the proposed tools on different cities and regions, this will give a clear comparative analysis and value proposition to the ARM'D City tool.

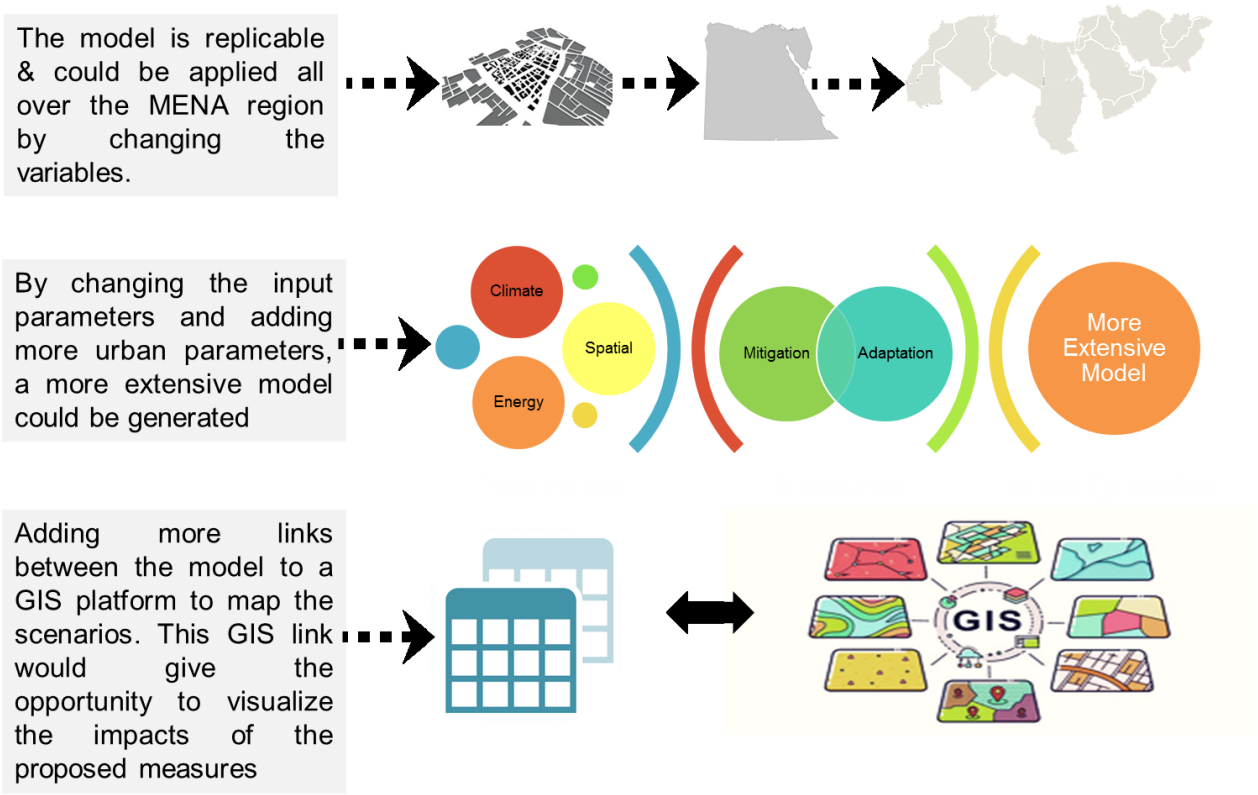


Figure 99 Further implications of the research. Source: Author

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11 Annexes

11.1 Annex 1: Measures Inventory

Table 36 Mitigation and Adaptation Sectoral Measures Inventory. Source: Author based on UN Habitat, 2014

	Adaptation		**Mitigation**
Water	Expanded rainwater harvesting		energy-efficient pumping systems
	Water storage and conservation techniques		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft
	Water re-use		System monitoring and automation.
	Desalination		Biogas Energy Production
	Water-use and irrigation efficiency		Heat Recovery from Wastewater
			Hydropower generation
			Secondary Wastewater Products
Agriculture	Adjustment of planting dates and crop variety		Improved crop and grazing land management to increase soil carbon storage
	Crop relocation		Restoration of cultivated peaty soils and degraded lands
	Improved land management e.g. erosion control and soil protection through tree planting		Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions
	Urban and peri-urban agriculture		Improved nitrogen fertilizer application techniques to reduce N_2O emissions
			Dedicated energy crops to replace fossil fuel use
			Improved energy efficiency
			Improvements of crop yields
Infrastructure/settlement (including coastal zones)	Relocation		hazard specific control activities such as flood levees or bushfire mitigation strategies
	Seawalls and storm surge barriers		design improvements to infrastructure or services
	Dune reinforcement		land use planning and design decisions that avoid developments and community infrastructure in areas prone to hazards
	Land acquisition and creation of wetlands as buffer against sea level rise and flooding		community awareness campaigns to increase knowledge of how to prepare for disaster events
	Protection of existing natural barriers		community education programs to build knowledge of the appropriate actions to prepare for and respond to a disaster event
			capital works such as levee bank construction to reduce the impacts of flooding
			resilience activities including partnership building and engagement between sectors
			Annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).

Human health	Heat-health action plans		Access to water, sanitation
	Emergency medical services		Knowledge about hygiene
	Improved climate-sensitive disease surveillance and control		Vector-borne disease control
	Safe water and improved sanitation		Knowledge about vector borne diseases
Tourism	Diversification of tourism attractions and revenues		conservation of natural areas
	Shifting ski slopes to higher altitudes and glaciers		Establish environmental management systems (EMS)
	Artificial snow-making		Support low-carbon holiday options and carbon labelling
			Avoid promoting long-haul destinations
Transport	Realignment/relocation		More fuel-efficient vehicles
	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage		Hybrid vehicles
			Cleaner diesel vehicles
			Biofuels
			Modal shifts from road transport to rail and public transport systems
			Non-motorized transport (cycling, walking)
			Land-use and transport planning
			Higher efficiency aircraft
Energy	Strengthening of overhead transmission and distribution infrastructure		Improved supply and distribution efficiency
	Underground cabling for utilities		Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy);
	Energy efficiency		Combined heat and power
	Use of renewable sources		Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas);
	Reduced dependence on single sources of energy		*CCS for gas*
			Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics
Buildings	Climate proofing of new buildings		Efficient lighting and daylighting
	climate proofing of old buildings		More efficient electrical appliances and heating and cooling devices
	Development of early warning systems		Improved cook stoves, improved insulation
	Passive and active solar design for		Passive and active solar design for heating

	heating and cooling		and cooling
	Integrated renewables in buildings		Alternative refrigeration fluids, recovery and recycling of fluorinated gases
	Off grid and storage during emergency		Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;
			Solar photovoltaics integrated in buildings
Industry	Insurance plans		More efficient end-use electrical equipment
	Share losses with public funds		Heat and power recovery
	change in operating practices		Material recycling and substitution
	Development of early warning systems		Control of non-CO_2 gas emissions
	Off grid and storage during emergency		Process-specific technologies
			Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture;
			Inert electrodes for aluminum manufacture
Forestry/ forests	Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;		Afforestation
	▪ Seeding and planting e.g. selecting and introducing better adapted reproductive material.		Reforestation
	Modification of frequency and intensity of tending and thinning practices.		Forest management
	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.		Reduced deforestation
	Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen		Harvested wood product management
	pest and disease management;		Use of forestry products for bioenergy to replace fossil fuel use
	forest fire protection		Tree species improvement to increase biomass productivity and carbon sequestration
	Reduction of the forest fragmentation		Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change

