

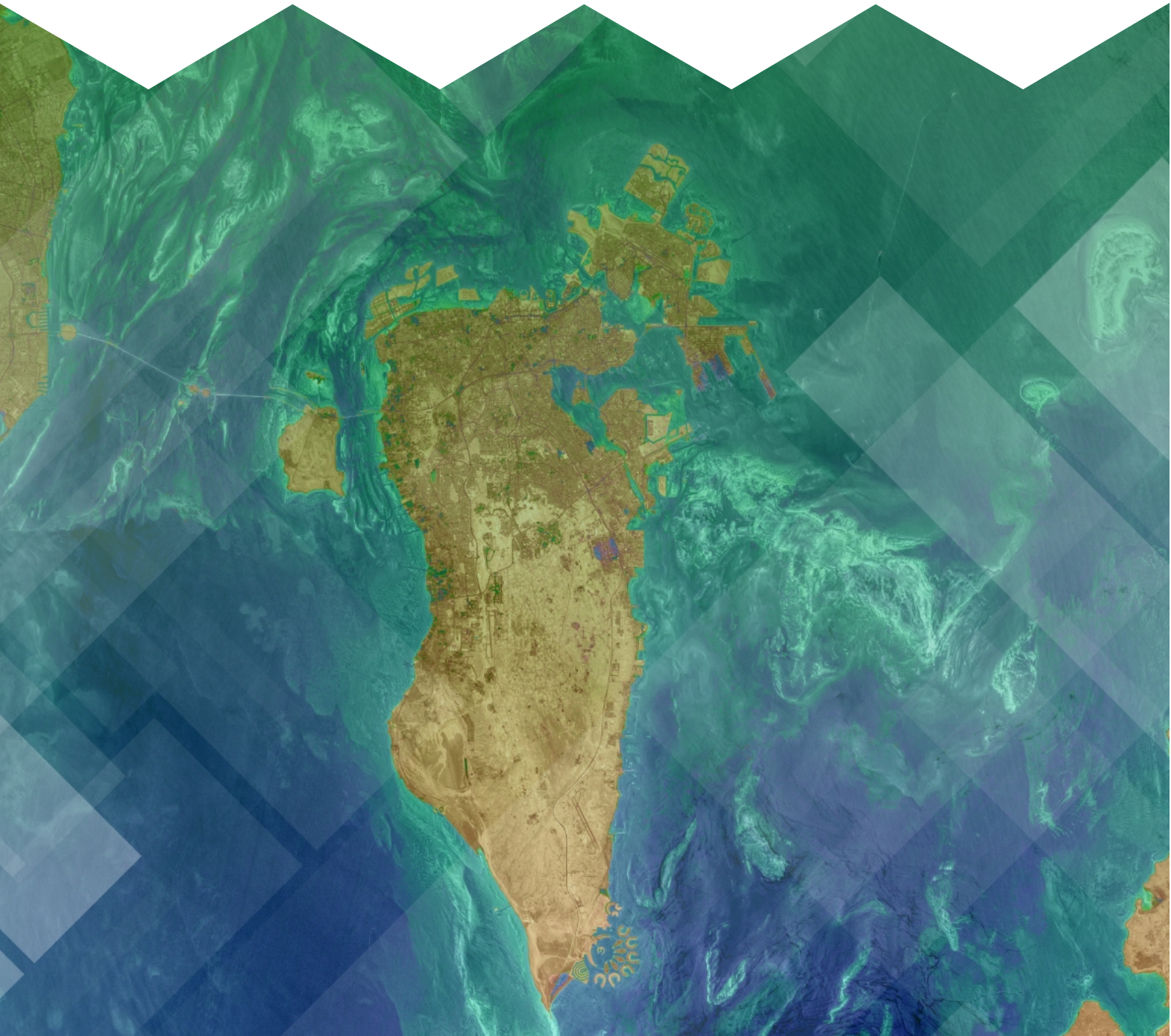


KINGDOM OF BAHRAIN  
Supreme Council  
for Environment



# The Kingdom of Bahrain's National Adaptation Investment Plan (NAIP)

*Developed in partnership with the Global Green Growth Institute (GGGI) and key line ministries.*







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**Contact information**  
Supreme Council for Environment  
Tel +973 80 001 112 - +973 17 386 999  
E-mail. [info@sce.gov.bh](mailto:info@sce.gov.bh)  
P.O.Box. 18233 Manama, Kingdom of Bahrain

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**The Late Amir of Bahrain,  
His Highness Shaikh Isa bin  
Salman Al Khalifa**  
May God rest his soul in peace

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**His Majesty  
King Hamad bin Isa Al Khalifa**  
The King of the Kingdom of Bahrain

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**His Royal Highness  
Prince Salman bin Hamad Al Khalifa**  
Crown Prince and Prime Minister

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# LIST OF ACRONYMS

<b>CSR</b>	Corporate Social Responsibility
<b>DFI</b>	Development Finance Institution
<b>EWA</b>	Electricity and Water Authority
<b>FAO</b>	Food and Agriculture Organization
<b>GCC</b>	Gulf Cooperation Council
<b>GCF</b>	Green Climate Fund
<b>GEF</b>	Global Environmental Facility
<b>Ha</b>	Hectare
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>m<sup>3</sup></b>	Cubic meter
<b>MAR</b>	Managed Aquifer Recharge
<b>M&amp;E</b>	Monitoring and evaluation
<b>Mm<sup>3</sup></b>	Million cubic meter
<b>NAP</b>	National Adaptation Plan
<b>NAIP</b>	National Adaptation Investment Plan
<b>NbS</b>	Nature Based Solutions
<b>NDC</b>	Nationally Determined Contribution
<b>NIAD</b>	National Initiative for Agricultural Development
<b>PA</b>	Paris Agreement
<b>RCP</b>	Representative Concentration Pathway
<b>SCE</b>	Supreme Council of Environment
<b>SEPPD</b>	Sanitary Engineering Planning & Projects Directorate
<b>STP</b>	Sewage Treatment Plant
<b>TNC</b>	Third National Communication of Kingdom of Bahrain to UNFCCC
<b>TSE</b>	Treated Sewage Effluent
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>WHO</b>	World Health Organization

# 1.0 INTRODUCTION

The Kingdom of Bahrain is a small low-lying state in the Arabian Gulf that faces unique circumstances regarding the threat of climate change. Situated in the Middle East, an arid region that has been warming almost twice as fast as the global average, Bahrain is vulnerable to extreme temperature and water scarcity. Layered onto these circumstances is a rapidly growing population and development activities over the past 20 years, putting increased strain on natural resources while generating mounting pressure on the environment. These factors pose a challenge to Bahrain's efforts to transition toward climate resilient green growth.

Climate change impacts have already been observed in Bahrain and are further elaborated in the Third National Communication (2020) report to UNFCCC. To adapt to the increasingly adverse impacts of climate change in future, the Kingdom of Bahrain has stated in its Nationally Determined Contribution (2021) commitment to the UNFCCC that it will prioritize climate adaptation actions, especially those with mitigation co-benefits as a key pillar of its climate action strategy. Unlike most countries that have strengthened climate adaptation processes by developing National Adaptation Plans (NAPs) or equivalent plans and strategies, the Kingdom of Bahrain national adaptation planning efforts aim at translating its adaptation priorities into investment plans that can mobilize both public and private financing. This approach of translating adaptation plans into investment plans will enable the Kingdom of Bahrain to translate climate adaptation actions into investment projects by assessing the bankability of climate adaptation projects at the early development stage.

As a result of this approach, the National Adaptation Investment Plan (NAIP) has been developed as the guiding document to identify climate adaptation actions and systematically translate the climate adaptation actions into a portfolio of investable projects. Prioritization of individual investments within the portfolio is guided by factors such as climate resilience impact, bankability, contribution to development priorities, potential to provide public goods, mitigation co-benefits, nature-positive returns, job opportunities, and project readiness. This will help determine the appropriate source of financing for the individual projects, such as the government budget, the private sector, or other sources.

The development of the National Adaptation Investment Plan has the following four objectives:

1. To systematically describe what adaptation to the adverse impacts of climate change means in Bahrain and to identify objectives for adaptation (***situational analysis***)
2. To identify the stakeholders in the different sectors affected by the adverse impacts of climate change on which successful adaptation will depend (***stakeholder analysis***)
3. To identify actions to increase resilience to climate change (***project pipeline***)
4. To identify relevant options of how to finance these adaptation actions (***climate finance strategy***)

The NAIP development process is driven by an informed participation of local stakeholders as the effectiveness of the investment plan depends on an inclusive and participatory planning process. This provides an opportunity to engage with respective stakeholders on climate adaptation before investments are identified, through the development and appraisal of adaptation actions. Such upstream engagement ensures the right type of adaptation investments are identified and

form the basis for developing a pipeline of investments, thereby aligning financial flows toward climate-resilient development. Moreover, the project costs contained in the NAIP are estimates based on stakeholder feedback, government reports, and country benchmarking. These estimated costs are not a comprehensive and conclusory costing of all the financial resources required to meet the adaptation needs of the Kingdom of Bahrain.

## 1.1 Development of the National Adaptation Investment Plan

The NAIP has been developed based on the following inputs:

- The United Nations Framework Convention on Climate Change (UNFCCC) NAP preparation guidelines have been broadly followed in the NAIP development process with relevant modifications to reflect the country's national circumstances.
- The climate vulnerability assessments from the National Communication Reports to the UNFCCC provided the basis for identifying the sectors in need of climate adaptation actions.
- International knowledge and know-how in climate change adaptation were utilized by involving key international experts in the development of the NAIP.
- National experience in climate change adaptation was integrated by involving national experts in the development of the NAIP.
- National consultations at different levels were undertaken to identify main stakeholders, build long-term commitment, mobilize support and create a consensus for action.

