Climate Adaptation: Risks and Measures

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INTRODUCTION

CLIMATE ADAPTATION: RISKS AND MEASURES

As climate change is projected to worsen further in coming decades, even with strong mitigation of greenhouse gas emissions, adaptation measures are essential to limit threats to peoples' wellbeing, livelihood, water, food, infrastructure, energy security and economic growth. Many climate-exposed countries have consistently emphasised adaptation as a critical consideration in their climate change strategy. Each city, country and region has to answer the questions: what is the expected real impact of all the major effects of climate change on health, life, and various aspects of the economy? And what measures can be taken to adapt and improve resilience?

Sustainability Report

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a prevalent sustainable development topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners and universities, as well as made available online to all Foundation members.

EXECUTIVE SUMMARY

- The world is already experiencing significant climate change and substantial further damage is predicted to occur up to 2100, even if the Paris Agreement's 1.5°C target is achieved. The world is on course for more than 3°C if action is not taken[i]. Consequently, no country is immune to the devastating impact of climate change, making adaption measures a necessity for all countries.
- Adaptation is not a choice; it is unavoidable. The question is whether it is done well or badly, cost-effectively, or not, how much climate damage is tolerated and how it is distributed.
- Climate change brings a wide range of impacts, which vary greatly between and within countries and industries. Therefore, the options for adapting are also considerably varied.
- Climate change impacts include much higher temperatures, extreme weather (hurricanes, droughts, floods), glacier melting, the spread of vector-borne diseases, lower crop yields, ecosystem changes, coral reef die-off, sea-level rise, and many others. These have consequences including economic damage, weakening of state's institutions/ systems, and mass migration.
- Adaptation is a complex challenge, involving long-range planning and integrated thinking. Nations can cooperate but, unlike mitigation, it is largely a local and national issue rather than a global one.
- A range of plans and financing instruments have been made available for adaptation, under the UNFCCC and the Paris Agreement, though they remain underfunded.
- The MENA region is particularly vulnerable to climate change because of high temperatures, (semi)-arid climates, insufficient indigenous food production, and exposure of major cities and infrastructure to sea-level rise. The region can learn from and cooperate with some other countries in similar situations.
- Qatar has a wide range of options to meet its adaptation challenges, and several of them have already been implemented or studied. All the options need to be fully assessed for cost and feasibility and incorporated into a comprehensive overall strategy and plan.

SUBSTANTIAL CLIMATE CHANGE TODAY IS ALREADY UNAVOIDABLE

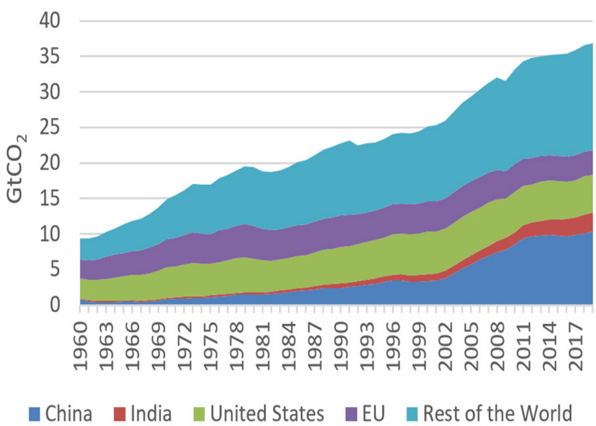
The Paris Agreement, signed in 2016, had the objective to limit the global average temperature increase to "well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels[ii] . Yet given slow progress to date, these goals may be unattainable.

The Paris Agreement had climate change adaptation as one of its core areas: Article 7, Paragraph 9 states "each party shall, as appropriate, engage in adaptation planning processes and the implementation of actions, including the development or enhancement of relevant plans, policies and/or contributions." Parties to the agreement concurred on a long-term goal for adaptation and fostering climate resilience. Each party's Nationally Determined Contribution (NDC) should include its efforts to reduce emissions and to adapt to the effects of climate change. Climate finance, as addressed in the Paris Agreement, is intended to facilitate the flow of funds for addressing both climate mitigation and adaptation[iii].

Even with falling coal use in the US and Europe, emissions from fossil fuels and industry are expected to hit 36.8 $GtCO^2$ in 2019, up 0.6% (0.24 $GtCO^2$) from 2018's levels. According to these numbers, the world is not on track to meet the Paris Agreement's 2°C target, let alone the more ambitious 1.5°C goal, which requires global emissions to fall by 7.6% a year until 2030[iv].

The Covid-19 crisis is estimated to have reduced global emissions by 11-25% in April 2020, and by 4-7% through 2020 as a whole[v]. While the climate change crisis is moving slower than the Covid-19 pandemic, it should be clear that climate's long-term effects are far more threatening. The level of urgency, innovative approaches, and ambitious spending that many countries have deployed to meet Covid-19 needs to be harnessed and sustained over a long period to mitigate climate change and to adapt to its unavoidable effects.