Waste	Technological solutions to decrease odor and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.		Landfill CH_4 recovery
	Recycling, reuse & waste minimization		Waste incineration with energy recovery
	Controlled landfilling		Composting of organic waste
	Wastewater control and treatment		Controlled wastewater treatment
			Recycling and waste minimization
			Bio covers and bio filters to optimize CH_4 oxidation

11.2 Annex 2: Climate Hazards Sectoral Measures Inventory

Table 37Climate Hazards Sectoral Measures Inventory. Source: Author

Climate Change Hazard	Water	Infrastructure/ settlement	Human health	Tourism	Energy	Buildings	Forestry	Agriculture	Waste	Transport	Industry
Increasing Temperature	Biogas Energy Production	hazard specific control activities such as flood levees or bushfire mitigation strategies	Access to water	Diversification of tourism attractions and revenues	Strengthening of overhead transmission and distribution infrastructure	Green walls	Seeding and planting e.g. selecting and introducing better adapted reproductive material.	farm to market sustainable transportation modes	Controlled wastewater treatment	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More efficient end-use electrical equipment
	Heat Recovery from Wastewater	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Heat-health action plans	Shifting ski slopes to higher altitudes and glaciers	Underground cabling for utilities	Green roofs	Afforestation	Urban and peri urba agriculture	Waste incineration with energy recovery	More fuel-efficient vehicles	Advanced energy efficiency
	Secondary Wastewater Products	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Emergency medical services	conservation of natural areas	Energy efficiency	Mixed use developments	Reforestation	Improved energy efficiency of equipment	Landfill CH_4 recovery	Hybrid vehicles	Heat and power recovery
	system monitoring and automation.	Strengthening of overhead transmission and distribution infrastructure	Food security plans	Artificial snow-making	Use of renewable sources	Walkable neighborhoods	Reduced deforestation	Dedicated energy crops to replace fossil fuel use	Biocovers and biofilters to optimize CH_4 oxidation	Cleaner diesel vehicles	Off grid and storage during emergency
	Water-related hazards management	Underground cabling for utilities			Fuel switching	Efficient lighting and daylighting	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions		Biofuels	
	National water policies	Centralized renewable sources infrastructure			Reduced dependence on single sources of energy	More efficient electrical appliances and heating and cooling devices	Modification of frequency and intensity of tending and thinning practices.	Improved nitrogen fertiliser application techniques to reduce N_2O emissions		Modal shifts from road transport to rail and public transport systems	
	Integrated water resources management	Monitoring and controlling systems			Combined heat and power	Improved cook stoves, improved insulation	Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen			Non-motorised transport (cycling, walking)	
					Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Passive and active solar design for heating and cooling	pest and disease management;			Higher efficiency aircraft	
					Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	pest and disease management;				
					Carbon Capture and Storage CCS	Climate proofing of new buildings	forest fire protection				
					Carbon Capture and Reuse CCR	climate proofing of old buildings	Reduction of the forest fragmentation				
					Carbon Capture and Utilization CCU	Alternative refrigeration fluids, recovery and recycling of fluorinated gases	Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change				
					Carbon Offsets	Solar photovoltaics integrated in buildings	Tree species improvement to increase biomass productivity and carbon sequestration				
					Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas	Integrated Renewbles in buildings	Use of forestry products for bioenergy to replace fossil fuel use				
						Feed in energy supply to grid					
						Rooftop Advertismenet usage for renewable devices					

Decreasing Temperature	Biogas Energy Production		Emergency medical services		Strengthening of overhead transmission and distribution infrastructure	Mixed use developments	Seeding and planting e.g. selecting and introducing better adapted reproductive material.	farm to market sustainable transportation modes	Controlled wastewater treatment		Heat and power recovery
	Secondary Wastewater Products		Food security plans		Underground cabling for utilities	Walkable neighborhoods	Afforestation	Urban and peri urba agriculture	Waste incineration with energy recovery		Off grid and storage during emergency
	system monitoring and automation.		Access to water		Energy efficiency	Efficient lighting and daylighting	Reforestation	Improved energy efficiency of equipment	Landfill CH_4 recovery		
	Heat Recovery from Wastewater				Use of renewable sources	More efficient electrical appliances and heating and cooling devices	Reduced deforestation	Dedicated energy crops to replace fossil fuel use	Biocovers and biofilters to optimize CH_4 oxidation		
	National water policies				Fuel switching	Improved cook stoves, improved insulation	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions			
	Integrated water resources management				Reduced dependence on single sources of energy	Passive and active solar design for heating and cooling	Modification of frequency and intensity of tending and thinning practices.	Improved nitrogen fertiliser application techniques to reduce N_2O emissions			
	Water-related hazards management				Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen				
					Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Climate proofing of new buildings	pest and disease management;				
					Carbon Capture and Storage CCS	climate proofing of old buildings	pest and disease management;				
					Carbon Capture and Reuse CCR	Alternative refrigeration fluids, recovery and recycling of fluorinated gases	Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change				
					Carbon Capture and Utilization CCU	Solar photovoltaics integrated in buildings	Tree species improvement to increase biomass productivity and carbon sequestration				
					Carbon Offsets	Integrated Renewbles in buildings	Use of forestry products for bioenergy to replace fossil fuel use				
					Combined heat and power	Feed in energy supply to grid					
						Rooftop Advertismenet usage for renewable devices					

Increasing precipitation	Rainwater harvesting	Land acquisition and creation of wetlands as buffer against sea level rise and flooding			Energy efficiency	avoid developments and community infrastructure in areas prone to hazards	Seeding and planting e.g. selecting and introducing better adapted reproductive material.	Urban and peri urba agriculture		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Off grid and storage during emergency
	system monitoring and automation.	Protection of existing natural barriers			Fuel switching	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	Afforestation	Crop relocation			
	Water-use and irrigation efficiency	hazard specific control activities such as flood levees or bushfire mitigation strategies			Reduced dependence on single sources of energy	Climate proofing of new buildings	Reforestation				
	Biogas Energy Production	avoid developments and community infrastructure in areas prone to hazards			Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	climate proofing of old buildings	Reduced deforestation				
	National water policies	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage			Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Integrated Renewbles in buildings	Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.				
	Integrated water resources management	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).			Carbon Capture and Storage CCS	Off grid and storage during emergency	Modification of frequency and intensity of tending and thinning practices.				
	Water-related hazards management	Monitoring and controlling systems			Carbon Capture and Reuse CCR	Development of early warning systems	Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen pest and disease management;				
		Underground cabling for utilities			Carbon Capture and Utilization CCU						
					Carbon Offsets		Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change				

							change					
	Rainwater harvesting				Energy efficiency		Seeding and planting e.g. selecting and introducing better adapted reproductive material.	Multi-functional farming	Controlled wastewater treatment		Off grid and storage during emergency	
	Water re-use				Fuel switching		Afforestation	Urban and peri urba agriculture				
	Water storage and conservation techniques				Reduced dependence on single sources of energy		Reforestation	Crop relocation				
	Water-use and irrigation efficiency				Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)		Reduced deforestation	Restoration of cultivated peaty soils and degraded lands				
	energy-efficient pumping systems				Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics		Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	Improved crop and grazing land management to increase soil carbon storage				
Decreasing precipitation	system monitoring and automation.				Carbon Capture and Storage CCS		Modification of frequency and intensity of tending and thinning practices.	Improvements of crop yields				
	reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft				Carbon Capture and Reuse CCR		Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen					
	National water policies				Carbon Capture and Utilization CCU		pest and disease management;					
	Integrated water resources management				Carbon Offsets		pest and disease management;					
	Water-related hazards management						Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use					