Based on these inputs, the NAIP was developed through a 3-step process, giving local stakeholders a leading role in determining the content and scope of the investment plan and ensuring that actions align with relevant existing policies and plans. In the first step, a stocktaking analysis was conducted for identifying priorities for adaptation. The analysis utilized a standardized framework to assess the exposure and sensitivity of different sectors to the various climate change related threats.

Second, a project pipeline was developed. Potential projects for the pipeline were identified based on the situational analysis' results, existing government priorities as well as stakeholder recommendations. Project ideas were shortlisted by the Supreme Council of Environment (SCE) and the relevant line ministries. Stakeholders selected the climate adaptation actions based on the expected economic, environmental, and social impacts.

Third, financing instruments and funding sources corresponding to the prioritized projects were identified. This process considered the expected availability of public resources, options for private finance and public-private partnerships, the potential for fiscal instruments, such as incentives, as well as opportunities to access international climate finance. As referenced in Section 1.0, the project costs contained in the NAIP are estimates based on stakeholder feedback, government reports, and country benchmarking. These estimated costs are not a comprehensive and conclusory costing of all the financial resources required to meet the adaptation needs of the Kingdom of Bahrain.

## 1.2 Alignment with National Policies, Laws and International Agreements

The NAIP aims to support the implementation of existing national policies, reinforce the environmental legislative system, and help adhere to the many regional and international agreements, conventions, and protocols that the Kingdom of Bahrain has ratified to protecting the environment, strengthening the global response to climate change, and achieving sustainable development.

Sectoral actions were designed in line with strategies and plans relevant to the priority areas for adaptation, such as the National Water Strategy, National Initiative for Agricultural Development, National Biodiversity Strategy and Action Plan as well as Nationally Determined Contribution (NDC) commitments to the UNFCCC (2021) and the Paris Agreement (PA). Actions were formulated in line with key guiding policies and strategies in the Kingdom, including Bahrain's Economic Vision 2030 and the 2030 Agenda on Sustainable Development.

Listed in Table 1 are some of the climate adaptation related environmental laws and regulations in the Kingdom of Bahrain that the NAIP seeks to strengthen, which are already among the most advanced in the region.

**Table 1: Environmental Legislation**

<b>Year</b>	<b>Environment Decrees, Laws, and Ministerial Edicts</b>
<b>2022</b>	Law 7 of 2022 on the Environment (replacing the previous Decree-Law (21) of 1996 on the Environment)
<b>2007</b>	Edict 4/2007 on authorizing some Public Commission for the Protection of the Marine Resources, Environment and Wildlife staff to act as Judicial officers
<b>2006</b>	Law 53/2006 on designating Tubli Bay a natural reserve
<b>2005</b>	Decree 43/2005 on re-structuring the Public Commission for the Protection of the Marine Resources, Environment and Wildlife
<b>2003</b>	Edict 4/2003 with respect to declaring Arad Bay as a natural and marine sanctuary
<b>2002</b>	Decree-Law 20/2002 with respect to the Regulation of Fishing and Exploitation of Marine Resources
<b>2002</b>	Edict 1/2002 on designating Mashtan island as a protected area
<b>1996</b>	Edict 16/1996 on designating Hawar islands and the surrounding marine region as a protected area, in accordance with Decree-Law 2/1995 on wildlife conservation

Listed in Table 2 are some of the important international agreements ratified by the Kingdom of Bahrain that are related to climate change adaption.

**Table 2: International Environment Agreements**

<b>Accession</b>	<b>Name of the convention</b>
<b>2016</b>	Royal Decree 75 of 2016 on ratifying the Paris Agreement within the United Nations Framework Convention on Climate Change (UNFCCC)
<b>2011</b>	Cartagena Protocol on Biosafety
<b>2005</b>	Kyoto Protocol to the United Nations Framework Convention on Climate Change
<b>2002</b>	Convention on the Conservation Wildlife and its Natural Habitats in the Gulf Cooperation Council
<b>1997</b>	United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification
<b>1996</b>	Convention on Biological Diversity
<b>1994</b>	United Nations Framework Convention on Climate Change
<b>1990</b>	Protocol concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf and the Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources
<b>1983</b>	Arab Convention No. (1) of 1981 on Work Environment
<b>1982</b>	United Nations Convention on the Law of the Sea
<b>1978</b>	Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution
<b>1971</b>	Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention)

## 2.0 SITUATIONAL ANALYSIS

The situational analysis chapter provides a systematic overview of the sectors that are adversely impacted by climate change in Bahrain, namely: Water Resources, Agriculture & Food Production, Ecosystem Services & Biodiversity, and Urban Development. Each of these sectors was assessed regarding its exposure to climate change, its relevance to Bahrain and how the adverse impacts of climate change will affect performance within the sector, and the sector's ability to cope. It is necessary to systematically assess Bahrain's vulnerability to climate change to identify actions that will strengthen its adaptive capacity.

### Methodology

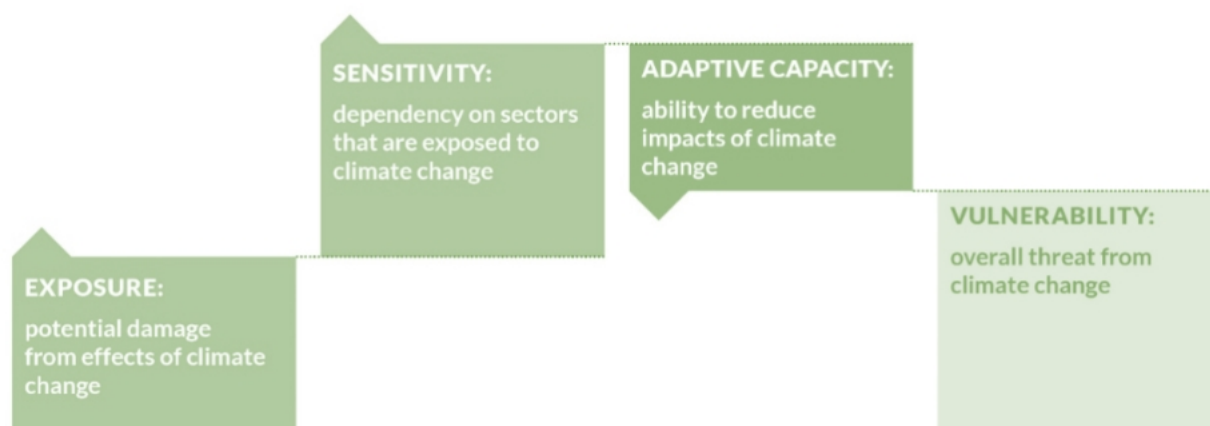
Climate change is an inherently complex topic, manifesting in a wide spectrum of impacts that affect multiple sectors. Therefore, systematically assessing climate change vulnerability and comparing the extent to which different sectors are affected by climate change is important. The Intergovernmental Panel on Climate Change (IPCC), the intergovernmental body of United Nations for assessing the science related to climate change, defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes." The IPCC further defines vulnerability as a function of three factors:

- **Exposure:** The degree to which a system is exposed to the effects of climate change.
- **Sensitivity:** The degree to which a system is affected by the effects of climate change. This is influenced by factors such as the physical characteristics of the system, its economic and social structure, and its ability to adapt.
- **Adaptive capacity:** The ability of a system to adjust to the effects of climate change. This includes the ability to make changes to infrastructure, policies, and practices in order to reduce the negative impacts of climate change.

As per the IPCC definition of vulnerability, the situational analysis considers three distinct components of vulnerability to climate change:

1. Bahrain's exposure to phenomena related to climate change.
2. Bahrain's sensitivity to the adverse impacts of climate change.
3. Bahrain's adaptive capacity to cope with the adverse impacts of climate change.

**Figure 1: Aspects of vulnerability to climate change**



## Exposure

Exposure describes to what extent Bahrain is affected by climate change. The Government of Bahrain’s National Communications to the United Nations Framework Convention on Climate Change (UNFCCC) mention four climate change impacts of various levels of threat to the Kingdom , i.e., rising temperatures, decreasing rainfall, and rising sea levels (Table 3).

**Table 3. Climate change threats and their potential impacts**

Climate change threats	Potential impacts
Rise in temperatures	<ul style="list-style-type: none"> <li>• Decrease in scarce fresh-water resources, due to increase in evapotranspiration rates reducing soil moisture, rainfall infiltration and aquifer.</li> <li>• Increased demand for water for municipal consumption, agriculture, and industry.</li> <li>• Extensive coral bleaching associated with considerable loss of coral cover.</li> <li>• Increasing urban heat island effect.</li> </ul>
Change in rainfall rate	<ul style="list-style-type: none"> <li>• Increase rainfall rate unevenness will give rise to the risk of extreme events, including floods and droughts and that will lead to increase the water scarce condition in Bahrain.</li> </ul>
Rise in sea levels	<ul style="list-style-type: none"> <li>• Land loss due to increase in coastal inundation, flooding, and erosion.</li> <li>• Increase in saline intrusion into the soil and aquifer, affecting soil ecosystems, agricultural productivity, and reducing freshwater resources.</li> <li>• Inundation of intertidal mudflats, with potential impact on populations of migratory shorebirds and/or reduction of light levels, affecting photosynthetic rates of already threatened seagrass beds.</li> <li>• Destruction of mangroves.</li> <li>• Possibly negative impact on some infrastructure assets, including roads, buildings, electricity systems, and industries.</li> </ul>

## Sensitivity

Sensitivity describes to what extent Bahrain’s economy and population rely on sectors, services, and resources that are exposed to climate change impacts. Based on a literature review, conversations with representatives of the Government of Bahrain, and experiences in other countries in the region, four sectors have been identified as being affected by the adverse impacts of climate change in Bahrain. These sectors are water, agriculture, ecosystems and biodiversity, and urban development.