FIGURE 1 ANNUAL CO^2 EMISSIONS FROM FOSSIL FUELS AND INDUSTRY BY MAJOR COUNTRIES, 1960-2019



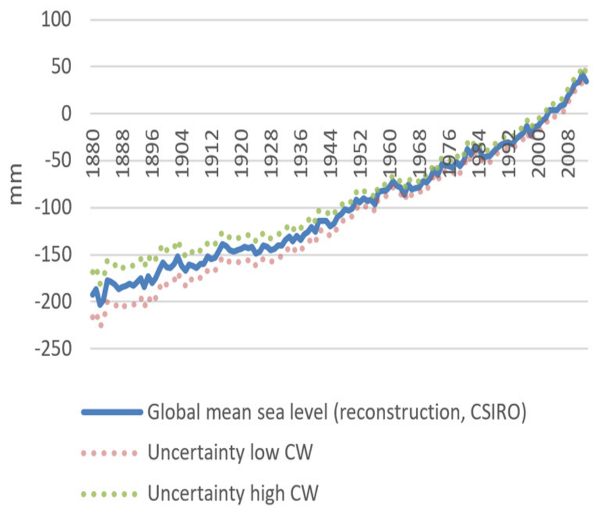
SUBSTANTIAL CLIMATE CHANGE TODAY IS ALREADY UNAVOIDABLE

According to many reliable estimates, the NDCs submitted by 2016, even if all countries were able to deliver on them, would translate to an equivalent of 2.3°C temperature rise by 2100[vi]. Therefore, countries should be prudently planning to adapt to at least 2.3°C of average worldwide warming, as a good no-regret strategy, in addition to the individual changes in temperature profile, precipitation and other climate impacts that vary from country to country. In line with the findings of the Intergovernmental Panel on Climate Change (IPCC), in its 2018 special report on the impacts of 1.5°C of warming[vii], mitigation should be planned for a 1.5°C scenario and adaptation should be planned in anticipation of a temperature rise well above 2°C.

CLIMATE CHANGE BRINGS A WIDE RANGE OF IMPACTS AND THREATS

In 2015, global warming reached 1°C, above pre-industrial levels for the first time[viii]. According to the IPCC, climate change threats are identified based on how environmental feedback systems are impacted. If temperature rises between 1.5°C and 2°C above pre-industrial levels, environmental systems will experience a number of catastrophic changes by 2100. Among these, extreme temperatures are likely in highly populated areas; intense extreme weather such as droughts and floods is expected to occur more frequently; sea-level rise is projected at 0.26-0.93 m; biodiversity will incur significant losses; and ocean acidity along with de-oxygenated oceanic waters are expected to increase. About 0.3 m of sea-level rise has already been observed since 1880 (FIGURE 2), with an acceleration since the 1980s.

FIGURE 2 OBSERVED CHANGE IN GLOBAL MEAN SEA LEVEL 1880-2013[ix]



These changes are likely to affect potable water availability and terrestrial ecosystems due to more frequent and prolonged drought periods as well as the seawater intrusion into inland waterways. Biodiversity is expected to diminish, including the loss of local pollinators, putting food security at risk. Ocean acidity, diminished oxygen levels, and increased water temperature represent a major threat to marine ecosystems, particularly a projected 70-99% loss of coral reefs. Coral bleaching events have become increasingly common, with the Great Barrier Reef in Australia suffering its most extensive bleaching in March 2020[x]. The recent giant spill of 20,000 tonnes of diesel in Russia's far north, into the Ambarnaya River, was blamed on a collapse of a storage tank because of melting permafrost[xi]. The melting of permafrost risks increased floods, damage to buildings, roads and pipelines, and coastal erosion in the medium-long term.

The 2019, a record heatwave in Europe was made 100 times more likely by climate change[xii]. It may have caused several thousand additional deaths in the UK, France and the Netherlands, as well as disrupting rail and air traffic. Xu et al[xiii]. point out that most human population has historically clustered in areas with a mean annual temperature between 11-15°C. Over the next 50 years, climate change without large-scale migration will leave 1-3 billion people in areas with mean annual temperature above 29°C, currently found only in small parts of the Earth's surface, mostly the Sahara.

The rainfall from Hurricane Harvey, which struck Houston in August 2017, was 38% more than would have occurred without global warming[xiv].

Climate change also has direct bearing on pandemics, such as the 2020 Covid-19 outbreak. Pandemics can disrupt climate preparedness and hamper disaster relief. Conversely, adverse impacts of climate change can hamper measures to combat outbreak of pandemics. For instance, after Hurricane Maria, Puerto Rico had to stop monitoring and responding to the Zika virus[xv].

Thus, climate change has a wide range of direct impacts, but can also indirectly influence other parts of society such as causing higher food prices which could lead to political instability. With the indirect impacts, climate change can be a "threat multiplier", increasing the probability or severity of risks even if it is not the original or only cause[xvi].

Climate change can have a cascade of impacts through trade, infrastructure, geopolitics, human mobility, and finance. On trade, threats cover both agricultural and non-agricultural commodities, manifested in raw materials supply disruptions, feedstock shortages for the manufacturing industry, global food price volatility, and unreliable networks of supply and distribution. The impacts on infrastructure range from risks to energy supply, vulnerable energy infrastructure and disruptions to transportation and distribution networks.