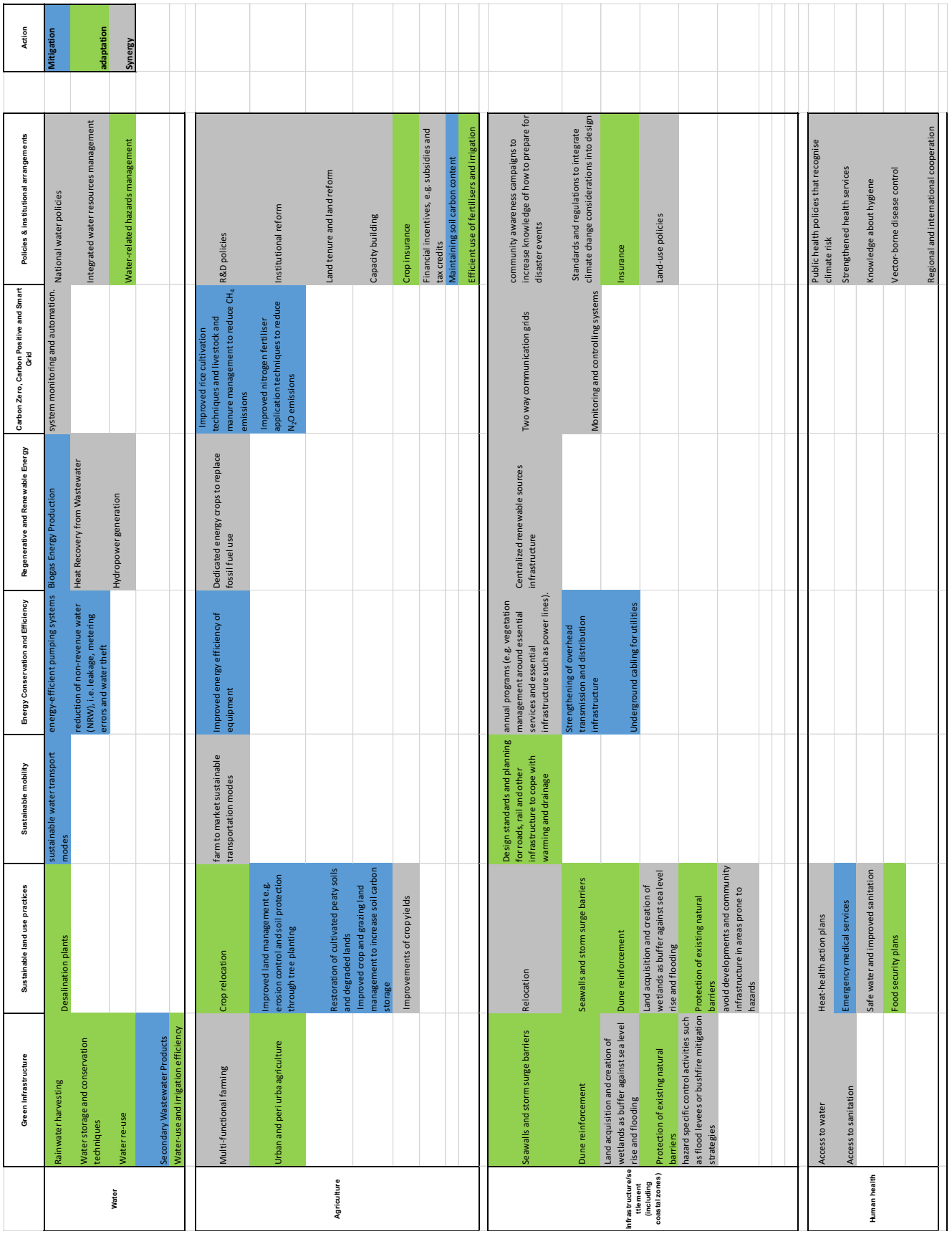
	Hydropower generation	Seawalls and storm surge barriers			Energy efficiency	avoid developments and community infrastructure in areas prone to hazards		Crop relocation		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Off grid and storage during emergency
	system monitoring and automation.	Dune reinforcement			Fuel switching	Climate proofing of new buildings		Improved land management e.g. erosion control and soil protection through tree planting		Realignment/relocation	
	Desalination plants	Land acquisition and creation of wetlands as buffer against sea level rise and flooding			Reduced dependence on single sources of energy	climate proofing of old buildings					
	National water policies	Protection of existing natural barriers			Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Off grid and storage during emergency					
	Integrated water resources management	hazard specific control activities such as flood levees or bushfire mitigation strategies			Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Development of early warning systems					
	Water-related hazards management	avoid developments and community infrastructure in areas prone to hazards			Carbon Capture and Storage CCS						
		Monitoring and controlling systems			Carbon Capture and Reuse CCR						
		Relocation			Carbon Capture and Utilization CCU						
Rising sea level					Carbon Offsets						
Severe storms		Seawalls and storm surge barriers	Access to water	conservation of natural areas	Improved supply and distribution efficiency	avoid developments and community infrastructure in areas prone to hazards				Realignment/relocation	Off grid and storage during emergency
		Protection of existing natural barriers	Access to sanitation	Establish environmental management systems (EMS)	Two way communication grids	Climate proofing of new buildings				Land-use and transport planning	Development of early warning systems
		Relocation	Emergency medical services		Monitoring and controlling systems	climate proofing of old buildings					
		avoid developments and community infrastructure in areas prone to hazards	Safe water and improved sanitation			Off grid and storage during emergency					
		Two way communication grids	Food security plans			Development of early warning systems					
		Dune reinforcement									
		Monitoring and controlling systems									
Dispersion of particulate matter,intensify the formation of near-surface ozone	sustainable water transport modes		Vector-borne disease control	Support low-carbon holiday options and carbon labelling	Carbon Capture and Storage CCS	Walkable neighborhoods			Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Modal shifts from road transport to rail and public transport systems	Location close to main roads to decrease emissions
			Knowledge about hygiene	Avoid promoting long-haul destinations	Carbon Capture and Reuse CCR				Controlled landfilling	Non-motorised transport (cycling, walking)	Industry to market sustainable transportation modes
					Carbon Capture and Utilization CCU				Recycling and waste minimization	Higher efficiency aircraft	Control of non-CO_2 gas emissions
					Carbon Offsets						CCS for cement, ammonia, and iron manufacture
											Material recycling and