**Table 4. Sectors sensitive to the adverse impacts of climate change**

Sector	Aspects
Water	<ul style="list-style-type: none"> <li>• Reduced supply of drinking water and water for municipal consumption and agriculture.</li> <li>• Increase in demand.</li> <li>• Impacts on distribution infrastructure due to corrosion of pipes and pumping stations increasing water losses.</li> </ul>
Agriculture	<ul style="list-style-type: none"> <li>• Reduced supply of water.</li> <li>• Increase in water demand.</li> <li>• Reduced availability of arable land.</li> </ul>
Ecosystems and biodiversity	<ul style="list-style-type: none"> <li>• Changes in the availability of marine goods and services, including fish stocks, seagrass beds, coral reefs, and mangroves.</li> </ul>
Urban development	<ul style="list-style-type: none"> <li>• Reduced land availability.</li> <li>• Increased electricity consumption due to higher demand for air conditioning, thus also undermining mitigation efforts.</li> </ul>

## Adaptive capacity

Adaptive capacity is the ability to cope with the adverse impacts of climate change, despite the level of exposure and sensitivity. Adaptive capacity is the ability of a system to anticipate, respond, and adjust to stress induced by climate change and to minimize, cope with, and recover from the negative consequences of climate change. While exposure and sensitivity increase a country’s overall vulnerability to climate change, adaptive capacity reduces overall vulnerability.

Each sector’s existing adaptation goals and measures are described as a part of assessing adaptive capacity. In addition, adaptation actions that further reduce the negative impacts of climate change on Bahrain and its population are proposed. Table 5 presents a summary of the proposed actions.

**Table 5. Overview of possible actions to strengthen adaptive capacity**

Category	Potential actions
<b>Water</b>	<ul style="list-style-type: none"> <li>• Expanding the use of treated wastewater in agriculture, reducing the need for desalinated water and groundwater.</li> <li>• Inclusion of rainwater harvesting and greywater reuse and recycling in new building codes.</li> <li>• Prevention of saline intrusion in aquifers, pollution and over-extraction from aquifers</li> </ul>
<b>Agriculture</b>	<ul style="list-style-type: none"> <li>• Expansion of hydroponics to increase agricultural productivity and reduce water demand.</li> <li>• Promoting and providing guidance and subsidized efficient irrigation systems for farmers.</li> <li>• Land-based aquaponics employing vertical farming.</li> <li>• Installation of energy-efficient cooling technologies for animal and crop protection and expanding growing seasons</li> </ul>
<b>Ecosystems and biodiversity</b>	<ul style="list-style-type: none"> <li>• Restricting coastal development and shoreline modification of natural systems, including careful planning for land reclamation.</li> <li>• Minimizing pollution, sewage discharge, and sedimentation into the marine environment.</li> <li>• Preventing over-fishing of coral reef-associated fish and protecting adequate areas of each habitat within no-fish zones.</li> <li>• Protecting key ecosystem features and building a heterogeneous system of protected areas.</li> <li>• Ensuring connectivity between protected areas to facilitate continued migration of species.</li> </ul>
<b>Urban development</b>	<ul style="list-style-type: none"> <li>• Retrofitting buildings and revising the building code in response to increasing temperatures.</li> <li>• Identification of technologies and specific timeline to increase the energy efficiency of space cooling, potentially through district cooling.</li> <li>• Identification of locations and specific timeline to increase green spaces in urban areas.</li> </ul>

The following sections provide a more detailed assessment of exposure, sensitivity, and adaptive capacity for the four sectors impacted by climate change in Bahrain, i.e., water, agriculture, ecosystems and biodiversity, and urban development.

## 2.1 Water Resources

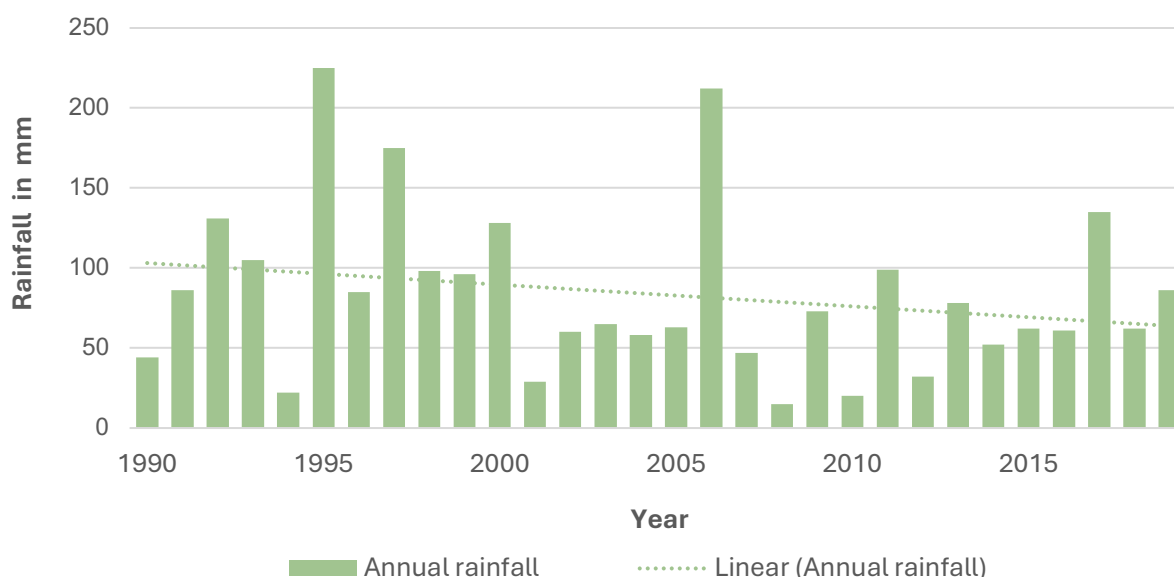
Bahrain is located in an arid region that experiences high temperatures and low rainfall with a high evapotranspiration rate. As a result of these arid conditions, Bahrain has no surface water sources such as rivers and lakes, and groundwater is the only natural source of fresh water supply. Furthermore, rapid population growth and urbanization in the past four decades has resulted in a high demand for water despite an increasingly vulnerable water supply.

Bahrain's water requirements are met mainly by desalination plants, groundwater abstraction (renewable and non-renewable), and to a lesser extent by tertiary treated wastewater. The main water-consuming sectors in the Kingdom are the municipal sector and the agricultural sector. The municipal sector water requirements are mainly met by desalination plants, while the agricultural sector water requirements are met by groundwater abstraction and tertiary treated wastewater.

Bahrain has two groundwater systems: the Dammam aquifer system and the Rus-Umm Er Radhuma (Rus-UER) aquifer system. The first aquifer (Dammam) is being recharged by the equivalent aquifer system in Eastern Saudi Arabia, and therefore is considered as a renewable aquifer system, while the latter aquifer (Rus-UER) occurs in the form a brackish water lens and is considered non-renewable. Interaction between the two aquifer systems occur at certain parts of Bahrain.

The only source of natural replenishment for the aquifers is rainfall. According to data from the Meteorological Directorate, rainfall is erratic and has decreased over the past 20 years (Figure 2). In addition, rainfall is concentrated within short periods, with average annual rainfall of approximately 74 millimeters distributed across an average of merely ten days per year.

**Figure 2: Annual rainfall in Bahrain since 1990**



Since the 1970s, Bahrain has been resorting to desalination to meet the quality requirements of the municipal / domestic water sector and has been increasingly relying on the private sector to reduce water supply financial costs. The total desalination capacity in Bahrain has reached about 969,300 m<sup>3</sup>/day (about 354 million m<sup>3</sup>/year) in 2021 (EWA Statistics 2021). Although Bahrain has been able to meet the municipal water demands by the extensive installation of desalination

plants, this has been achieved with heavy burden on the Kingdom's national budget, high consumption of energy, and numerous environmental externalities concerns.

In the past ten years, treated wastewater has emerged as an important source of water in the Kingdom and its role in meeting the Kingdom's water requirements is expected to grow with time, in proportion to the growth in the population and water demand. Currently, four out of the 11 STPs (Tubli WPC, Muharraq, North Sitra, and Madinat Salman STPs) account for over 99% of the potential TSE reuse flow in Bahrain. It is estimated that the total TSE production in the Kingdom is estimated to reach approximately 600,000 m<sup>3</sup>/day by 2050.

## Exposure

The rise in temperature and sea level are the two threats linked to climate change that affect water resources in Bahrain. The main effects of the expected increase in temperature and sea level can be summarized as follows:

- Increased evapotranspiration rates reduce soil moisture, rainfall infiltration and aquifer recharge, resulting in an overall reduction of already scarce fresh-water resources.
- Increased saline intrusion into the soil and aquifer due to sea level rise affects soil ecosystem and reduces agricultural productivity and available freshwater resources.
- Increased water demand for municipal consumption, agriculture, and industry usage as a direct result of higher temperatures.

The growing pressure on freshwater resources, combined with increasing water demand, is expected to lead to greater reliance on seawater desalination. This results in more saline discharges into the sea, especially in shallow coastal areas, gradually raising seawater salinity. Over time, this can make the desalination process more challenging.

Under a high emission scenario (RCP 8.5), these impacts are estimated to result in a significant cost to Bahrain's economy. Though not documented for Bahrain, an over-extraction of the aquifer can cause the ground to sink, as is currently occurring in Jakarta, Mexico City, and Tokyo. Such sinking also appears to be happening in geographical proximity to Bahrain, in locations with similar arid conditions, such as Dubai and Cairo.

## Sensitivity

The limited amounts of groundwater and the absence of surface water sources mean that Bahrain must satisfy its water demand mainly through the desalination of sea water and increasingly through treated wastewater. Both desalination and wastewater treatment plants have considerable energy requirements and generate byproducts with potentially negative environmental impacts. For example, desalination plants produce saline waste that can have a detrimental effect on marine life, requiring adequate dilution of the saline solution before its release to the sea. Furthermore, desalination plants often pump in small fish or fish larvae, negatively affecting marine life.

The combination of increasing temperatures and sea level rise will reduce the available water supply while raising water demand, particularly affecting drinking water, municipal consumption, and agriculture.