Some consequences of climate change, such as longer growing seasons and leisure opportunities in high latitudes, are positive. But most climate change impacts are negative and becoming increasingly severe as climate change worsens.

Climate impacts are also highly heterogeneous, for instance, between urban and rural societies, coastal and inland locations, and between cold, temperate, hot arid and hot tropical environments.

CLIMATE CHANGE BRINGS A WIDE RANGE OF IMPACTS AND THREATS

A selection of the main climate impacts is shown in TABLE 1.

TABLE 1 MAIN CLIMATE CHANGE IMPACTS

Systems	Risks
Health	Extreme weather events Heat stress Lower ambient air quality Increased range of pests and vector-borne diseases Waste management
Livelihood	Floods and droughts result in destroyed homes, displacement, and food crises in low-middle income countries (e.g. Bangladesh, Kenya, South Sudan) Difficulty of outside work in high temperatures Disruption or displacement of tourist activities (e.g. skiing)
Water availability	Droughts Floods Seasonal changes (e.g. loss of glacier melt) Upstream dams and water conflict Aquifer depletion Saline water intrusion into coastal aquifers
Food security and biodiversity	Declining agricultural yields, mainly in hot and arid climates Rises in food prices Loss of fishing grounds / aquaculture due to higher water temperatures, ocean acidification Forest fires Coral bleaching Spread of agricultural pests and diseases Ecosystem shifts
Infrastructure	Sea-level rise making coastal infrastructure, ports, etc., unusable
Energy security	Large scale energy infrastructure damage due to extreme weather changes (e.g. flood damage to dams; storm and forest fire damage to electricity grids; pipeline subsidence due to permafrost melting; hurricane damage to offshore oil platforms; sea-level rise affecting coastal nuclear power plants; shutdown of nuclear power plants due to overheated cooling water) Weather interruptions to offshore oil loading (e.g. Basra Oil Terminal, Iraq) Conflicts between countries on pursuing different policies Higher energy use for air-conditioning
Economic growth	Decline in rainfall, drought, natural disasters, hot weather leading to capital depreciation and defensive investment; insurance losses and uninsurability
Political and security	"Climate refugees", international conflict, failed states, terrorism – caused or exacerbated by food insecurity, extreme weather, economic decline, sea-level rise and other climatic effects

Each of these impacts has cumulative larger magnitude over a prolonged period. For instance, a community can recover from a single storm or flood, but repeated events may threaten its economic viability or liveability.

AT HIGHER LEVELS OF WARMING, IMPACTS INCREASE AND ADAPTATION BECOMES MORE DIFFICULT AND COSTLY

The impacts of warming become greater at higher temperatures (TABLE 2), in a non-linear fashion. Most of the impacts become much worse in the apparently small move from 1.5°C to 2°C, and even more so in rising to 3°C. Fewer studies have been conducted on 3°C or more of warming, but such a scenario remains very plausible without strong and rapid emissions cuts.

TABLE 2 IMPACTS OF GLOBAL WARMING[xvii]

	1.5°C	2°C	3°C
Sea-level rise by 2100	48 cm	56 cm	
Arctic ice-free summers	3%	16%	63%
Annual maximum temperature	+1.7°C	+2.6°C	
% population with 1 severe heatwave per 5 years	14%	37%	
Average drought length (months)	+2	+4	+10
Category 5 cyclones / year	+1.4	+1.2	
Maize crop yield by 2100	-6%	-9%	
% of plant species losing >50% of range	8%	16%	67%
% of invertebrate species losing >50% of range	6%	18%	68%
Coral reef decline	70-90%	99%	

Effective adaptation, to the extent it is possible, would reduce climate damage and so cut the amount of mitigation required.

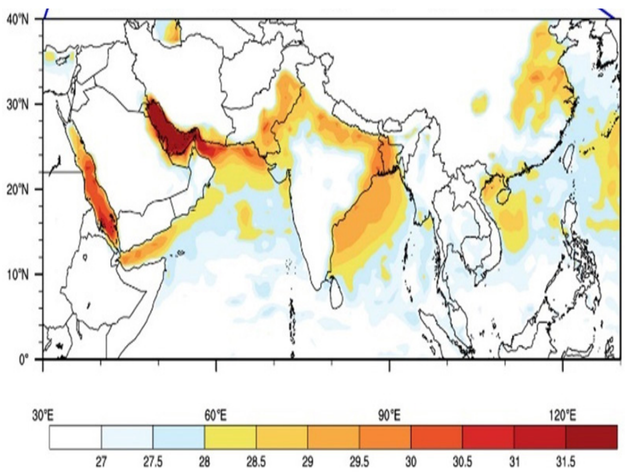
For relatively small climate changes, such as slightly hotter and drier weather, there are multiple effective forms of adaptation, and probably others that will be developed in future.

However, it's unlikely that we would be able to adapt in any meaningful way to extreme changes in climate. Adaptation may be feasible up to a point (e.g. raising seawalls and levees) until eventually it reaches the point of being impractical.