Affect lifecycle							Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;	Restoration of cultivated peaty soils and degraded lands	Composting of organic waste		
							Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.	Improved crop and grazing land management to increase soil carbon storage			
							Modification of frequency and intensity of tending and thinning practices.	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions			
							Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen pest and disease management;	Improved nitrogen fertiliser application techniques to reduce N_2O emissions			

Policies	National water policies	community awareness campaigns to increase knowledge of how to prepare for disaster events	Public health policies that recognise climate risk	Integrated planning (e.g. carrying capacity	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources	Standards and regulations to integrate climate change considerations into design	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests	R&D policies	Financial incentives for improved waste and wastewater management	Integrating climate change considerations into national transport policy	Provision of benchmark information; performance standards; subsidies; tax credits
	Integrated water resources management	Standards and regulations to integrate climate change considerations into design	Regional and international cooperation	Linkages with other sectors)	Incorporating climate change in design standards	Land-use policies	Land-use regulation and enforcement	Institutional reform	Renewable energy incentives or obligations	Investment in R&D for special situations, e.g. permafrost areas	Tradable permits
	Water-related hazards management	Land-use policies		Financial incentives, e.g. subsidies and tax credits	Reduction of fossil fuel subsidies	Building codes		Land tenure and land reform	Waste management regulations	Mandatory fuel economy; biofuel blending and CO_2 standards for road transport	Insurance plans
		Insurance			Taxes or carbon charges on fossil fuels	Insurance		Capacity building		Taxes on vehicle purchase, registration, use and motor fuels;	Share losses with public funds
					Feed-in tariffs for renewable energy technologies	Appliance standards and labelling		Crop insurance		Road and parking pricing	change in operating practices
					Renewable energy obligations; producer subsidies	Building codes and certification		Financial incentives, e.g. subsidies and tax credits		Influence mobility needs through land-use regulations and infrastructure planning	Voluntary agreements
						Demand-side management programmes		Financial incentives and regulations for improved land management		Investment in attractive public transport facilities and non-motorised	
						Public sector leadership programmes, including procurement		Maintaining soil carbon content			
						Incentives for energy service companies (ESCOs)		Efficient use of fertilisers and irrigation			

11.3 Annex 3: Options Synergies

Table 38 Options synergies. Source: Author



Tourism		Diversification of tourism attractions and revenues				Support low-carbon holiday options and carbon labelling	Integrated planning (e.g. carrying capacity
		Shifting ski slopes to higher altitudes and glaciers				Avoid promoting long-haul destinations	Linkages with other sectors)
		conservation of natural areas					Establish environmental management systems (EMS)
		Artificial snow-making					Financial incentives, e.g. subsidies and tax credits
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Realignment/relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Hybrid vehicles		Integrating climate change considerations into national transport policy
		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Non-motorized transport (cycling, walking)	Cleaner diesel vehicles		Investment in R&D for special situations, e.g. permafrost areas
		Land-use and transport planning	Hybrid vehicles	Higher efficiency aircraft	Biofuels		Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
			Cleaner diesel vehicles				Taxes on vehicle purchase, registration, use and motor fuels; Road and parking pricing
			Biofuels				
			Modal shifts from road transport to rail and public transport systems				Influence mobility needs through land-use regulations and infrastructure planning
			Non-motorised transport (cycling, walking)				Investment in attractive public transport facilities and non-motorised
Energy	Strengthening of overhead transmission and distribution infrastructure	Strengthening of overhead transmission and distribution infrastructure	Energy efficiency	Strengthening of overhead transmission and distribution infrastructure	Use of renewable supply sources	Carbon Capture and Storage CCS	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
	Underground cabling for utilities		Use of renewable sources	Underground cabling for utilities	Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Carbon Capture and Reuse CCR	Incorporating climate change in design standards
			Fuel switching	Energy efficiency	Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Carbon Capture and Utilization CCU	Reduction of fossil fuel subsidies
				Reduced dependence on single sources of energy		Carbon Offsets	Taxes or carbon charges on fossil fuels
				Combined heat and power		Two way communication grids	Feed-in tariffs for renewable energy technologies
				Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas		Monitoring and controlling systems	Renewable energy obligations; producer subsidies
				Improved supply and distribution efficiency			
Industry		Location close to main roads to decrease emissions	Industry to market sustainable transportation modes	More efficient end-use electrical equipment	Heat and power recovery	CCS for cement, ammonia, and iron manufacture	Provision of benchmark information; performance standards; subsidies; tax credits
				Control of non-CO_2 gas emissions	Material recycling and substitution	Development of early warning systems	Tradable permits
				Advanced energy efficiency	Off grid and storage during emergency		Insurance plans
							Share losses with public funds
							change in operating practices
							Voluntary agreements

Forestry/ forests	Seeding and planting e.g. selecting and introducing better adapted reproductive material.	Afforestation			Tree species improvement to increase biomass productivity and carbon sequestration	Tree species improvement to increase biomass productivity and carbon sequestration	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests
	Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;	Reforestation			Use of forestry products for bioenergy to replace fossil fuel use		Land-use regulation and enforcement
		Reduced deforestation					
		Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.					
		Modification of frequency and intensity of tending and thinning practices.					
		Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen					
		pest and disease management;					
		forest fire protection					
		Reduction of the forest fragmentation					
		Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change					
Waste	Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Controlled wastewater treatment		Recycling and waste minimization	Waste incineration with energy recovery	Landfill CH_4 recovery	Financial incentives for improved waste and wastewater management
		Controlled landfilling			Composting of organic waste	Biocovers and biofilters to optimize CH_4 oxidation	Renewable energy incentives or obligations
							Waste management regulations
Buildings	Green walls	avoid developments and community infrastructure in areas prone to hazards	Walkable neighborhoods	Efficient lighting and daylighting	Passive and active solar design for heating and cooling	Feed in energy supply to grid	Standards and regulations to integrate climate change considerations into design
	Green roofs	Mixed use developments		More efficient electrical appliances and heating and cooling devices	Alternative refrigeration fluids, recovery and recycling of fluorinated gases	Development of early warning systems	Land-use policies
				Improved cook stoves, improved insulation	Solar photovoltaics integrated in buildings		Building codes
				Passive and active solar design for heating and cooling	Passive and active solar design for heating and cooling		Insurance
				Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	Integrated Renewbles in buildings		Appliance standards and labelling
				Climate proofing of new buildings	Off grid and storage during emergency		Building codes and certification
				climate proofing of old buildings	Rooftop Advertismenet usage for renewable devices		Demand-side management programmes
							Public sector leadership programmes, including procurement
							Incentives for energy service companies (ESCOs)