- **Drinking water and municipal consumption:** Reducing the water available from the aquifer and increased salinity due to over-extraction and sea level rise will increase dependence on water supply from desalination plants. Concurrently, population growth and temperature rise will increase water demand.
- **Agriculture:** As with drinking water, the combination of rising temperatures and sea levels will reduce available water supply while increasing water demand. Increased salinity of the aquifer will lead to a stronger reliance on recycling wastewater for agriculture use and require more efficient agriculture methods.
- **Infrastructure:** Increased salinity of soils and rising temperatures will increase the vulnerability of infrastructure, as the saline content corrodes pipes and pumping stations as well as the concrete structures that contain them. Corrosion of pipes leads to water losses and health risks through contamination of water supply from infiltrations.

## Adaptive Capacity

Numerous policy actions to protect water resources were launched in the 1980s and the 1990s. More recently, the Royal Decree 36/2009 reactivated the Water Resources Council (WRC) as a framework to ensure efficient levels of water resources, coordinate and integrate government policies, and set priorities in strategies and programs. In addition, policies that were put in place to reduce consumption at the municipal level, aiming to increase awareness of the need to minimize consumption and reduce leakage, helped reduce per capita consumption. Despite lower per capita consumption and additional water resources from desalination plants and wastewater treatment for agricultural usage, an increasing population has resulted in over-extraction of the aquifer to meet water demand.

The measures needed to address water resource resilience in the context of climate change are addressed by the National Water Strategy 2030, which are:

- Increase the collection of relevant data to inform decision making and control water abstraction.
- Increase operational efficiency to reduce water losses in water supply systems.
- Reduce water abstraction by conserving water in agriculture and reducing domestic consumption.
- Improve wastewater treatment and reuse of tertiary treated wastewater.
- Improve cost recovery for wastewater collection and treatment from users.

In 2018, a Water Resources Management Unit (WRM) was established to implemented a project funded by the Green Climate Fund that aims to enhance the resilience of the Kingdom's water sector by:

- Establishing a knowledge management platform for climate change impacts on Bahrain's water sector to facilitate improved water demand management.

- Building the institutional capacity of the water resources council to establish and operate a climate resilient integrated water resources management (IWRM) framework in a cross-sectoral manner.
- Promoting water conservation technologies and practices at household and farm level.
- Producing guidelines for rainwater harvesting and greywater reuse and recycling.

In regard to wastewater, Bahrain is currently expanding the reuse of treated wastewater in irrigation and reducing the need for desalinated water, principally through the free delivery of treated wastewater to farmers' lands. However, the volume of tertiary treated wastewater is limited, thus restricting the water that can be distributed to farms. Expansion of treated wastewater network would make higher volumes of water available for agriculture usage. Bahrain's main wastewater treatment plant is Tubli (TWPCC), including several secondary wastewater plants, with a production capacity of 95,000 m<sup>3</sup>/ day. There are plans for upgrading and expanding other wastewater treatment plants, including a 7 km deep gravity sewer line connected to the TWPCC. In addition to agriculture, usage of partially treated wastewater for industry or groundwater recharge is being considered.

The inclusion of rainwater harvesting and greywater reuse and recycling in building codes is regarded as a relevant measure to reduce water abstraction. Greywater usage should be limited to certain activities (e.g., watering of green spaces, agriculture, car washing, etc.,) and the maximum permitted levels of pathogens within greywater need to be defined.

In regard to drinking water, regular upgrading of water infrastructure, including corroded pipes and increasing the capacity of desalination plants, has enabled a water supply system with relatively few losses. Leakages (also considered non-revenue water) amounted to less than 10% in 2018 and require further monitoring.

Saline intrusion into groundwater reservoirs can be prevented by several means. First, reducing and monitoring groundwater extraction will lead to increase groundwater levels and reduce saline intrusion. on the other hand, an aquifer recharge and saline intrusion wall (though costly and with only a few examples currently implemented globally) this could offer a long-term solution for Bahrain.

## 2.2 Agriculture & Food Production

The agriculture and food production sector in Bahrain, which includes livestock and fisheries sub-sectors, is subject to challenging climatic conditions with poor quality soils and limited water availability. The multifaceted effects of climate change present particular challenges regarding food security in Bahrain. Approximately 10% of Bahrain's total land is arable, with most soils characterized by a sandy texture, a deficiency in major nutrients, low water-holding capacity, and high infiltration rates. The country's arable lands are also exposed to an arid desert climate distinguished by high temperatures (mean air temperature fluctuates between 14°C and 41°C), high humidity, and scanty, and often erratic rainfall.

Given the climatic conditions, the cropping season is mostly restricted to the winter months. The main crops produced under different systems are dates, vegetables, and fodder crops, with dates being the most traditional food crop. Dates and fruit production comprise approximately half of the total cultivable area and vegetable production accounted for nearly a quarter of the total cultivable land. Vegetables are Bahrain's most important cash crop, which are cucumber,

lettuce, okra, onion, and tomato. The area under animal fodder cultivation was reported at 16% of the total cultivable area, with alfalfa being the main fodder crop and other fodder crops including Bermuda, Rhodes, and Sudan grasses.

Livestock resources only fulfil around 12% of national consumption needs. Due to the challenges of high temperatures, scarce land, and water shortages, including limited land to produce fodder, Bahrain has taken a strategic decision to focus on poultry and egg production, and has established modern, “high-tech” broiler farms with high yielding breeds. This currently contributes to 25% of national consumption needs for poultry and 20% for eggs. However, increasing the production of livestock in Bahrain is not a sustainable option, and therefore import of livestock is necessary to satisfy the needs of a growing population and reduce the stress on available land and water resources.

Fish resources in Bahrain supply around 50% of national consumption needs. In addition to national consumption, Bahrain exported around 12,000 metric tons of fish and shrimps in 2022.

In addition to challenging conditions, Bahrain is constrained by a limited supply of capital and skilled workforce and continuing loss of agricultural land from land-use changes for urban, industrial, recreational, and other services developments. Other challenges included restricted water resources, limited size of farm holdings and the decreased number of people interested in the agricultural sector. All of these factors are further exacerbated by climate change.

## Exposure

Among the different threats related to climate change, the agriculture and food production sector in Bahrain is particularly exposed to rising sea levels and increasing temperatures. Substantial agricultural land areas and communities might be at risk of seawater inundation without effective adaptation measures. As per Bahrain’s Third National Communication report (2020) to the UNFCCC, substantial agricultural land areas and communities might be at risk of seawater inundation without effective adaptation measures. Potential future seawater inundations could increase soil salinization, leading to gradual desiccation and destruction of coastal plantations.

In addition to sea level rise, air temperatures have been steadily increasing over the last 50 years. Climate change can exacerbate disease in livestock, and some diseases are especially sensitive to climate change. There is evidence that higher temperatures are associated with climate-related diseases with livestock, particularly heat stress and higher incidences of vector borne diseases. Livestock diseases also have impacts on human health as over 60% of human pathogens are zoonotic, or transmissible from animals. Studies have shown that a correlation exists between increased food-borne diseases in humans and higher temperatures.

Climate change will vastly impact fish supplies in the Kingdom, and particularly in terms of increased seawater temperature, as many species cannot tolerate this increase. While species may adapt by moving deeper, the Arabian Gulf’s shallow depth limits species’ ability for such relocation. Climate-driven perturbations in local and regional environmental conditions have the potential to make most of the southern Gulf unsuitable for certain species and as a result, the fishery contribution to national economy of Bahrain could be affected by climate change.

## Sensitivity

The agriculture sector contributes a relatively small share (0.3%) to Bahrain’s GDP, and only covers a small fraction of the country’s food needs but accounts for approximately 30% of annual water consumption in the country. Most farms in Bahrain still use traditional surface irrigation,

which has an efficiency of only 25-40%. The small size and fragmentation of farm holdings have restricted investment in more expensive modern irrigation techniques with drip and sprinkler irrigation applied to approximately 32% and 3% of agricultural areas, respectively. Other factors also contribute to the high level of water consumption, including the cultivation of high water-consuming crops (e.g., alfalfa) and the absence of cost-reflective agricultural water tariffs.

Water supply is particularly sensitive to the adverse impacts of climate change and directly affects the agriculture sector. Furthermore, this situation is exacerbated by the scarcity of arable land comprising only 2.1% of the available land and competing demand for land resources from other sectors. Additionally, high soil salinity, resulting from the use of groundwater for irrigation, has reduced the area of arable land that can be used for cultivation. As a result, the already low productivity of the agricultural sector due to limited arable land and the arid climate, will be further exacerbated by climate change.

Although the fisheries and aquaculture sectors are less vulnerable to the climate change threats that affect agricultural production, they are nevertheless threatened by long-term stresses from climate change. Increases in water temperatures due to climate change alter the ecosystem fishers rely on for their catch, while economic growth and human activity irrevocably alter fish habitats. Safi for example is a highly demanded local species but rising seawater temperatures are causing its migration to the deeper sea. Sea bream is also sensitive to increasing temperatures. For example, at 37°C over 90% of the sea bream stocks could be lost.

Already scarce water and arable land, compounded by possible climate change impacts, limit any substantial expansion of the agricultural sector. As such, Bahrain has leveraged its economic wealth to import over 90% of its food requirements. A critical concern for Bahrain is how increasingly frequent droughts, extreme temperatures and other climate change impacts might impact the key food production supply chains and the resulting high food prices.

## Adaptive Capacity

To be able to increase domestic food production in Bahrain, optimize use of available water, and safeguard natural resources, there is an urgent need in finding long-term, cost-effective solutions and actions to ensure sustainability of local production and mitigate the adverse impact of climate change on essential imported food commodities. Some of these actions include:

- Adopt innovative sustainable and resilient agricultural approaches (such as climate-smart agriculture), taking into consideration water and water use efficiency and soil quality, including further research into stress-tolerant crops.
- Invest in innovative crop production, water-efficient and renewable energy technologies to ensure sustainability and identify potential for high-value crops that have better yield per drop of water.
- Ensure that climate change and resource management is factored into policymaking, research, and practices to ensure sustainability.
- Undertake further analysis to better understand the impacts of climate change on food markets (especially wheat and rice), considering relevant global studies, and diversify imports accordingly.