Even smaller changes can cross the biophysical limit of adaptation. For instance, for rice farming in South Asia, it has not proved possible to breed rice varieties that pollinate above 32-35°C. Also wet bulb temperatures above 35°C, at which a healthy person is likely to die within six hours, are already regularly approached in the Arabian Gulf, Red Sea, northern Indian subcontinent and eastern China (FIGURE 3).With high levels of climate change, large populations will face deadly heatwaves and severe restrictions on working in non-airconditioned environments in summer.

All these factors greatly complicate planning for adaptation: planners must cover a wide range of possibilities. They must avoid alarmism and over-spending, while still providing for protection against plausible, dangerous future extreme occurrences. Adaptation is also an ongoing process. For example, a port relocated to cope with 50 centimetres of sea-level rise may have to be moved again or protected when and if sea-level rise reaches 1 metre. Change may be relatively linear and progressive, but some changes can be abrupt.

FIGURE 3 HIGHEST DAILY WET BULB TEMPERATURE, 1979-2015 (°C)[xviii]



AT HIGHER LEVELS OF WARMING, IMPACTS INCREASE AND ADAPTATION BECOMES MORE DIFFICULT AND COSTLY

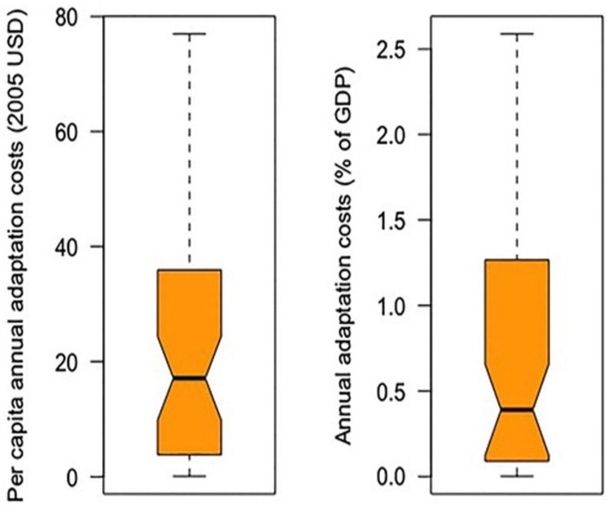
Unplanned adaptation is much more expensive than planned adaptation. For instance, 2005's Hurricane Katrina caused $81 billion of property damage, $250 billion in total economic losses, and 1800 deaths in the south-eastern US[xix], exacerbated by a lack of emergency preparedness, poor evacuation plans, and inadequate levees[xx]. Properly built levees would have reduced flooding by half[xxi].

However, planning adaptation is often difficult to sell politically. Very effective pre-adaptation to an anticipated change may prevent or minimise climate damages and cause authorities to be blamed for over-reacting to a disaster that never occurs. For instance, a government that builds an effective system of flood management at significant cost may then incur criticism for over-spending when a storm does not cause flooding.

There can also be a tension between adaptation and mitigation. For instance, greater use of air-conditioning (particularly outdoors in very hot climates) and desalination will increase emissions if not powered with zero-carbon energy. Some adaptation, such as sea defences and dams, may have a negative effect on local ecosystems.

THE COSTS OF ADAPTATION ARE NECESSARY BUT SUBSTANTIAL

FIGURE 4 RANGE OF ANNUAL ADAPTATION COSTS (PER CAPITA (LEFT) AND GDP (RIGHT))NOTE: MIDDLE DARK LINE REPRESENTS MEDIAN, THE BOX REPRESENTS THE INTERQUARTILE RANGE AND WHISKERS REPRESENT THE LOWEST AND HIGHEST QUARTILES[xxii]



The aggregate per capita annual adaptation costs in developing countries is estimated at $5-35 during 2020-30, with a median of $20 (FIGURE 4). In GDP terms, this equates to 0.1-1.3% (0.4% as a median estimate). The adaptation costs assessed for upper-middle income countries in dollars range from $25-105, with a median estimate of $55, significantly higher than that of low-middle income countries.

These costs are already substantial but are likely to escalate post-2030 as climate change impacts become more severe.

ADAPTATION TO CLIMATE CHANGE INVOLVES A WIDE RANGE OF RESPONSES

Adaptation to climate change is addressed in the Intergovernmental Panel on Climate Change (IPPC)'s 2014 Assessment Report 5 (AR5)[xxiii]. It involves changing behaviour, technologies, equipment, and structures, to function better in a changed climate. Adaptation can be via retreat, i.e. avoiding the change (for instance, ceasing to use land flooded by rising sea levels); co-exist (minimise the effect of the change); or defend (actively reverse the change).

Adaptation can be anticipatory or reactive. For instance, expecting a certain amount of sea-level rise, new buildings can avoid coastal areas that would be expected to flood regularly within the next fifty years. Or, when sea-levels increase, sea defences can be built to protect coastal homes or farmland.

The number of climate changes and the range of situations they act on is vast. Similarly, the number of human responses is large, and can increase with innovation and technology development. It is therefore not possible to list all possible adaptation measures, but TABLE 3 gives some examples.