11.4 Annex 4: Options Feasibility

Table 39 Options Feasibility. Source: Author

	Green Infrastructure	Sustainable land use practices	Sustainable mobility	Energy Conservation and Efficiency	Regenerative and Renewable Energy	Carbon Zero, Carbon Positive and Smart Grid	Policies & institutional arrangements	Feasibility
Water	Rainwater harvesting	Rainwater harvesting	sustainable water transport modes	energy-efficient pumping systems	Biogas Energy Production	system monitoring and automation.	National water policies	high cost
	Water storage and conservation techniques	Desalination plants		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Heat Recovery from Wastewater		Integrated water resources management	medium cost
	Water re-use				Hydropower generation		Water-related hazards management	low cost
	Secondary Wastewater Products							
	Water-use and irrigation efficiency							
Agriculture	Multi-functional farming	Crop relocation	farm to market sustainable transportation modes	Improved energy efficiency of equipment	Dedicated energy crops to replace fossil fuel use	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions	R&D policies	
	Urban and peri urba agriculture	Improved land management e.g. erosion control and soil protection through tree planting				Improved nitrogen fertiliser application techniques to reduce N_2O emissions	Institutional reform	
		Restoration of cultivated peaty soils and degraded lands					Land tenure and land reform	
		Improved crop and grazing land management to increase soil carbon storage					Capacity building	
		Improvements of crop yields					Crop insurance	
							Financial incentives, e.g. subsidies and tax credits	
							Maintaining soil carbon content	
							Efficient use of fertilisers and irrigation	
Infrastructure/settlement (including coastal zones)	Seawalls and storm surge barriers	Relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Centralized renewable sources infrastructure	Two way communication grids	community awareness campaigns to increase knowledge of how to prepare for disaster events	
	Dune reinforcement	Seawalls and storm surge barriers		Strengthening of overhead transmission and distribution infrastructure		Monitoring and controlling systems	Standards and regulations to integrate climate change considerations into design	
	Land acquisition and creation of wetlands as buffer against sea level rise and flooding	Dune reinforcement		Underground cabling for utilities			Land-use policies	
	Protection of existing natural barriers	Land acquisition and creation of wetlands as buffer against sea level rise and flooding					Insurance	
	hazard specific control activities such as flood levees or bushfire mitigation strategies	Protection of existing natural barriers						
		avoid developments and community infrastructure in areas prone to hazards						
Human health	Access to water	Heat-health action plans					Public health policies that recognise climate risk	
	Access to sanitation	Emergency medical services					Strengthened health services	
		Safe water and improved sanitation					Knowledge about hygiene	
		Food security plans					Vector-borne disease control	
							Regional and international cooperation	

							Regional and international cooperation
Tourism		Diversification of tourism attractions and revenues				Support low-carbon holiday options and carbon labelling	Integrated planning (e.g. carrying capacity
		Shifting ski slopes to higher altitudes and glaciers				Avoid promoting long-haul destinations	Linkages with other sectors)
		conservation of natural areas					Establish environmental management systems (EMS)
		Artificial snow-making					Financial incentives, e.g. subsidies and tax credits
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Realignment/relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Hybrid vehicles		Integrating climate change considerations into national transport policy
		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Non-motorized transport (cycling, walking)	Cleaner diesel vehicles		Investment in R&D for special situations, e.g. permafrost areas
		Land-use and transport planning	Hybrid vehicles	Higher efficiency aircraft	Biofuels		Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
			Cleaner diesel vehicles				Taxes on vehicle purchase, registration, use and motor fuels;
			Biofuels				Road and parking pricing
			Modal shifts from road transport to rail and public transport systems				Influence mobility needs through land-use regulations and infrastructure planning
			Non-motorised transport (cycling, walking)				Investment in attractive public transport facilities and non-motorised
Energy	Strengthening of overhead transmission and distribution infrastructure	Strengthening of overhead transmission and distribution infrastructure	Energy efficiency	Strengthening of overhead transmission and distribution infrastructure	Use of renewable supply sources	Carbon Capture and Storage CCS	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
	Underground cabling for utilities		Use of renewable sources	Underground cabling for utilities	Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Carbon Capture and Reuse CCR	Incorporating climate change in design standards
			Fuel switching	Energy efficiency	Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Carbon Capture and Utilization CCU	Reduction of fossil fuel subsidies
				Reduced dependence on single sources of energy		Carbon Offsets	Taxes or carbon charges on fossil fuels
				Combined heat and power		Two way communication grids	Feed-in tariffs for renewable energy technologies
				Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas		Monitoring and controlling systems	Renewable energy obligations; producer subsidies
				Improved supply and distribution efficiency			
Industry		Location close to main roads to decrease emissions	Industry to market sustainable transportation modes	More efficient end-use electrical equipment	Heat and power recovery	CCS for cement, ammonia, and iron manufacture	Provision of benchmark information; performance standards; subsidies; tax credits
				Control of non-CO_2 gas emissions	Material recycling and substitution	Development of early warning systems	Tradable permits
				Advanced energy efficiency	Off grid and storage during emergency		Insurance plans
							Share losses with public funds
							change in operating practices
							Voluntary agreements

Forestry/ forests		Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen					
		pest and disease management;					
		forest fire protection					
		Reduction of the forest fragmentation					
		Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change					
Waste	Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Controlled wastewater treatment		Recycling and waste minimization	Waste incineration with energy recovery	Landfill CH_4 recovery	Financial incentives for improved waste and wastewater management
		Controlled landfilling			Composting of organic waste	Biocovers and biofilters to optimize CH_4 oxidation	Renewable energy incentives or obligations
							Waste management regulations
Buildings	Green walls	avoid developments and community infrastructure in areas prone to hazards	Walkable neighborhoods	Efficient lighting and daylighting	Passive and active solar design for heating and cooling	Feed in energy supply to grid	Standards and regulations to integrate climate change considerations into design
	Green roofs	Mixed use developments		More efficient electrical appliances and heating and cooling devices	Alternative refrigeration fluids, recovery and recycling of fluorinated gases	Development of early warning systems	Land-use policies
				Improved cook stoves, improved insulation	Solar photovoltaics integrated in buildings		Building codes
				Passive and active solar design for heating and cooling	Passive and active solar design for heating and cooling		Insurance
				Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	Integrated Renewbles in buildings		Appliance standards and labelling
				Climate proofing of new buildings	Off grid and storage during emergency		Building certification
				climate proofing of old buildings	Rooftop Advertismenet usage for renewable devices		Demand-side management programmes
							Public sector leadership programmes, including procurement
							Incentives for energy service companies (ESCOs)