Improving the general resilience of fisheries and aquaculture systems can reduce their vulnerability to the impacts of climate change and climate variability on resources and to severe weather episodes. Some of the key climate resilience measures include:

- Strengthening the implementation and enforcement of current regulations to protect marine resources and ensure the high quality of coastal water near fisheries operation sites and areas with potential for aquaculture.
- Promote responsible development of the fisheries sector based on ecosystem-based management approach to enhance adaptive capacity to climate change and ensure that environmental carrying capacity is not exceeded.
- Climate-proofing investments along the fisheries value chain (handling, transport, storage and processing) to build the adaptive capacity of the sector to climate change.
- Ensure that climate change and resource management are factored into fisheries' policymaking, research, and practices to ensure sustainability.

To address climate change impacts on the livestock and poultry sector and the resulting food-borne diseases, the following measures are recommended:

- Improve disease surveillance and response to detect changes in disease in a timely way, thus dramatically reducing the costs of response.
- Improve animal health service delivery by investing in the public sector and supporting innovations in the private sector.
- Support eradication of priority diseases by developing effective diagnostics, vaccines and promoting adoption of good practices and strengthening biosecurity.
- Increase the resilience of livestock systems by promoting species and breeds that are more resistant to disease and climate change.

Responding to the challenges posed by climate change for food security requires an integrated, cross-sectoral approach, guided by multi-stakeholder dialogue and partnerships.

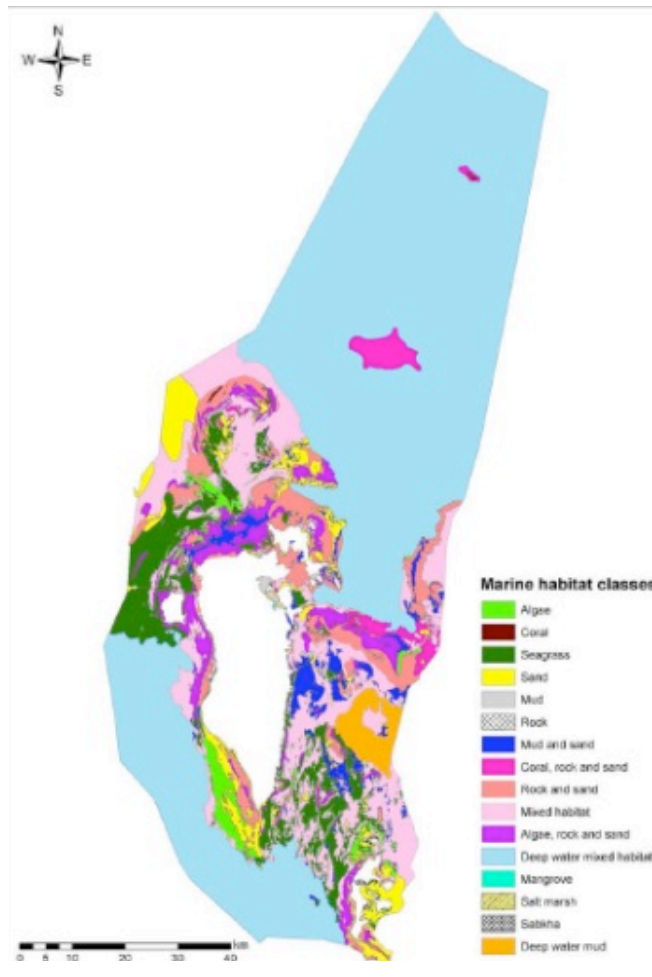
## **2.3 Ecosystem Services & Biodiversity**

Bahrain is an archipelago consisting of approximately 84 natural and artificial islands in addition to several islets, shoals, and patches of reef. The main island is predominantly a desert ecosystem, except for a narrow fertile strip along the northern and northwestern coastline, surrounded by marine and coastal ecosystems. The coastline, measuring 946 km in length, includes areas that have been extensively reclaimed over the last 30 years, causing damage to coastal areas and deteriorating many coral reefs and seagrass beds. The National Biodiversity Strategy and Action Plan (2016) identified four main ecosystem types: marine, coastal, desert, and agricultural.

Marine waters and coastal areas support several important ecosystems including mangroves, seagrass beds, coral reefs, and intertidal mudflats (Figure 3). These habitats provide a variety of ecosystem services to the country and its economy, including shoreline stabilization and protecting coastlines against storms, enabling areas for diving and recreational activities, carbon sequestration, biodiversity and fisheries for food security.

Seagrass beds occupy approximately 33,700 ha, with most of the seagrass habitats located in the eastern subtidal waters of the country, mainly south of Fasht Al-Adham extending to Hawar Islands and in the western subtidal areas. Seagrass beds constitute a habitat and rich feeding ground for commercial fisheries, mollusks, and crustaceans. They also support internationally recognized populations of endangered species, particularly the world's largest group, and second largest population of dugongs. Seagrass beds offer considerable potential for carbon

**Figure 3: Marine Habitat Classes (2009)**



Source: Louehland & Zainal, 2009

sequestration. While wide arrays of seagrass exist in Bahrain (Figure 3) some extents have been damaged by sedimentation and pollution which can greatly impact their ability to photosynthesize.

Coral reefs, locally known as 'Fasht', expand over a large area in Fasht Al-Adham and Khawr Fasht, Fasht Al Jarim, and Najwat Bulthama. Coral reefs provide similar ecosystem services as seagrass beds and help maintain a large diversity of fish, supporting over 230 species and numerous shellfish species. They also constitute the nurseries for commercial fish species. In 1996 and 1998, Bahrain was severely affected by hot summers resulting in coral bleaching events.

Mangroves are a saline-adapted forest ecosystem that occurs in coastal regions of the world. In Bahrain, mangroves, populated by *Avicennia marina*, are naturally present in Tubli Bay at 80ha with the largest natural extant in Ras Sanad at 50 ha. Manual transplanting of mangroves has been conducted throughout the country to restore and promote this ecosystem and

its associated services. Some of these locations include Sitra, Arad Bay and Al-Aker. Mangroves stabilize navigation channels and shorelines, prevent inundation from sea level rise and shamal-induced flooding of coastal property by the sea. Mangroves are also one of the most important buffers against catastrophic flooding brought about by cyclones or tidal waves. However, the natural mangrove area in Bahrain has been reduced to Tubli Bay by land reclamation, pollution, and sewage discharge.

Bahrain's terrestrial ecosystems include both the desert and agriculture ecosystems which encompass palm groves, freshwater springs, local variety of crops and home to numerous species of insects, reptiles, birds, and wild mammals. Inland arid regions and plateaus support regional biodiversity and a wide range of migratory birds. They contain freshwater springs and streams that support biodiversity. Deserts show three landforms including Jabals (small rocky hills), depressions, and dunes. Jabals reach 130m in altitude, with the most well-known mountain

being Jabal Al Dukhan. The most significant ecosystems are oases and freshwater springs that are important in supporting biodiversity and providing ecosystem services. The Kingdom designated the Al Areen Wildlife Park as a nature reserve and zoo, which covers 800 ha and hosts the Arabian oryx. In July 2022, Wadi Al-Buhair was declared a terrestrial protected area.

The Kingdom hosts a number of protected areas, among which are several sites of international significance, including Ramsar and UNESCO World Heritage Sites. Species with the highest conservation value consist of dugong, breeding sea birds, and sea turtles, including leatherback, hawksbill, and green turtle species. The Kingdom supports important regional breeding bird populations, including the largest breeding populations of Socotra cormorant in the world; the largest breeding population of western reef heron (*Egretta gularis*) in the Middle East, and is recognized as a regional hotspot for seasonal migratory birds.

There are six designated marine protected areas in Bahrain: Hawar Islands, Tubli Bay, Arad Bay, Mashtan Island, Northern Hayrat, and Najwat Bulthamah. Together, these marine protected areas cover 21.4% of Bahrain's territorial waters. Hawar Islands constitute an archipelago of coastal habitats, including extensive seagrass beds, supporting dugong, turtles, dolphins, and breeding and migratory colonies of birds. Mashtan Island is a Marine Protected Area, characterized by large seagrass beds that provide a habitat for dugong and sea turtles. Najwat Bulthama contains the healthiest coral reefs in Bahraini waters and important fishery stocks. The Northern Hayrat (Hayr Bulthamah, Hayr BuA'mamah and Hayr Shttayah) are pearl oyster beds and designated as both a Marine Protected area and a UNESCO World Heritage Site which stems inland to include mainland historical sites comprising of the "Pearling Path".

Tubli Bay, in the northeast of Bahrain, supports mudflats, seagrass, and mangroves, providing essential nurseries for fish species and feeding grounds for shorebirds and was established as a marine protected area and a Ramsar site. Tubli Bay is the only natural extant of mangroves in Bahrain, with an approximate area of 80 ha. Dohat Arad is a shallow bay located in the northeast of Bahrain, designated as a protected area. The bay is essential for inter-tidal mudflats, and a key site in the mangrove planting project where mangroves have been transplanted and witnessing a natural expansion in the area.

## Exposure

Climate change will likely have direct and indirect impacts on Bahrain's marine ecosystems. The marine ecosystems are particularly vulnerable to the combined effects of warming oceans, sea level rise, increased evaporation, and potential changes in storm patterns. Given its limited land area, Bahrain has engaged in considerable land reclamation efforts. Reclamation has resulted in the addition of approximately 115 sq. km of land between 1981 and 2018, representing an increase of 17% of the total land area (Bahrain Open Data Portal). As a result, reclamation activities have extensively modified more than 80% of Bahrain's coastline. These activities affected the coastal and marine environment, including marine mammals.

