



Rapid and Systematic Climate Change Impacts, Vulnerability and Adaptation Assessment for Abu Dhabi, UAE and Arabian Peninsula

Table 1: Summary of core sub-project activities of the climate change work programme

Strategic theme	Spatial Scale			Total sub-projects
	Abu Dhabi (local)	UAE (national)	Arabian Gulf (regional)	
Regional climate change	---	---	<ul style="list-style-type: none"> • Atmospheric modeling • Arabian Gulf modeling 	2
Environment	---	---	<ul style="list-style-type: none"> • Terrestrial biodiversity • Marine biodiversity 	2
Water resources	<ul style="list-style-type: none"> • Al Ain water resources 	<ul style="list-style-type: none"> • Water resource management 	<ul style="list-style-type: none"> • Transboundary groundwater 	3
Coastal zones	---	<ul style="list-style-type: none"> • Coastal vulnerability index 	<ul style="list-style-type: none"> • Sea level rise 	2
Socioeconomic systems	<ul style="list-style-type: none"> • Public health benefits of GHG mitigation 	<ul style="list-style-type: none"> • Food security 	<ul style="list-style-type: none"> • Desalinated water supply 	3
Total sub-projects	2	3	7	12

I. Concept briefs

Taken together, the Phase II climate change research programme provides an operational framework for a rapid and systematic assessment of climate change at the emirate/nation/region scales. The work is driven by AGEDI's vision for a more sustainable future founded on informed decisions, based on access to environmental and societal data by all those who need it. Informed by a 5-stage stakeholder consultative process involving nearly 100 stakeholders, the scope of the programme encompasses twelve (12) highly integrated sub-projects, organized around five (5) thematic areas, across three (3) spatial scales. An overview of the programme is provided in Table 1. The rest of this section provides a brief discussion of the salient details of each sub-project.

Regional climate change

The first two sub-projects are concerned with regional climate change modeling. One sub-project is focused on the atmosphere; the other sub-project is focused on Arabian Gulf waters. Undertaking these particular sub-projects at the outset of the overall Phase II Climate Change Programme is important because they are foundational to many of the other sub-projects. Specifically, the outputs of the two regional climatic change modeling efforts provide important inputs for eight (8) other sub-projects in the overall Programme.

Sub-project #1 is focused in regional climatic modeling of the atmosphere. It will help explain how climate change is expected to unfold in the Arabian Peninsula. Currently, the Arabian Peninsula region is lacking an assessment of how regional climate will be affected by increasing concentrations of greenhouse gases in the atmosphere. The current understanding of climate change for the region is based on the outputs of coarse-resolution atmosphere-ocean general circulation models that do not provide a representative description of *regional* climate change. Regional climate modeling is able to represent climate on a smaller scale by accounting for local topography, land use, coastlines, and vegetation characteristics and are able to project changes in temperature, precipitation, humidity, and wind patterns for the Arabian Peninsula region itself. Given the availability of improved methods for regional climatic modeling and the greater availability and quality of regional meteorological data, the tools and data necessary to perform first-pass regional climate modeling in the Arabian Peninsula are now in place. Key aspects of the sub-project are described in the bullets below.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps for policymakers as well as user-friendly datasets for follow-up research by the regional scientific community. In addition, supporting information will be provided in the form of a comprehensive technical report.

Sub-project #2 is focused on regional climatic modeling of the oceans. It will help explain how Arabian Gulf waters will be affected by increasing concentrations of greenhouse gases in the atmosphere. The current understanding of climate change for the Arabian Gulf is based on the outputs of coarse-resolution atmosphere-ocean general circulation models that do not provide an adequate description of biophysical changes within Gulf waters themselves. Regional ocean models do a better job at representing ocean conditions on a smaller scale by accounting for local bathymetry and tidal characteristics, and are able to project changes in sea surface temperature, salinity, currents, and other marine parameters for the Arabian Gulf itself. While considerable research and data are available on current/past Arabian Gulf conditions, there has not yet been any research regarding the future conditions of the Gulf due to climate change. Over the last decade, methods for regional ocean modeling under climate change have advanced considerably. Key aspects of the sub-project are described in the bullets below.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps for policymakers as well as user-friendly datasets for follow-up research by the regional scientific community. In addition, supporting information will be provided in the form of a comprehensive technical report.

Environment

The next two sub-projects are concerned with the impacts of climate change on biodiversity. One sub-project is focused on the terrestrial ecosystems; the other sub-project is focused on marine ecosystems. Both of these sub-projects are focused at the regional scale.