11.5 Annex 5: Options Applicability

Table 40 Options Applicability. Source: Author

	Green Infrastructure	Sustainable land use practices	Sustainable mobility	Energy Conservation and Efficiency	Regenerative and Renewable Energy	Carbon Zero, Carbon Positive and Smart Grid	Policies & institutional arrangements
Water	Rainwater harvesting	Rainwater harvesting	sustainable water transport modes	energy-efficient pumping systems	Biogas Energy Production	system monitoring and automation.	National water policies
	Water storage and conservation techniques	Desalination plants		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Heat Recovery from Wastewater		Integrated water resources management
	Water re-use				Hydropower generation		Water-related hazards management
	Secondary Wastewater Products						
	Water-use and irrigation efficiency						
Agriculture	Multi-functional farming	Crop relocation	farm to market sustainable transportation modes	Improved energy efficiency of equipment	Dedicated energy crops to replace fossil fuel use	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions	R&D policies
	Urban and peri urba agriculture	Improved land management e.g. erosion control and soil protection through tree planting				Improved nitrogen fertiliser application techniques to reduce N_2O emissions	Institutional reform
		Restoration of cultivated peaty soils and degraded lands					Land tenure and land reform
		Improved crop and grazing land management to increase soil carbon storage					Capacity building
		Improvements of crop yields					Crop insurance
							Financial incentives, e.g. subsidies and tax credits
							Maintaining soil carbon content
							Efficient use of fertilisers and irrigation
Infrastructure/settlement (including coastal zones)	Seawalls and storm surge barriers	Relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Centralized renewable sources infrastructure	Two way communication grids	community awareness campaigns to increase knowledge of how to prepare for disaster events
	Dune reinforcement	Seawalls and storm surge barriers		Strengthening of overhead transmission and distribution infrastructure		Monitoring and controlling systems	Standards and regulations to integrate climate change considerations into design
	Land acquisition and creation of wetlands as buffer against sea level rise and flooding	Dune reinforcement		Underground cabling for utilities			Land-use policies
	Protection of existing natural barriers	Land acquisition and creation of wetlands as buffer against sea level rise and flooding					Insurance
	hazard specific control activities such as flood levees or bushfire mitigation strategies	Protection of existing natural barriers					
		avoid developments and community infrastructure in areas prone to hazards					
Human health	Access to water	Heat-health action plans					Public health policies that recognise climate risk
	Access to sanitation	Emergency medical services					Strengthened health services
		Safe water and improved sanitation					Knowledge about hygiene
		Food security plans					Vector-borne disease control
							Regional and international cooperation

Capacity
Governmental
Enterprise /Civil
Public participattion / Individuals

Tourism		Diversification of tourism attractions and revenues				Support low-carbon holiday options and carbon labelling	Integrated planning (e.g. carrying capacity
		Shifting ski slopes to higher altitudes and glaciers				Avoid promoting long-haul destinations	Linkages with other sectors)
		conservation of natural areas					Establish environmental management systems (EMS)
		Artificial snow-making					Financial incentives, e.g. subsidies and tax credits
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Realignment/relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Hybrid vehicles		Integrating climate change considerations into national transport policy
		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Non-motorized transport (cycling, walking)	Cleaner diesel vehicles		Investment in R&D for special situations, e.g. permafrost areas
		Land-use and transport planning	Hybrid vehicles	Higher efficiency aircraft	Biofuels		Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
			Cleaner diesel vehicles				Taxes on vehicle purchase, registration, use and motor fuels;
			Biofuels				Road and parking pricing
			Modal shifts from road transport to rail and public transport systems				Influence mobility needs through land-use regulations and infrastructure planning
			Non-motorised transport (cycling, walking)				Investment in attractive public transport facilities and non-motorised
Energy	Strengthening of overhead transmission and distribution infrastructure	Strengthening of overhead transmission and distribution infrastructure	Energy efficiency	Strengthening of overhead transmission and distribution infrastructure	Use of renewable supply sources	Carbon Capture and Storage CCS	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
	Underground cabling for utilities		Use of renewable sources	Underground cabling for utilities	Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Carbon Capture and Reuse CCR	Incorporating climate change in design standards
			Fuel switching	Energy efficiency	Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Carbon Capture and Utilization CCU	Reduction of fossil fuel subsidies
				Reduced dependence on single sources of energy		Carbon Offsets	Taxes or carbon charges on fossil fuels
				Combined heat and power		Two way communication grids	Feed-in tariffs for renewable energy technologies
				Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas		Monitoring and controlling systems	Renewable energy obligations; producer subsidies
				Improved supply and distribution efficiency			
Industry		Location close to main roads to decrease emissions	Industry to market sustainable transportation modes	More efficient end-use electrical equipment	Heat and power recovery	CCS for cement, ammonia, and iron manufacture	Provision of benchmark information; performance standards; subsidies; tax credits
				Control of non-CO_2 gas emissions	Material recycling and substitution	Development of early warning systems	Tradable permits
				Advanced energy efficiency	Off grid and storage during emergency		Insurance plans
							Share losses with public funds
							change in operating practices
							Voluntary agreements

Forestry/ forests	▪ Seeding and planting e.g. selecting and introducing better adapted reproductive material. Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;	Afforestation			Tree species improvement to increase biomass productivity and carbon sequestration	Tree species improvement to increase biomass productivity and carbon sequestration	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests
		Reforestation			Use of forestry products for bioenergy to replace fossil fuel use		Land-use regulation and enforcement
		Reduced deforestation					
		Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency.					
		Modification of frequency and intensity of tending and thinning practices.					
		Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen					
		pest and disease management;					
		forest fire protection					
		Reduction of the forest fragmentation					
		Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change					
Waste	Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Controlled wastewater treatment		Recycling and waste minimization	Waste incineration with energy recovery	Landfill CH_4 recovery	Financial incentives for improved waste and wastewater management
		Controlled landfilling			Composting of organic waste	Biocovers and biofilters to optimize CH_4 oxidation	Renewable energy incentives or obligations
							Waste management regulations
Buildings	Green walls	avoid developments and community infrastructure in areas prone to hazards	Walkable neighborhoods	Efficient lighting and daylighting	Passive and active solar design for heating and cooling	Feed in energy supply to grid	Standards and regulations to integrate climate change considerations into design
	Green roofs	Mixed use developments		More efficient electrical appliances and heating and cooling devices	Alternative refrigeration fluids, recovery and recycling of fluorinated gases	Development of early warning systems	Land-use policies
				Improved cook stoves, improved insulation	Solar photovoltaics integrated in buildings		Building codes
				Passive and active solar design for heating and cooling	Passive and active solar design for heating and cooling		Insurance
				Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control;	Integrated Renewbles in buildings		Appliance standards and labelling
				Climate proofing of new buildings	Off grid and storage during emergency		Building certification
				climate proofing of old buildings	Rooftop Advertismenet usage for renewable devices		Demand-side management programmes
							Public sector leadership programmes, including procurement
							Incentives for energy service companies (ESCOs)

11.6 Annex 6: Options Scale

Table 41 Options Scale. Source: Author

	Green Infrastructure	Sustainable land use practices	Sustainable mobility	Energy Conservation and Efficiency	Regenerative and Renewable Energy	Carbon Zero, Carbon Positive and Smart Grid	Policies & institutional arrangements
Water	Rainwater harvesting	Rainwater harvesting	sustainable water transport modes	energy-efficient pumping systems	Biogas Energy Production	system monitoring and automation.	National water policies
	Water storage and conservation techniques	Desalination plants		reduction of non-revenue water (NRW), i.e. leakage, metering errors and water theft	Heat Recovery from Wastewater		Integrated water resources management
	Water re-use				Hydropower generation		Water-related hazards management
	Secondary Wastewater Products						
	Water-use and irrigation efficiency						
Agriculture	Multi-functional farming	Crop relocation	farm to market sustainable transportation modes	Improved energy efficiency of equipment	Dedicated energy crops to replace fossil fuel use	Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions	R&D policies
	Urban and peri urba agriculture	Improved land management e.g. erosion control and soil protection through tree planting				Improved nitrogen fertiliser application techniques to reduce N_2O emissions	Institutional reform
		Restoration of cultivated peaty soils and degraded lands					Land tenure and land reform
		Improved crop and grazing land management to increase soil carbon storage					Capacity building
		Improvements of crop yields					Crop insurance
							Financial incentives, e.g. subsidies and tax credits
							Financial incentives and regulations for improved land management
							Maintaining soil carbon content
							Efficient use of fertilisers and irrigation
Infrastructure/settlement (including coastal zones)	Seawalls and storm surge barriers	Relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	annual programs (e.g. vegetation management around essential services and essential infrastructure such as power lines).	Centralized renewable sources infrastructure	Two way communication grids	community awareness campaigns to increase knowledge of how to prepare for disaster events
	Dune reinforcement	Seawalls and storm surge barriers		Strengthening of overhead transmission and distribution infrastructure		Monitoring and controlling systems	Standards and regulations to integrate climate change considerations into design
	Land acquisition and creation of wetlands as buffer against sea level rise and flooding	Dune reinforcement		Underground cabling for utilities			Land-use policies
	Protection of existing natural barriers	Land acquisition and creation of wetlands as buffer against sea level rise and flooding					Insurance
	hazard specific control activities such as flood levees or bushfire mitigation strategies	Protection of existing natural barriers					
		avoid developments and community infrastructure in areas prone to hazards					
Human health	Access to water	Heat-health action plans					Public health policies that recognise climate risk
	Access to sanitation	Emergency medical services					Strengthened health services
		Safe water and improved sanitation					Knowledge about hygiene
		Food security plans					Vector-borne disease control
							Regional and international cooperation