The low-lying nature of the coastal zone habitats exposes them to rising sea levels, affecting mangroves, wetlands, and seagrass beds. Mangroves have high exposure to sea level rise as the mangrove species are sensitive to prolonged exposure to seawater flooding. As a result of urbanization around Tubli Bay, there are no natural areas for mangroves to migrate inwards. Wetlands are also projected to be affected by sea level rise. Under a 0.5 m sea level rise, approximately 27 sq.km, or nearly half of all wetlands would be impacted and nearly three quarters of the wetlands would be impacted if sea levels rise by up to 1.5 meters. As a result, many low-lying coastal habitats, such as in the Hawar Islands, might witness a loss of resident

and migratory sea birds. Third, sea level rise may also indirectly impact seagrass beds and coral reefs, particularly related to reduced light levels. Finally, sea level rise is predicted to result in seawater intrusion of inland aquifers. While the specific implications for freshwater oases located inland have not been ascertained, rising sea levels combined with precipitation change are likely to result in lower levels of groundwater recharge.

Coral bleaching affects coral reefs when temperatures go 1°C above normal summer averages. The Arabian Gulf has some of the warmest summer temperatures in the world reaching 33°C in the summer. Based on past thermal stress metrics, it is thought that Bahrain has experienced three or four bleaching events since 1985. The coral mortality during these events, and subsequent recovery, is unknown as there is no regular monitoring of coral reefs in Bahrain. However, a recent study conducted by SCE indicates that corals in the Arabian Gulf may be naturally adapted to higher temperatures and resistant to coral bleaching. As a result, annual bleaching events are not considered as a concern until 2080.

Impacts of oceanic warming, salinity fluctuation, and acidification on ecosystems interact cumulatively. Extreme seasonal temperatures and salinity fluctuations have and will continue to lead to natural selection for species with high tolerance or adaptability to such short-term changes. Such selection will impact the overall species composition within the ecosystems and may represent a natural adaptive response.

## Sensitivity

Climate change is expected to impact marine organisms and associated fisheries. Under a high emission scenario (RCP 8.5), Bahrain is projected to experience a moderate decline in the maximum potential catch in marine species currently being exploited compared to other countries located around the Arabian Gulf (see Table 6). Climate-driven perturbations in local and regional environmental conditions will make most of the southern Gulf unsuitable for certain species. The decline in species habitat suitability is projected to be translated directly into a decrease in maximum fisheries catch potential. Traditionally, the shrimp fishery is the most important in Bahrain. Although total catches have generally shown an increasing trend since the mid-1980s, the species composition has changed with declines in catches of some originally targeted species being compensated by increases in the catch of crustaceans such as shrimps and crabs.

**Table 6. Projected sensitivity of fisheries to adverse impacts of climate change**

Country	Decline in maximum potential catch	Socio-economic impact
<b>Bahrain</b>	0.40 (5)	0.73 (1)
<b>Iran</b>	0.39 (6)	0.48 (2)
<b>Oman</b>	0.90 (2)	0.13 (7)
<b>United Arab Emirates</b>	0.96 (1)	0.38 (3)
<b>Iraq</b>	0.10 (8)	0.34 (4)
<b>Qatar</b>	0.76 (3)	0.22 (5)
<b>Saudi Arabia</b>	0.58 (4)	0.09 (8)
<b>Kuwait</b>	0.16 (7)	0.18 (6)

Source: *Climate change impacts on marine biodiversity, fisheries, and society in the Arabian Gulf*. PLoS ONE, Vol. 13 Issue 5, 1-26, Wabnitz, et al., 2018

Note: Socio-economic impact considers the importance of the marine fisheries sector to local livelihoods, the importance of as a source of nutrition, the share of the fisheries sector in the domestic economy, and the importance of marine ecosystems for coastal protection

Average sea temperatures in Bahrain are predicted to warm by between 1 and 6°C by 2100, depending on the emissions scenario. A warming of 6°C under high emissions scenario (RCP 8.5) would mean it is unlikely that corals will persist. The fate of local coral reefs will be linked to the achievement of global climate commitments. However, ocean acidification is unlikely to be a major threat as the Arabian Gulf has one of the highest aragonite saturations in the world and it is expected to stay within suitable ranges for coral reefs within this century.

## Adaptive Capacity

Coastal and marine ecosystems are particularly vulnerable to the combined impacts of climate change, including warming oceans, sea level rise, and increased evaporation. These climate impacts need to be addressed to create resilient ecosystems in Bahrain.

The Kingdom of Bahrain has taken proactive steps to protect its coastlines, most notably conducting a precautionary study and developing a coastal resilience plan that addresses different scenarios. The study culminated in the recommendation of over 192 actions to increase the Kingdom's climate resilience and to protect residential areas, commercial premises, cultural and religious assets, and key national infrastructure.

As part of this modelling assessment, an online WebMap tool was created, enabling relevant actors to interactively interrogate the inundation extents for all examined sea level rise (SLR) scenarios and the exposure of individual assets to each scenario. Accordingly, the WebMap may be used to align present and future decision-making related to coastal resilience, as new data becomes available, and a multitude of factors are adjusted on the tool. Key recommendations for future data gathering and coastal monitoring identified in this modelling assessment included:

- Continued monitoring of tide levels around Bahrain to generate longer time series that can be used for calibration of hydrodynamic models, or directly for water level assessments.
- Collation of records of all coastal structures (geometry, material, foundations and condition) for a complete understanding of existing defenses, and potential vulnerabilities.
- Continued refinement of central asset records, in particular the identification of asset sector, function, and type.
- Monitoring of changes to coastal morphology and marine habitats to inform development of appropriate protection or enhancement projects as part of longer-term adaptation plans and flood risk mitigation.

In regard to ecosystems' resilience, the establishment of resilient and diverse marine protected areas and the development of sustainable management strategies are considered essential options to protect coastal and marine ecosystems. To strength resilience and adaptive capacity, key principles should be considered including:

- Protecting key ecosystem features and building a heterogeneous system of protected areas; for example, seagrass beds adjacent to coral reefs can reduce the impacts of acidification.
- Ensuring connectivity between protected areas to facilitate continued migration of those species faced with changing salinities, temperature, and acidification; for example: marine protected area networks
- Supporting the evolutionary potential to protect a variety of species, habitats, and populations in multiple places to balance potential losses from climate disturbances, and where possible, manage these systems in ways that assist positive evolutionary change (such as the incorporation of migratory corridors).

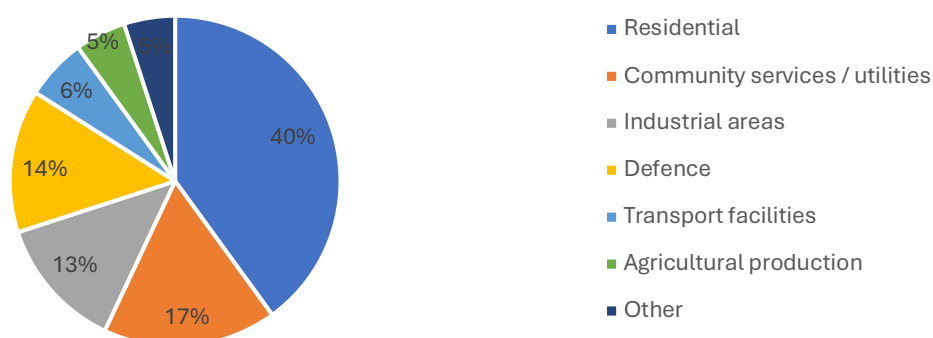
In recognition of the contribution of the country’s natural assets to culture, economic, and scientific value, the Government of Bahrain has developed different plans and strategies, including the National Biodiversity Strategy and Action Plan 2016-2021, National Environmental Strategy (2006), and the Nationally Determined Contribution (2020). These plans and strategies have provided a framework and targets for maintaining and enhancing the country’s conservation values, considering climate factors and the need to reduce and mitigate anthropogenic impacts. Notably, a review and update of the National Biodiversity Strategy and Action Plan, aligned with the Post-2020 Global Biodiversity Framework, is underway.

## 2.4 Urban Development

Bahrain is a highly urbanized country, with nearly 90% of the country’s population living in urban areas. Most of the population is centered in the capital, Manama, and other major urban centers like Muharraq, Riffa and Hamad Town. The national population has grown rapidly from 0.5 million in 1990 to approximately 1.6 million in 2023 and is projected to increase to 2 million by 2030. The rapid population growth has led to considerable urban development, putting strain on the country’s ecological resources, and reducing land availability.

Given Bahrain’s small geographical size, a considerable share of the land area is dedicated to urban and industrial land use, limiting the amount of land available for agriculture and other purposes. According to the Urban Planning and Development Authority, about 40% of the land is currently dedicated to residential areas and housing projects, 17% to community services/utilities, 14% to defense, 13% to industrial areas, 6% to transport facilities, 5% to agricultural production, and 3% to tourism.