Sub-project #3 is a quantitative assessment of the vulnerability of key terrestrial species and ecosystems to long-term changes in temperature and precipitation associated with climate change. This sub-project will improve the understanding of what climate change means for the region's unique biodiversity. Over the last decade, methods for modeling the potential responses of species to climate change have advanced considerably while at the same time, the availability of geo-referenced species occurrence data and datasets describing current and future environmental conditions have increased dramatically. As such, the tools and datasets necessary to perform a data-driven assessment of climate change impacts on biodiversity in the Arabian Peninsula are now in place. Once completed, the proposed research will inform adaptation strategies for climate change and will set the stage for more detailed future analyses, such as incorporating dispersal processes for species of greatest concern to identify key migration pathways.

- *Key outputs:* The major deliverables of the sub-project include high-resolution maps depicting current and future habitat suitability for key species, adaptation options, as well as user-friendly datasets for follow-up research by the regional scientific community. In addition, supporting information will be provided in the form of a comprehensive technical report.

Sub-project #4 is a quantitative assessment of the vulnerability of marine ecosystems and fisheries to long-term physical, chemical and biological changes from climate change. This sub-project will improve the understanding of what climate change could mean for the region's unique marine biodiversity. Climate change is expected to alter ocean conditions in the Arabian Gulf region including changes in sea surface temperature, salinity, oxygen levels, acidity and primary productivity. These changes will have direct and indirect impacts for the Arabian Gulf where already extreme environmental conditions render its marine ecosystems and their associated fisheries particularly sensitive to climate change. Previously published results of global-scale modelling analyses show that climate change may result in a high rate of local extinction and a large reduction in maximum fisheries catch potential in the Gulf region. This

highlights the potentially high vulnerability of the Gulf's marine ecosystems and fisheries to climate change and need for a detailed assessment. The assessment will also develop strategic plans to ensure that adaptation measures are identified and taken to protect marine ecosystems.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps depicting species invasion/extinction and fish catch potential, as well as user-friendly datasets for follow-up research by the regional scientific community. In addition, supporting information will be provided in the form of a comprehensive technical report.

Water Resources

The next three sub-projects are concerned with the impacts of climate change on water resources. One sub-project focuses on climate change impacts on transboundary groundwater resources (regional scale); another is focused on climate change impacts on water resource management (national UAE scale); and the remaining sub-project focuses on climate change impacts on renewable water resources in Al Ain (Abu Dhabi Emirate scale).

Sub-project #5 is a quantitative assessment of the vulnerability of Arabian Peninsula's shared, transboundary groundwater resources due to sea level rise associated with long-term climate change and socioeconomic growth. At present, the Dammam aquifer, the main groundwater resource that is shared by all countries in the region, is already characterized by unsustainable groundwater use, which over the past decades has contributed to increasing saltwater intrusion and water quality challenges. With climate change, sea levels are projected to rise in the Arabian Gulf further exacerbating the potential for saltwater intrusion into the aquifer. In addition, declining rainfall in the mountains of central Saudi Arabia may lead to reduced groundwater recharge levels into the aquifer when compared to historical patterns. Moreover, economic and population growth in the region may lead to increased groundwater demand, further threatening sustainable use of the aquifer. A vulnerability assessment will produce a better understanding of how the regional Dammam aquifer will respond to this combination of stresses. Once completed, the proposed research will inform potential adaptation strategies that could be implemented within a regional cooperation framework.

- *Key outputs:* The major deliverables of the sub-project include high-resolution maps depicting future groundwater levels, adaptation options, as well as user-friendly datasets for follow-up scientific research by the regional scientific community. In addition, supporting information will be provided in the form of a comprehensive technical report.

Subproject #6 is a quantitative national-level assessment of the vulnerability of its overall water resources due to long-term regional climate change and socioeconomic growth. At present, a quantitative assessment of climate change impacts on water resources have been focused exclusively at the emirate level of Abu Dhabi. For the six other emirates, water is also very much a cross-cutting sector, with implications for agriculture, human health, coastal zones, energy, and infrastructure, as well as its essential role in ecosystems and sustaining life. In these other emirates, the share of groundwater in the overall mix of water resources and management arrangements can vary significantly from that of the Abu Dhabi emirate, and hence the results obtained from the initial study may not transfer well to conditions in Dubai, Ajman, Sharjah, Ras Al-Khaimah, Umm al-Qaiwain, and Fujairah. With climate change, managing already acute water scarcity will become an even greater challenges due to additional risks associated with sea level rise, temperature increases, higher evaporation rates, all of which are likely to occur within the context of increasing national water demand due to strong socioeconomic growth.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps depicting future water resource requirements, adaptation options, and model outputs for follow-up

research by national water supply and demand planning. In addition, supporting information will be provided in the form of a comprehensive technical report.