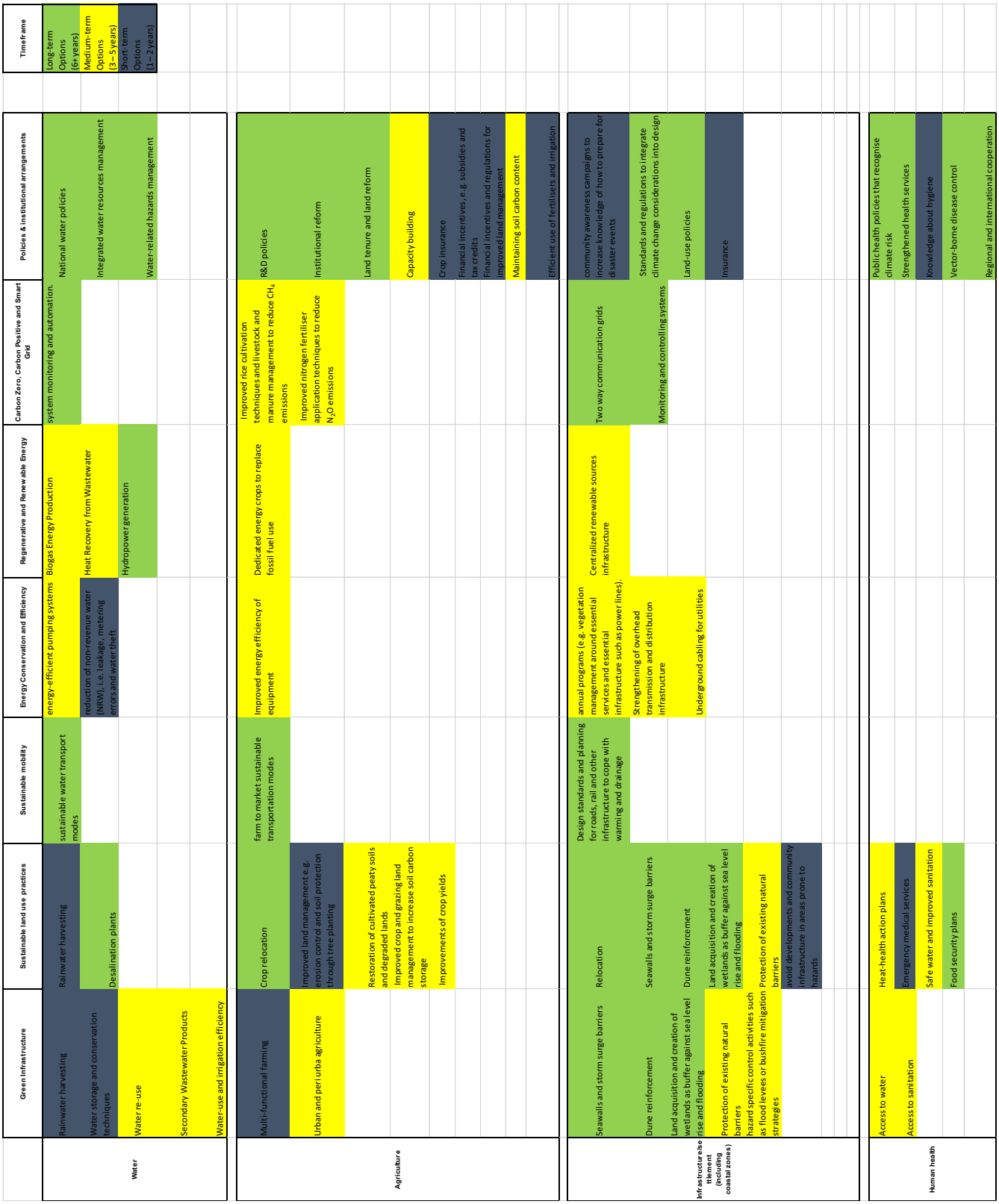
Scale
National plan
City wide
Neighborhood
Plot

Tourism		Diversification of tourism attractions and revenues				Support low-carbon holiday options and carbon labelling	Integrated planning (e.g. carrying capacity
		Shifting ski slopes to higher altitudes and glaciers				Avoid promoting long-haul destinations	Linkages with other sectors)
		conservation of natural areas					Establish environmental management systems (EMS)
		Artificial snow-making					Financial incentives, e.g. subsidies and tax credits
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Realignment/relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Hybrid vehicles		Integrating climate change considerations into national transport policy
		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Non-motorized transport (cycling, walking)	Cleaner diesel vehicles		Investment in R&D for special situations, e.g. permafrost areas
		Land-use and transport planning	Hybrid vehicles	Higher efficiency aircraft	Biofuels		Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
			Cleaner diesel vehicles				Taxes on vehicle purchase, registration, use and motor fuels;
			Biofuels				Road and parking pricing
			Modal shifts from road transport to rail and public transport systems				Influence mobility needs through land-use regulations and infrastructure planning
			Non-motorised transport (cycling, walking)				Investment in attractive public transport facilities and non-motorised
Energy	Strengthening of overhead transmission and distribution infrastructure	Strengthening of overhead transmission and distribution infrastructure	Energy efficiency	Strengthening of overhead transmission and distribution infrastructure	Use of renewable supply sources	Carbon Capture and Storage CCS	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
	Underground cabling for utilities		Use of renewable sources	Underground cabling for utilities	Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Carbon Capture and Reuse CCR	Incorporating climate change in design standards
			Fuel switching	Energy efficiency	Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Carbon Capture and Utilization CCU	Reduction of fossil fuel subsidies
				Reduced dependence on single sources of energy		Carbon Offsets	Taxes or carbon charges on fossil fuels
				Combined heat and power		Two way communication grids	Feed-in tariffs for renewable energy technologies
				Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas		Monitoring and controlling systems	Renewable energy obligations; producer subsidies
				Improved supply and distribution efficiency			
Industry		Location close to main roads to decrease emissions	Industry to market sustainable transportation modes	More efficient end-use electrical equipment	Heat and power recovery	CCS for cement, ammonia, and iron manufacture	Provision of benchmark information; performance standards; subsidies; tax credits
				Control of non-CO_2 gas emissions	Material recycling and substitution	Development of early warning systems	Tradable permits
				Advanced energy efficiency	Off grid and storage during emergency		Insurance plans
							Share losses with public funds
							change in operating practices
							Voluntary agreements