**Figure 4: Land Use Pattern in Bahrain (2016)**



*National Detail Land Use Map 2030*

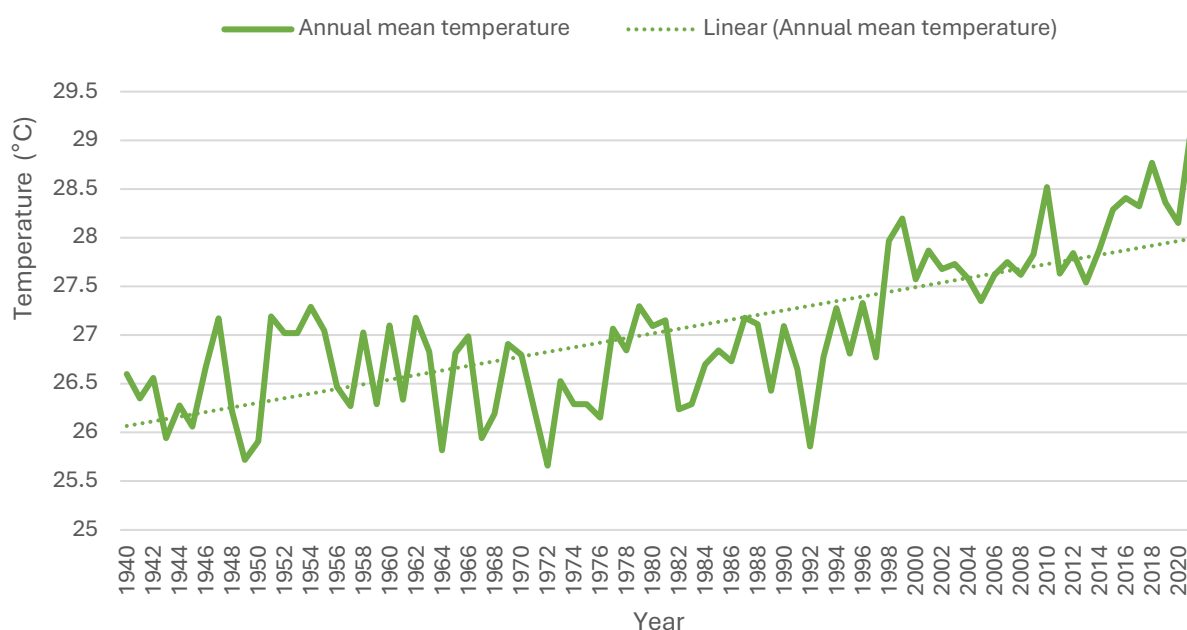
Land reclamation has increased Bahrain’s land area from 665 sq.km in 1981 to 780 sq.km in 2018. However, land reclamation has been insufficient to address the land-use need for infrastructure. Estimates suggest that urbanized areas in Bahrain have doubled from 76.2 sq.km in 1987 to 155 sq.km in 2013 and has contributed to a decline in arable land area. The Urban Planning and Development Authority has started exploring the concept of sustainable urban development.

## Exposure

Urban development and the built environment in Bahrain will be exposed to two threats related to climate change: rising sea levels and increasing temperatures. The coastal areas of Bahrain have a high population density and are only located 5 meters above sea level on average. As a result, some coastal areas are exposed to the threat of rising sea levels. Exposure differs between the various islands that constitute Bahrain, depending on land elevation. Bahrain’s Coastal Resilience Study 2023 identifies that the risk after 2050 from a 0.5m SLR accompanied with a surge event is greater for several locations, predominantly in the Northwest of Bahrain, such as Muharraq and Manama, which host significant numbers of critical infrastructure assets in residential and industrial areas. The impact on Southern Bahrain Island from rising sea levels is expected to be moderate.

Bahrain’s urban development and the built environment are also exposed to increasing ambient temperature. Different greenhouse gas (GHG) emissions scenarios suggest an increase in average annual temperature between 0.22°C and 0.96°C by 2035. As a country already situated in an arid region, even a comparatively small increase in temperature could have considerable impacts. In particular, the capital city Manama, has increasingly witnessed the urban heat island effect, which is defined as an area experiencing higher temperatures than its surrounding neighborhood. This effect is primarily driven by a shortage in green spaces and impervious surfaces that can help reduce ambient temperatures.

**Figure 5: Mean annual temperature in Bahrain (1940-2021)**



## Sensitivity

The built environment plays a central role in Bahrain's past and future economic prosperity. Bahrain is a highly urbanized country, with about 90% of the country's population residing in urban areas. In addition, the country's economy is highly dependent on industrial facilities extracting and processing crude oil and natural gas, with the sector accounting for roughly a quarter of the gross domestic product.

Bahrain's Economic Vision 2030 also underlines the central role of physical infrastructure for future economic development. It envisions the establishment of world-class infrastructure, including the expansion of urban infrastructure such as roads, buildings, utilities, and services. Future construction and development of urban areas must consider coastal resilience and increasing temperatures on its physical infrastructure. Therefore, preventive actions should be taken to build infrastructure to ensure the safety of communities.

Sea level rise is expected to have several effects, including inundation and saline intrusion into freshwater sources. Of the two, inundation is considered more relevant for the built environment, as saline intrusion affects water supply and agriculture. Inundation caused by sea level rise is limited to the most extreme (and unlikely) scenarios, but it may reduce available land and damage to infrastructure, such as buildings, industrial facilities, roads, and the airport.

Second, rising temperatures are expected to increase electricity consumption due to a higher demand for air conditioning. An estimated 93% of the total building stock consists of residential and commercial buildings, which together represent about 87% of annual electricity consumption. Bahrain will be able to accommodate the rising demand. However, given that electricity in the country is exclusively generated from natural gas, higher electricity consumption is likely to cause higher levels of GHG emissions, undermining mitigation efforts.

## Adaptive Capacity

The Government of Bahrain has taken some actions to address the adverse impacts of climate change on urban areas.

In response to rising sea levels, the Government of Bahrain has decided to consider 0.5 meters of sea level rise as the planning standard for all purposes. In 2008, the 'Guidelines for coastal development lands and artificial islands' were updated to reflect the expected sea level rise of 0.5 meters. Furthermore, in 2009, building codes were revised to reflect potential impacts from sea level rise. The revised code mandates that the ground floor of any new building has to be located 1.5 meters above pavement level. However, this provision only applies to new buildings and not the existing building stock.

As part of the scope of work of the 2023 coastal resilience study (See Section 2.3), a committee consisting of a range of relevant government stakeholders was formalized to adopt recommendations, agree priorities and timescales, and prepare an action plan for ministries, companies and relevant parties affected by potential sea level rise. Proposed actions include both nature-based and engineered solutions, such as beach enhancements, coastal boulevards and short walls. In some cases, these actions an opportunity to enhance public amenities or a continuation of existing action being undertaken in the Kingdom such as planting mangroves.

In response to increasing temperatures, options for adaptation include changes in building design, more energy-efficient space cooling, and nature-based solutions. First, retrofitting buildings and revising the building code to include provisions on building orientation, heat

management of windows, and external shading, can strengthen adaptation to increased temperatures. While there is an initiative to retrofit government buildings, future initiatives may consider targeting other private buildings.

Second, rising temperatures are expected to result in higher electricity consumption for air conditioning. Unless Bahrain moves away from electricity generation from natural gas to renewable sources or increases the energy efficiency of space cooling, higher electricity consumption will cause an increase in GHG emissions, undermining mitigation efforts. Efficiency can be increased by replacing existing air conditioning units with less energy-intensive individual systems or changing system design away from individual units to district cooling, relying on the centralized distribution of chilled water through an insulated underground piping network.

Bahrain is considering long-term solutions to reduce temperatures, such as increasing green cover in the urban areas by planting. Nature-based solutions such as increasing green cover in the urban areas are effective solutions to combat rising temperatures and the resulting urban heat island effects. The Urban Planning and Development Authority has approved the Capital Governorate zoning map, which lays out various zones in the country, focusing on the main island. Zones such as the green building area, commercial green area, and special nature projects area seem to contribute to green spaces that could help limit temperature rise in the city core.

In addition, initiatives and strategies such as the Biodiversity Strategy and Action Plan, and the National Afforestation Plan in Bahrain aim at increasing green open spaces. The National Afforestation Plan outlines tree species that can be planted considering the geography, soil type, and climatic factors, such as high temperatures and high dust levels, limited water availability, wind, and salinity levels. Treated wastewater irrigation, rather than freshwater, is suggested for public landscaping to avoid negative effects on water availability.

## 3.0 PROJECT PIPELINE

### 3.1 Long List of Adaptation Actions

Based on the situational analyses of the four sectors – Water Resources, Agriculture & Food Production, Ecosystem Services & Biodiversity, and Urban Development, a wide range of climate adaptation actions in alignment with governmental policies and plans and respective sectoral objectives were identified. A total of 47 adaptation actions in the four sectors were identified for the NAIP project pipeline, each demonstrating potential for significant need of climate finance.

**Table 7: Identified climate adaptation actions**

Adaptation Sector	Sub-Sector	Number of Adaptation Actions
Water Resources	Groundwater Resources	3
	Municipal Water Supply	5
Agriculture & Food Production	Advanced Farming Practices	4
	Crop Production	8
	Livestock Production	4
Ecosystem Services & Biodiversity	Coastal Zones	7
	Marine & Desert Ecosystems	4
Urban Development	Urban Environment	7
	Climate Resilient Buildings	5

The potential climate adaptation actions for the respective sub-sectors along with the climate adaptation impact are summarized in the tables below.

#### Groundwater Resources

Seawater intrusion and reduced precipitation combined with groundwater over exploitation have direct impacts on groundwater recharge, discharge, and storage characteristics. Climate change and sea level rise are expected to further intensify these impacts. The potential actions identified for the NAIP project pipeline are summarized in Table 8.

**Table 8: Potential actions to enhance resilience of groundwater resources**

No.	Adaptation Actions	Climate Adaptation Impact
1	Saline reduction in natural aquifers through development of artificial subsurface barriers	Reduces vulnerabilities arising from water scarcity and increasing salinity of natural freshwater sources
2	Relocation of groundwater pumping location from coastal regions to inland regions	
3	Groundwater recharge using treated wastewater	

## Municipal Water Supply

Increasing water scarcity is one of the main climate change threats. Water efficiency measures will lower water demand, reduce costs, and make utilities less vulnerable to shortfalls due to high demand or service disruptions from extreme weather events. The potential actions identified for the NAIP project pipeline are summarized in Table 9.

**Table 9: Potential actions to enhance resilience of municipal water supply**

No.	Adaptation Actions	Climate Adaptation Impact
4	Smart metering devices for monitoring of water use to raise awareness among consumers	Reduces vulnerabilities arising from water scarcity and loss of natural freshwater sources
5	Use of water saving devices	
6	Leakage reduction measures in municipal water distribution pipelines	
7	Replacement of old pipelines with corrosion resistant water distribution pipelines	
8	Reuse of treated wastewater	

## Advanced Farming Practices

Under a changing climate, farming practices will need to adapt to deal with climate related threats through efficiency in water usage, enhanced resilience to droughts and avoid overheating of crops grown outdoors and indoors. The potential actions identified for the NAIP project pipeline are summarized in Table 10.