Subproject #7 is a quantitative assessment of the vulnerability to long-term climate change of a key area that has a renewable water supply, the city of Al Ain along the Hajar Mountains. At present, climate change impacts on water resources have been assessed relative to ancient “fossil” groundwater (i.e., groundwater that has been underground for thousands of years and is not recharged from rainfall or runoff) at the emirate level of Abu Dhabi. With climate change, rainfall patterns in the Hajar Mountains, which annually recharge groundwater levels in the Al Ain region, could be adversely affected, leading to a gradual decline in aquifer productivity and raising long-term sustainability concerns for the region. Using outputs from the regional climate modeling component, the proposed research will explore sustainable water resource management strategies in Al Ain relative to a set of regional climate change and socioeconomic development scenarios. Once completed, the proposed research will identify specific management strategies that can enhance long-term sustainability and resilience to climate change in the area.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps depicting future water recharge scenarios, adaptation options, and model outputs for follow-up scientific research. In addition, supporting information will be provided in the form of a comprehensive technical report.

Coastal Zones

The next two sub-projects are concerned with the impacts of climate change on coastal zones. One sub-project focuses on the impact of sea level rise on land use for long-term planning (regional scale); the other is focused on the development of coastal zone vulnerability indicators for near-term planning (national UAE scale).

Sub-project #8 is a quantitative region-specific assessment of coastal zone vulnerability due to a long-term rise in sea level from climate change. Much of the region’s population, infrastructure and economic activity are located in coastal zones and are vulnerable to climate change-induced sea level rise and potential storm surges that would accompany more frequent extreme weather events. Climate change (and other anthropogenic factors) could be a primary cause for the increasing degradation of such coastal areas leading to an increase in coastal erosion and the inundation of productive lands and infrastructure. A vulnerability assessment of the inundation extent associated with plausible sea level rise scenarios will produce a better understanding of the specific coastal zones in the region which are most at risk. Once completed, the proposed research will inform potential adaptation strategies that could be implemented within a regional cooperation framework.

- *Key outputs:* The major deliverables of the sub-project include high-resolution maps depicting inundation extent, tabular outputs of land use types affected, adaptation options, and model outputs for follow-up scientific research. In addition, supporting information will be provided in the form of a comprehensive technical report.

Sub-project #9 is a quantitative national-level assessment of near-term coastal zone vulnerability associated with sea level rise and other risks. Past studies of climate change impacts along coastal zones in the UAE have been undertaken from a long-term planning perspective. However, planners today in the UAE are in need of actionable information amenable to their near-term planning horizons. One vulnerability assessment approach that can meet this need is the “coastal vulnerability index” (CVI), an approach that has been applied in numerous other settings to good practical effect. A CVI can provide insights on issues of near-term concern to planners such as the relative risk to existing infrastructure, recommendations for

coastal protection priorities, strategic land development offset zones, and potential set-aside areas for future protection. Development of a CVI incorporates a range of factors that affect near-term coastal zones risks, including but not limited to current and projected levels of sea level rise. Once completed, the proposed research will inform potential coastal adaptation strategies that could be implemented within either an existing or enhanced coastal planning framework.

- *Key outputs:* The major deliverables of the sub-project includes high-resolution maps depicting vulnerability indexing results, tabular outputs of data used, adaptation options, and other outputs for follow-up scientific research. In addition, supporting information will be provided in the form of a comprehensive technical report.

Socioeconomic Systems

The remaining three sub-projects are concerned with the impacts of climate change on socioeconomic systems. One sub-project focuses on an assessment of the vulnerability of the Arabian Gulf to the combined impacts of climate change, intensive desalination, and power supply, together with a range of adaptation options (regional scale); another is focused on an assessment of the vulnerability of specific segments in the UAE population to food price shocks that are projected to accompany climate change, together with a range of adaptation options (national UAE scale); and the remaining sub-project focuses on an assessment of the public health benefits to the Abu Dhabi emirate from greenhouse gas mitigation strategies in the transport and power supply sectors (Abu Dhabi Emirate scale).

Sub-project #10 focuses on an assessment of business-as-usual practices in water desalination and electricity supply relative to the vulnerability of the Arabian Gulf to climate change. The production of potable water from seawater is highly energy intensive. This is particularly true in the Arabian Gulf with its high salinity levels. Most desalination takes place at dual-purpose power stations that are able to co-produce electricity and desalinated water. However, there are significant environmental impacts associated with current business-as-usual practices. Desalination is responsible for discharges of highly saline brine and treatment chemicals directly into the Gulf, causing harm to marine biodiversity. Electricity generation with oil (crude, diesel, residual) and natural gas is responsible for emissions of greenhouse gases that contribute to climate change, as well as emissions of air pollutants that harm human health. In a fast-growing region with virtually no renewable water resources and rapidly depleting fossil groundwater, desalination is currently considered the only option to meet future water supply requirements. However, with climate change, the Gulf may become even more saline due to increased evaporation from higher temperatures, reduced vertical circulation due to reduced shamal winds, and increased near-shore salinity due to permanently flooded salt-crusting sabkha areas from sea level rise. These potential impacts combined with the implementation of business-as-usual desalination plans in the small, shallow and slow-circulating Gulf, could lead to an environmental tipping point in which the chemical properties of Gulf waters exceed the coping thresholds of corals, fish species, and other marine life. An integrated assessment of climate change, desalinated water production, and electricity generation is therefore needed to better understand the region's options for reducing future water and air impacts to the Gulf.