Forestry/ forests	Seeding and planting e.g. selecting and introducing better adapted reproductive material. Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;	Afforestation Reforestation Reduced deforestation Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency. Modification of frequency and intensity of tending and thinning practices. Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen pest and disease management; forest fire protection Reduction of the forest fragmentation Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change			Tree species improvement to increase biomass productivity and carbon sequestration Use of forestry products for bioenergy to replace fossil fuel use	Tree species improvement to increase biomass productivity and carbon sequestration	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests Land-use regulation and enforcement
Waste	Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Controlled wastewater treatment Controlled landfilling		Recycling and waste minimization	Waste incineration with energy recovery Composting of organic waste	Landfill CH_4 recovery Biocovers and biofilters to optimize CH_4 oxidation	Financial incentives for improved waste and wastewater management Renewable energy incentives or obligations Waste management regulations
Buildings	Green walls Green roofs	avoid developments and community infrastructure in areas prone to hazards Mixed use developments	Walkable neighborhoods	Efficient lighting and daylighting More efficient electrical appliances and heating and cooling devices Improved cook stoves, improved insulation Passive and active solar design for heating and cooling Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; Climate proofing of new buildings climate proofing of old buildings	Passive and active solar design for heating and cooling Alternative refrigeration fluids, recovery and recycling of fluorinated gases Solar photovoltaics integrated in buildings Passive and active solar design for heating and cooling Integrated Renewbles in buildings Off grid and storage during emergency Rooftop Advertismenet usage for renewable devices	Feed in energy supply to grid Development of early warning systems	Standards and regulations to integrate climate change considerations into design Land-use policies Building codes Insurance Appliance standards and labelling Building codes and certification Demand-side management programmes Public sector leadership programmes, including procurement Incentives for energy service companies (ESCOs)

11.7 Annex 7: Options Timeframe

Table 42 Options Timeframe. Source: Author



Tourism		Diversification of tourism attractions and revenues				Support low-carbon holiday options and carbon labelling	Integrated planning (e.g. carrying capacity
		Shifting ski slopes to higher altitudes and glaciers				Avoid promoting long-haul destinations	Linkages with other sectors)
		conservation of natural areas					Establish environmental management systems (EMS)
		Artificial snow-making					Financial incentives, e.g. subsidies and tax credits
Transport	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Realignment/relocation	Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Hybrid vehicles		Integrating climate change considerations into national transport policy
		Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	More fuel-efficient vehicles	Non-motorized transport (cycling, walking)	Cleaner diesel vehicles		Investment in R&D for special situations, e.g. permafrost areas
		Land-use and transport planning	Hybrid vehicles	Higher efficiency aircraft	Biofuels		Mandatory fuel economy; biofuel blending and CO_2 standards for road transport
			Cleaner diesel vehicles				Taxes on vehicle purchase, registration, use and motor fuels;
			Biofuels				Road and parking pricing
			Modal shifts from road transport to rail and public transport systems				Influence mobility needs through land-use regulations and infrastructure planning
			Non-motorised transport (cycling, walking)				Investment in attractive public transport facilities and non-motorised
Energy	Strengthening of overhead transmission and distribution infrastructure	Strengthening of overhead transmission and distribution infrastructure	Energy efficiency	Strengthening of overhead transmission and distribution infrastructure	Use of renewable supply sources	Carbon Capture and Storage CCS	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources
	Underground cabling for utilities		Use of renewable sources	Underground cabling for utilities	Fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy)	Carbon Capture and Reuse CCR	Incorporating climate change in design standards
			Fuel switching	Energy efficiency	Advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics	Carbon Capture and Utilization CCU	Reduction of fossil fuel subsidies
				Reduced dependence on single sources of energy		Carbon Offsets	Taxes or carbon charges on fossil fuels
				Combined heat and power		Two way communication grids	Feed-in tariffs for renewable energy technologies
				Early applications of carbon dioxide capture and storage (CCS) (e.g. storage of removed CO_2 from natural gas		Monitoring and controlling systems	Renewable energy obligations; producer subsidies
				Improved supply and distribution efficiency			
Industry		Location close to main roads to decrease emissions	Industry to market sustainable transportation modes	More efficient end-use electrical equipment	Heat and power recovery	CCS for cement, ammonia, and iron manufacture	Provision of benchmark information; performance standards; subsidies; tax credits
				Control of non-CO_2 gas emissions	Material recycling and substitution	Development of early warning systems	Tradable permits
				Advanced energy efficiency	Off grid and storage during emergency		Insurance plans
							Share losses with public funds
							change in operating practices
							Voluntary agreements

Forestry/ forests	Seeding and planting e.g. selecting and introducing better adapted reproductive material. Natural regeneration: for example, by increasing diversity, maintaining population size, or by maintaining reproductive potential and fecundity;	Afforestation Reforestation Reduced deforestation Modification of harvesting activities e.g. by harvesting at smaller scales or at a different frequency. Modification of frequency and intensity of tending and thinning practices. Reducing the rotation length as a preventive measure in stands with high disturbance risks to allow an adaptation to faster growth associated with higher temperatures in cool environments and with high inputs of atmospheric nitrogen pest and disease management; forest fire protection Reduction of the forest fragmentation Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change			Tree species improvement to increase biomass productivity and carbon sequestration Use of forestry products for bioenergy to replace fossil fuel use	Tree species improvement to increase biomass productivity and carbon sequestration	Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests Land-use regulation and enforcement		
Waste	Technological solutions to decrease odour and dust from waste sites. Similarly, there is scope for improved methods for controlling pests and vermin, and also for detecting fires in waste.	Controlled wastewater treatment Controlled landfilling		Recycling and waste minimization	Waste incineration with energy recovery Composting of organic waste	Landfill CH_4 recovery Biocovers and biofilters to optimize CH_4 oxidation	Financial incentives for improved waste and wastewater management Renewable energy incentives or obligations Waste management regulations		
Buildings	Green walls Green roofs	avoid developments and community infrastructure in areas prone to hazards Mixed use developments	Walkable neighborhoods	Efficient lighting and daylighting More efficient electrical appliances and heating and cooling devices Improved cook stoves, improved insulation Passive and active solar design for heating and cooling Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; Climate proofing of new buildings climate proofing of old buildings	Passive and active solar design for heating and cooling Alternative refrigeration fluids, recovery and recycling of fluorinated gases Solar photovoltaics integrated in buildings Passive and active solar design for heating and cooling Integrated Renewbles in buildings Off grid and storage during emergency Rooftop Advertismenet usage for renewable devices	Feed in energy supply to grid Development of early warning systems	Standards and regulations to integrate climate change considerations into design Land-use policies Building codes Insurance Appliance standards and labelling Building codes and certification Demand-side management programmes Public sector leadership programmes, including procurement Incentives for energy service companies (ESCOs)		