TABLE 3 EXAMPLES OF ADAPTATION MEASURES

System	Example Measuresv		
	Retreat	Co-exist	Defend
Health	Population reduction or migration from disease-ridden areas	Use topical insect repellents	Implement vaccination programs; create genetically-engineered varieties to destroy disease vectors
	Migration from excessively hot areas	Avoid midday and midsummer work; shade and redesign cities to avoid urban heat islands	Air-conditioning
Livelihood	'De-growth'; cease certain activities	Develop dry-land agriculture; aquaculture in flooded areas	
Water supply	Migration from water-stressed areas	Desalination technologies; use water more efficiently; saline-tolerant crops Map flooding intensity Disseminate efficient irrigation technologies	Dams; water import from other areas; cloud-seeding
Food Security and Biodiversity	Change topography of land; abandon flooded or desertified areas	Adopt vertical farms; Change timing of farm operations Provide financial and technical advice to farmers	Substitute crops with drought and salt resistant cultivars
Infrastructure	Cease using flooded roads; abandon waterfront properties	Change to using floating structures; build structures that can survive periodic flooding Create 'green' sea defences, e.g. mangroves	Build sea-walls and coastal defences Raise river levees

ADAPTATION TO CLIMATE CHANGE INVOLVES A WIDE RANGE OF RESPONSES

Many countries identified climate change adaptation in their own national development strategies. Four examples are given in TABLE 4. These cover a wide range of threats, but sea-level rise, extreme weather, higher temperatures, loss of biodiversity and reduced agricultural productivity are common issues. Typical responses include distributed renewable energy, water management, extreme weather warning and infrastructure resilience, coastal defences and building resilience in agriculture and health.

TABLE 4 EXAMPLES OF NATIONAL ADAPTATION PLANS (NAPS)

Country	Threats	Strategy/National Adaptation Plan	Measures
Kenya	**Climate Risk Index: 19-67** Drought and flooding caused by the El Niño Southern Oscillation resulted in loss of lives and disastrous effects on Kenya's economy (-$12.2 B), agriculture (-$87.43 B) and infrastructure sectors. Mean annual temperature projected to rise by 0.8-1. 5°C by 2030s and 1.6-2.7°C by 2060s (GCM). This might go up to 3°C by 2100. Sea-level rise is a risk to five Kenyan coastal counties, with an estimated 4-6 km2 area in Mombasa likely to be submerged with a 0.3 m of seal-level rise. The agriculture sector across the coast is estimated to incur $472.8 M of losses. This will also lead to displacement and social tensions due to migration.	National Climate Change Response Strategy (NCCRS) (2010) National Climate Change Action Plan (NCCAP 2013-17)	• Conduct risk assessments • Increase awareness of climate change impacts to communities in counties • Increase solar, wind and other renewable energy systems to power underserved areas • Increase small hydropower and geothermal power generation plants in communities and businesses in rural areas • Rehabilitate water catchment areas to provide sustainable ecosystem services • Develop climate change financing tracking systems
Bangladesh	Increased mean temperature in the monsoon season (June-August) at an annual 0.03-0.05°C; average increase projected at 1.3°C and 2.6°C by 2030 and 2070, respectively. Winter precipitation expected to decrease by 2030, with no precipitation expected by 2075 (GCM)vi. Flooding, droughts, and heat stress affecting crop productivity yearly (1.32 m ha of cropland is highly prone to flooding and about 5.05 m ha is moderately flood-prone). Increased saline intrusion in coastal zones; increased sedimentation; riverbank erosion; increased cyclone frequency over the Bay of Bengal throughout November and May, according to the Meteorological Research Council. During the last 22 years, the rate of sea-level rise increased at 4 mm/year at Hiron point, 6mm/year at Char Changa and 7mm/year at Cox's Bazar.	Bangladesh Climate Change Strategy and Action Plan 2009vii	• Increase vulnerable groups' resilience through development of community-level adaptation, livelihood diversification, better access and scale-up of basic social services • Develop resilient cropping systems (crop varieties tolerant of flooding, drought and salinity suited for poor farmers' needs) • Strengthen the cyclone, storm surge and flood early warning systems for more accurate forecasts • Repair/rehabilitate existing infrastructure and design + construct urgently needed new infrastructure (cyclone shelters, urban drainage systems, etc.)