Key outputs: The major deliverables of the sub-project include high-resolution maps depicting Gulf impacts, model datasets, and the costs and benefits of adaptation options, and other outputs for follow-up activities. In addition, a comprehensive technical report will be prepared for follow-up research by the regional scientific community.

Sub-project #11 focuses on food security and will help explain how climate change impacts on global agricultural productivity are expected to affect the UAE's long-term food security. Currently, the UAE is lacking an assessment of the impact of climate change on

its long-term food security. The recent global food crisis of 2008, with its price spikes and subsequent unrest in several countries, represents an important challenge to the development of food security plans capable of producing human well-being and social harmony. Even without the additional threat posed by climate change, the global food crisis exposed interlinked vulnerabilities associated with agricultural productivity, international trade markets, and food commodity prices. With climate change, current challenges of soil destruction, inadequate water supply, and stagnant mono-cultured crop yields will likely be seriously exacerbated, leading to reduced crop productivity in food-exporting countries, steady increases in food prices, and increased food insecurity around the world. The UAE, a country that is heavily dependent on food imports, is particularly vulnerable. The combination of declining agricultural productivity in food-exporting countries, tightening world food markets, and price speculation pressures could lead to recurrent food price spikes, with resulting social disquietude, particularly among the UAE's large expatriate laborer workforce who would need to spend a growing share of limited income after remittances for food. An integrated adaptation assessment that accounts for climate change impacts on agriculture, international food trade, and economic livelihoods is therefore needed to better understand the country's options for increasing long-term food security under climate change.

- *Key outputs:* The major deliverables of the sub-project include a comprehensive technical report as well as model datasets for follow-up research by the regional scientific community.

Sub-project #12 focuses on public health and will help explain how the measures being planned in Abu Dhabi to reduce greenhouse gas emissions can also lead to public health benefits. Currently, The emirate of Abu Dhabi is lacking an assessment of the beneficial impact on public health from efforts to reduce greenhouse gas emissions. Several notable initiatives have been underway to reduce the carbon footprint of energy consuming activities in Abu Dhabi. While many of these initiatives have attempted to quantify the reduction in greenhouse gas emissions, to date there has not been a comprehensive assessment of the positive impacts that such measures can have on public health. These are considered a “co-benefit” of GHG mitigation are simply the improvements resulting from GHG-reducing activities that are not typically accounted for in the cost of saved carbon. Broadly speaking, co-benefits are associated with the simultaneous improvements in public health, macroeconomic, environmental, and aesthetic conditions associated with the implementation of policies and measures that reduce GHG emissions. Public health co-benefits are particularly important and include reductions in the incidence of, for example, respiratory illnesses, cardiovascular disease, and allergies. With continued progress in the Abu Dhabi emirate to expand and intensify GHG-reducing activities, particularly in the energy and transport sectors where the majority of potential GHG reductions exist, these public health co-benefits will likewise increase. An improved understanding of the public health benefits of current measures can help to leverage policymaker support for continued investments, while also promoting public awareness of the benefits of sustainable development practices. An integrated assessment that accounts for the public health co-benefits associated with initiatives in the power supply and transportation sectors is therefore needed to provide a more comprehensive accounting of the broader scope of benefits associated with the emirate's GHG mitigation initiatives.

Key outputs: The major deliverables of the sub-project include high-resolution maps depicting air quality improvements, a comprehensive technical report that contains tabular results of the cost-effectiveness of mitigation options, the adapted models for Abu Dhabi conditions, as well as model datasets for follow-up research by the regional scientific community.

Figure 1: Quarterly schedule for all sub-projects and project management activities

Theme	No.	Sub-project	Yr#1#	Year#2#(2014)					Year#3#(2015)				Year#4#(2016)			
			(2013)	Quarter					Quarter				Quarter			
			1	2	3	4	5	6	7	8	9	10	11	12	13	
Regional Modeling	1	Regional climate modeling (atmospheric)														
	2	Regional climate modeling (oceans)														
Environment	3	Terrestrial biodiversity														
	4	Marine biodiversity														
Water resources	5	Transboundary water														
	6	Water resources (UAE)														
	7	Water resources (Al Ain)														
Coastal zones	8	Sea level rise														
	9	Coastal vulnerability														
Socioeconomic systems	10	Desalination/energy supply														
	11	Food security														
	12	GHG mitigation benefits on public health														
Project management activities																