Japan	**Climate Risk Index: 5.5** Due to heavy rains, more frequent heat waves, Osaka earthquake and Jebi typhoon, Japan was declared the most threatened country in the world by climate change in 2018. Mean surface temperature estimated at 0.88°C above the 1981-2010 average; increased frequency and intensity of extreme weather; sea-level rise projected at 0.3-1.7 °C from (2081-2100). High sea-level rise implies an increase in storm surge, typhoons, and inundation, leading to declines in port waterfront industries and logistics.	National Plan for Adaptation to the Impacts of Climate Change (2015)	• Implement weather and marine monitoring • Conduct risk assessments and projections for inundation • Construct more robust structures • Design port and harbour business continuity plans • Promote technology development with a focus on levees, facilities in the event of natural hazards, measures against coastal erosionviii
Philippines	**Climate Risk Index: 11.17** Typhoon Mangkhut's passage through the country impacted more than 250,000 people (59 dead due to torrential rainfall); extreme weather events led to 455 deaths and more than $4.54 B in economic losses as well as a 0.48% drop in GDP per capita. Cyclones in the Philippines average 19-20 per year, of which 7-9 lead to landfall; projected increased incidence of extreme weather and hazard events. Temperature increase expected at 1.8-2.2 °C by 2050; sea-level rise estimated at 0.48-0.65m by 2100. These direct impacts have indirect impacts on agriculture (crop loss/failure; soil erosion; rising food prices), water (shortages, degraded quality, increased flood), energy (reduced production potential; increased demand), coastal ecosystems (coastal defence loss, reduced fish populations, biodiversity loss)ix.	National Framework Strategy on Climate Change (NFSCC 2011-2022)	• In the agriculture sector, build capacity and resilience into agriculture systems; R&D for a more robust sector; awareness and communication to inform farmers' decision-making • Develop vulnerability and risk assessment models of species and ecosystems and design adaptation programs • Develop renewable energy and reduce dependency on fossil fuels; conserve energy for transport and manufacturing (natural gas and electricity) • Build social and physical health infrastructure that are climate-proof and which can reduce climate health threats

NAPs' progress varies between countries due to climate risk exposure, government leadership, and differences in level of human development across regions. More efforts are also needed as regards adaptation planning on a sub-national level. The latter is highly contingent upon the country's level of decentralisation.

Apart from the design and implementation drawbacks, monitoring and evaluation systems are absent and limited. These systems are fundamental to assess the programmes' effectiveness and identify gaps to improve the implementation and design aspects of adaptation action.

MITIGATION IS GLOBAL; ADAPTATION IS (LARGELY) LOCAL

Mitigation is global, as greenhouse gases quickly spread through the atmosphere. Adaptation, on the other hand is local, since every area and its population are affected differently and have a different pre-existing set of behaviours and capital stock.

Some geographies are particularly vulnerable in different ways, for instance:

- Small island developing states (SIDS): sea-level rise; saltwater intrusion into aquifers; vulnerability to hurricanes; coral reef die-off due to marine heatwaves and ocean acidification
- Downstream riparian states: water shortages; floods; loss of glacier run-off
- Arctic communities: loss of hunting/fishing grounds; subsidence due to permafrost melt
- Highland communities: loss of tourism through snow melt; flooding and landslides
- Semi-arid and arid regions: desertification; extreme heat waves; rising energy use for cooling; water shortages; migrations and conflict

Countries or regions that are already economically and politically marginal or have small populations are doubly disadvantaged - they will find it difficult to adapt effectively, and they will also find it hard to mobilise international resources in their favour.

However, notwithstanding this differentiation, there is some scope for collaboration on adaptation measures between countries. Examples of possible areas for such collaboration include:

- Research such as building cooling; drought; saline- and disease-resistant crops;
- Cooperation on supply chains, to ensure multiple options and resilience[xxix];
- Cross-border infrastructure, such as sea-defences between Belgium, the Netherlands and northern Germany; upstream dams and water-sharing agreements;
- Plans on adaptation finance, emergency preparedness (for instance, ASEAN typhoon readiness), and management of migration.

EFFICACY AND COSTS OF ADAPTIVE MEASURES DEPEND ON NUMEROUS CONDITIONS

Adaptation planning is not a separate activity; it must be integrated into national development plans. It is an ongoing process, to be revised and iterated as a country's circumstances and its climatic situation change[xxx].

Some of the world's most detailed adaptation plans have been developed by cities rather than countries. For instance, in 2013, New York developed a $19.5 billion plan, based on hyperlocal climate models, and mainly focussed on resilience to storms, flooding and sea-level rise[xxxi]. Other cities' plans include measures to deal with heatwaves, smog, and rainwater runoff and re-use. For Quito, the capital city of a middle-income country, Ecuador, the plan includes action on clean drinking water and public health.

COUNTRIES HAVE APPROACHED ADAPTATION IN DIFFERENT WAYS

Under the UN Framework Convention on Climate Change (UNFCCC), parties developed the National Adaptation Plan (NAP) process in 2011[xxxii] . NAPs are not directly linked to NDCs, but the actions and priorities identified in a country's NAP can be integrated into the adaptation section of its NDC. The implementation of the NAP and NDC can also be strongly supportive of achieving the Sustainable Development Goals (SDGs), particularly those relating to health and wellbeing, clean water, ecosystems and biodiversity[xxxiii].

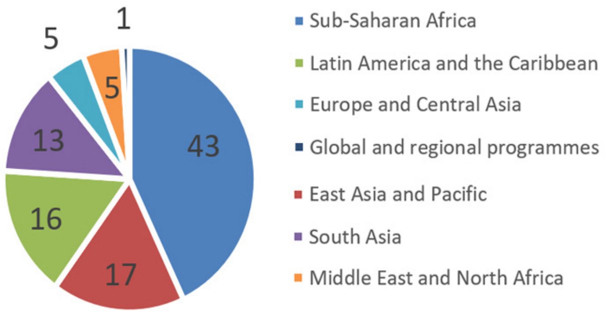
About 75% of countries' NDCs include sections on adaptation. In the MENA region, adaptation is mentioned in the NDCs of Qatar, Oman, Saudi Arabia, the UAE, Yemen, Iran, Sudan, Egypt, Lebanon and Jordan. Major developing countries covering adaptation in their NDCs include India, Brazil, Indonesia and Nigeria. As an example of what may be covered in such NDCs, India's section on adaptation says it was spending 2.82% of GDP on adaptation programmes during 2009-10, and mentions sustainable and climate-resilient agriculture, water quality and recharge, disease control, coastal defence areas, island protection, disaster management, ecosystem protection, and capacity-building[xxxiv].

Plans to date have mostly focussed on physical infrastructure. There is a need to pay more attention to institutions, supply chains and to a research and development (R&D) agenda. The Covid-19 pandemic in 2020 has revealed the challenges to supply chains. Similar problems could arise, for example, with supplies of food or key components affected by a hurricane or flood. Diversified global supply chains, and avoidance of knee-jerk actions such as export bans and protectionism [xxxv], should be part of an effective adaptation plan.

The Green Climate Fund was established in 2010 under the UNFCCC framework, and has a goal of raising $100 billion annually. As of early 2020, $10.3 billion had been pledged and $8.24 billion confirmed. Since November 2019, 48 proposals for adaptation totalling $116 million had been approved or were in the final stages of approval[xxxvi]. At least 50% of adaptation finance is intended to be focussed on African countries, Least Developed Countries (LDCs) and SIDS (FIGURE 5).

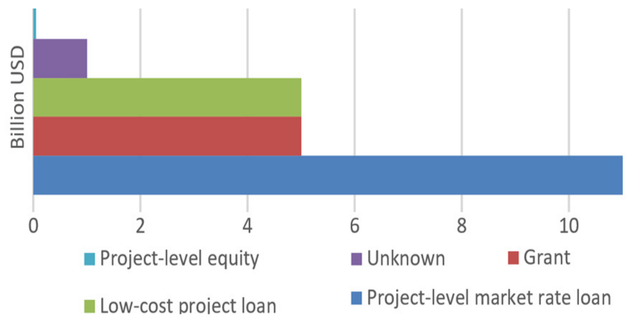
COUNTRIES HAVE APPROACHED ADAPTATION IN DIFFERENT WAYS

FIGURE 5 REGIONAL DISTRIBUTION OF APPROVED ADAPTATION FINANCE ($ BILLION, 2003-2018)[xxxvii]



Adaptation finance is provided through several routes, but loans at market rates has been most common, followed by concessionary loans and grants. Equity funding has hardly been used and could be expanded (FIGURE 6).

FIGURE 6 ADAPTATION FINANCE BY INSTRUMENT (2015-16 AVERAGE)[xxxviii]



THE MIDDLE EAST AND THE GCC ARE ESPECIALLY VULNERABLE TO CLIMATE CHANGE THREATS

The Middle East-North Africa (MENA) region faces major climate change threats ranging from water scarcity, sea-level rise, desertification, biodiversity loss, high temperature and high humidity.

Second-order risks from climate change include political conflict, massive migration, and food shortages or famines, with most countries in the region being net food importers.

Cross-border water resources are often areas of dispute that could be further exacerbated by greater evaporation and changing rainfall patterns. Major projects of upstream dam construction and agricultural water use are problematic in the cases of the Nile between Ethiopia and Egypt (and also affecting Sudan), the Tigris and Euphrates between Turkey, Syria and Iraq (and with some inflow from Iran), and the Jordan river between Israel, Jordan and the Palestinian territories.

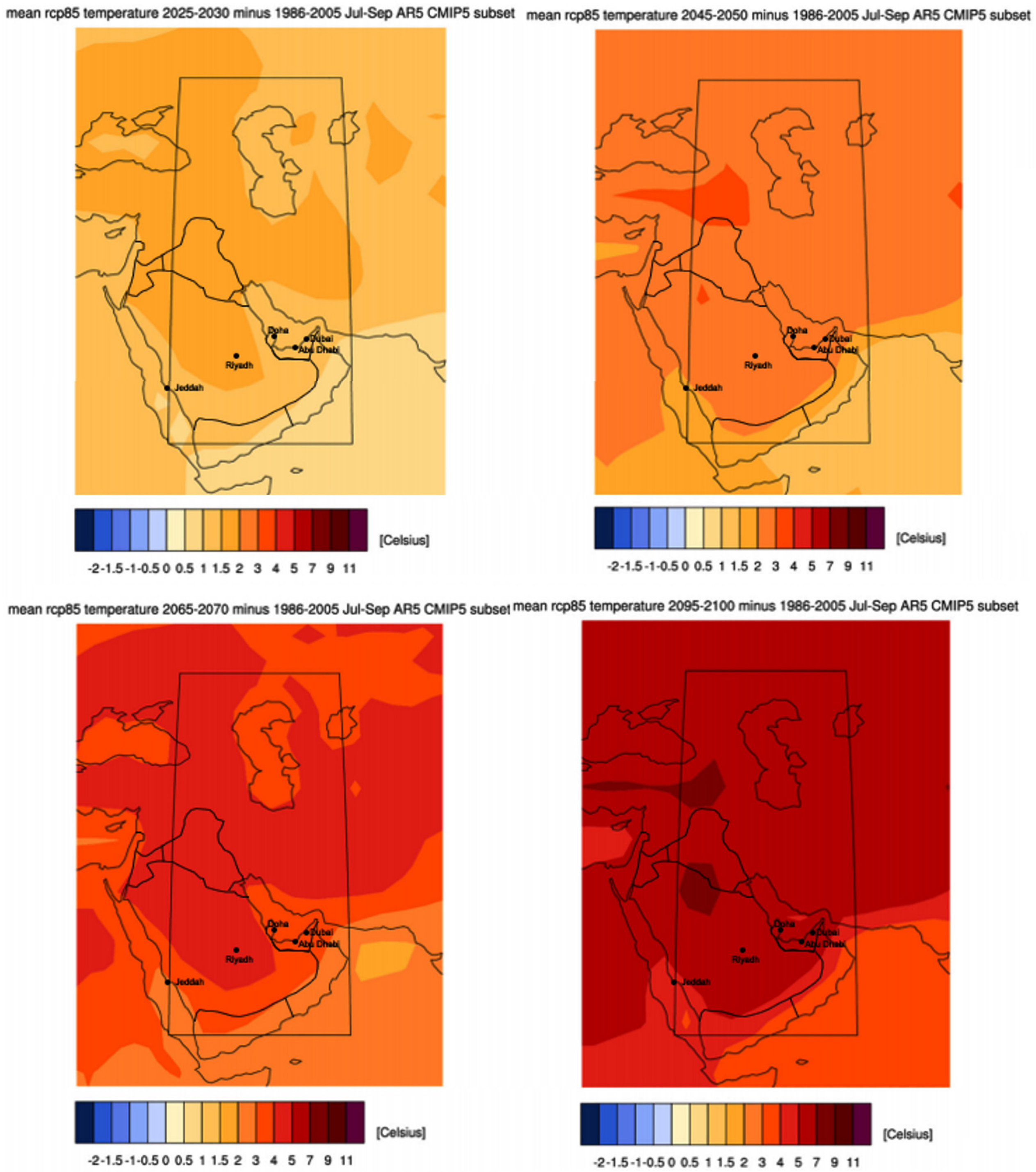
The absolute sea level rise in the Gulf has increased to 2.2 mm per year, when the global annual rise for the 20th century was 1.8 mm. The World Bank declared that 24 ports in the Middle East are at risk from sea level rise. Most major GCC cities are located on the coast and at risk of flooding due to sea-level rise. Qatar reported in the "Interim Coastal Development Guidelines" that some of the coastal areas may be subject to inundation due to sea level rise. 18% of its land is vulnerable to flooding by less than 5 m sea level rise.

Gulf countries' coastal regions have low elevations and experience high temperatures and humidity.

GCC countries have minimal natural freshwater resources, and subsurface aquifers have been heavily depleted. They rely on desalination plants which have high energy needs, release concentrated hot brine into the already saline Gulf.

Apart from water supply, electricity supply is also impacted by climate change. The rise in temperature and heat waves increases air-conditioning demand, diminishes power plant efficiency and transmission lines' capacity, and increases the loss in transformers.

FIGURE 7 MEAN TEMPERATURE RISE IN THE SUMMERS BETWEEN 2025-2030, 2045-2050, 2065-2070, 2095-2100 (BASED ON 1986-2005 LEVELS)



GCC countries can learn from their neighbours and from countries in similar situations, for instance Australia, California and South Africa, with a focus particularly on how wealthy but hot, arid and largely coastal countries can adapt. Singapore also may offer some lessons, as a water-scarce, food-importing densely populated coastal state, with a large concentration of petrochemical and refining industries and a major port.

THE MIDDLE EAST AND THE GCC ARE ESPECIALLY VULNERABLE TO CLIMATE CHANGE THREATS

The C40 Cities is an alliance bringing together 40 global cities to deal with climate mitigation and adaptation. Members include Amman, Karachi, Sydney, Durban, Singapore, Los Angeles and Houston[xxxix]. The Cities Climate Finance Leadership Alliance, of which C40 Cities form the core, seeks to increase investment in sustainable infrastructure from the current $2.5-3 trillion per year to the estimated need of about $6 trillion, 70% of which will be spent in urban areas[xxxl].

CONCLUSION

Climate change adaptation planning is occurring at substantial levels in both public and private sectors and across all government segments. Yet, few plans have been fully implemented, and those that are implemented mainly focus on incremental changes. Limited funding, legal and policy impediments, along with the difficulty of anticipating climate change at the local level, remain the reoccurring barriers to the proper implementation of adaptation measures. This is further exacerbated by the lack of evaluation and monitoring systems which are supposed to inform lessons learnt, in turn allowing for program design improvements.

At present most adaptation plans are focussed on visible and quantifiable impacts. There is a need to consider unexpected and second-order risks. Although these are harder to manage, addressing them is key to building resilience of infrastructure, society and the economy.

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