**Table 10: Potential actions to advance climate resilient farming practices**

No.	Adaptation Actions	Climate Adaptation Impact
9	Upgradation and cooling of greenhouse farm facilities with energy efficient cooling technologies, coupled with smart systems for monitoring and process optimization	Reduces vulnerabilities arising from water scarcity and extreme temperatures, and lowers GHG emissions
10	Modern vertical and controlled farming practices requiring less amount of freshwater such hydroponic, aeroponic and aquaponic methods	
11	Advanced rainwater harvesting systems to enhance groundwater recharge and reduce need for desalinated water	
12	Adoption of advanced water efficient drip, sprinkler, or micro-sprinkler irrigation systems	

## Crop Production

Crop production is highly sensitive to climate change and is affected by long-term trends in average rainfall and temperature, interannual climate variability and extreme weather events. The potential actions identified for the NAIP project pipeline are summarized in Table 11.

**Table 11: Potential actions to enhance resilience of crop production**

No.	Adaptation Actions	Climate Adaptation Impact
13	Cultivation of native and climate compatible crop species that require less freshwater	Reduces vulnerability arising from water scarcity and sea level rise by reducing the demand for freshwater from groundwater sources and desalination plants
14	Crop production using drought-resistant, salinity-tolerant seed varieties or those that can use lower quality water (treated wastewater)	
15	Adoption of organic fertilizers to reduce environmental damage caused by eutrophication and leaching into aquifers	
16	Genetically modified (GMO) crop production for improving yields, and increasing resistance to disease, draught, heat, and soil salinity	
17	Seaweed and macro-algae farming for use as animal fodder, thereby reducing freshwater requirement	
18	Production of animal fodder using saline water	
19	Land-based aquaculture - Use of brine from desalination plants in aquaculture, and integrated multi-trophic aquaculture	
20	Sea-based integrated multi-tropic aquaculture, reducing need for inland aquaculture farms	

## Livestock Production

Climate change, including the effects of climate variability and extremes, have direct effects on livestock productivity, either on the animal directly (e.g., through heat stress) or indirectly through effects on crop production and the disease vectors to which the livestock are exposed. The potential actions identified for the NAIP project pipeline are summarized in Table 12.

**Table 12: Potential actions to enhance resilience of livestock production**

No.	Adaptation Actions	Climate Adaptation Impact
21	Climate-controlled housing to protect animals from heat by installing energy efficient cooling technologies	Reduces heat stress in animals due to high temperatures

<b>22</b>	Improved animal health and husbandry practices (advanced vaccines, supplements, medicines etc.) to reduce the incidence and impact of diseases, parasites, and insect burdens	Improved animal health leads to better adaptation to heat and water stresses
<b>23</b>	Sustainable animal breeding practices to improve livestock's adaption to changing environments and resistance to stress, shocks and diseases	
<b>24</b>	Biofuel based Trigenation systems (combined cooling, heat, and power) utilizing animal and other bio-wastes as input feedstock to produce biogas using the anaerobic process	Reduces vulnerabilities arising from water scarcity and extreme temperatures, and lowers GHG emissions

## Coastal Zones

Coastal development and restoration measures aim at re-establishing the natural functions of wetlands that have been degraded by natural and human activities. The potential actions identified for the NAIP project pipeline are summarized in Table 13.

**Table 13: Potential actions to enhance resilience of coastal zones**

<b>No.</b>	<b>Adaptation Actions</b>	<b>Climate Adaptation Impact</b>
<b>25</b>	Restoration of mangrove forests	Increases coastal resilience and improves the restoration of coastal ecosystems and habitats
<b>26</b>	Restore and maintain seagrass beds to reduce erosion and enhance coastlines against storms by trapping and stabilizing the sediments	
<b>27</b>	Creation of artificial reefs for development of biodiversity hotspots and reduction of wave impacts	Restore marine ecosystems destroyed by human activities such as overfishing, island development and land extension along the coast lines
<b>28</b>	Enhance shoreline protection and fish-rearing habitats	
<b>29</b>	Construction of physical barriers along the coast (saline intrusion walls) to block seawater intrusion	Reduces vulnerability arising from sea level rise and water scarcity by reducing the seepage of sea water in the natural underground aquifers
<b>30</b>	Raise coastal roads and build storm surge defense structures to block seawater intrusion	
<b>31</b>	Coastal information and monitoring systems to enhance operational safety in offshore / inshore operations	Protection of marine ecosystems and related biodiversity. Reduces vulnerabilities from rise in sea level and increasing storm surges

## Marine and Desert Ecosystems

Healthy marine and desert ecosystems are critical factors in building resilience and addressing vulnerabilities to climate change. The potential actions identified for the NAIP project pipeline are summarized in Table 14.

**Table 14: Potential actions to enhance resilience of ecosystems**

No.	Adaptation Actions	Climate Adaptation Impact
32	Seawater intake and discharge optimization of thermal and desalination plants	Restores marine ecosystems at the water intake and discharge regions
33	Treatment of high saline industrial wastes	Restores marine ecosystems and coastal biodiversity
34	Protection and rehabilitation of desert ecosystems	Improves and sustains desert wildlife and related ecosystems.
35	Development of green belt areas in desert areas	Improves water retention and groundwater recharge, and provides natural protection from heat exposure

## Urban Environment

Cities need to adapt to climate change in order to remain livable, functional, and prosperous in the future. The potential actions identified for the NAIP project pipeline are summarized in Table 15.

**Table 15: Potential actions to enhance resilience of urban environment**

No.	Adaptation Actions	Climate Adaptation Impact
36	District cooling for urban areas	District cooling plants utilize seawater and is significantly more efficient, reliable, and sustainable when compared to conventional cooling systems
37	Increase afforestation and create greenbelts around urban centers to reduce wind speeds, dust pollution and desertification	Green spaces provide natural cooling through shading and enhanced evapotranspiration, thus reducing the heat island effect
38	Climate proof roads by incorporating more permeable and porous surfaces that stores less heat than asphalt and concrete	Reduces the Urban Heat Island effect and promotes water infiltration during storms
39	Heat-protective clothing for outdoor workers	Mitigates the human health impacts and reduced labor productivity from high temperatures and associated heat waves
40	Accessible hydration and cooling systems	
41	Medical surveillance and early detection of heat stress and heat stroke symptoms	

42	Climate proofing of urban mass transit systems	Climate resilient mass transit systems infrastructure can become shelters for the local population during an extreme weather event
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## Climate Resilient Buildings

Climate resilience measures can be integrated into commercial buildings and individual houses. New build property and re-developments/refurbishments of existing stock offer good opportunities to build-in climate resilience measures at lower capital cost. The potential actions identified for the NAIP project pipeline are summarized in Table 16.

**Table 16: Potential actions to promote climate resilient buildings**

No.	Adaptation Actions	Climate Adaptation Impact
43	Construction of new government buildings and public housing with green building standards for energy and water efficiency	Reduces vulnerabilities arising from water scarcity and extreme temperatures, and lowers GHG emissions
44	Refurbishment of existing buildings by developing green and blue roofs that can be used for water management and to create resilience in built environments	
45	Climate proofing of buildings against excessive heat through use of heat reflecting building façades, and responsive modular shade structures that follow the sun	
46	Implementation of natural cooling measures in buildings, dew harvesting, etc.	
47	Energy efficient buildings by installing external and internal insulation material that reduces energy consumption for cooling	

## 3.2 Prioritization Approach

A multi-criteria analysis approach was employed for prioritizing the adaptation actions that are most suited to Bahrain’s national circumstances. Key stakeholders from relevant government ministries and experts from the respective four sectors were consulted in the setting of criteria and the assessment of adaptation actions, as well as in the subsequent prioritization.

The multi-criteria analysis employed for identifying the NAIP project pipeline considered potential impacts across three categories:

1. Economic (monetary value of damages to property, livelihood, and infrastructure)

2. Social (size, segments and vulnerability of population affected)
3. Environmental (effects on species, habitats, or landscapes)

Key stakeholders from relevant government ministries and experts from the respective four sectors were consulted in the setting of criteria, assessment of adaptation options, as well as in the subsequent prioritization. Stakeholders who were engaged include the SCE; relevant line ministries, including the Ministry of Transportation and Telecommunications, the Ministry of Works, the Ministry of Municipalities Affairs and Agriculture; relevant authorities, such as the Electricity and Water Authority and the then-National Oil and Gas Authority, as well as the then-Sustainable Energy Center.

During consultative sessions conducted for each of the four sectors, experts were asked to provide a value for the expected magnitude of the impact of each of the adaptation options across those three dimensions. See Annex 1 for the information provided to participants to standardize the responses through a common definition of the various levels for perceived magnitude of impact.

The aggregate scores for adaptation actions were calculated and classified as per the formula below:

**Table 17: Multi-criteria analysis**

Assessment Criteria		Expected Impact (Score of 1-5)	Aggregate score (max = 100)		
Economic (MEco)		Very Small = 1 Small = 2 Moderate = 3 Large = 4 Very large = 5	Magnitude = $\frac{(M_{Eco}+M_{Env}+M_{Soc})}{15} \times 100$		
Environmental (MEnv)					
Social (MSoc)					
Classification of Climate Adaptation Impact (Based on magnitude of aggregate score)					
0 – 20	21 – 40	41 – 60	61 – 80	81 – 100	
Very Small	Small	Moderate	Large	Very Large	

Adaptation actions with an aggregate score greater than 60 were prioritized for the NAIP project pipeline.

### 3.3 Short List of Adaptation Actions

Based on consultation with stakeholders, 12 adaptation actions were prioritized in the four sectors most impacted by the threat of climate change. The investment concept notes have been developed to address these 12 actions prioritized by stakeholders.

These 12 priority adaptation actions are summarized in Table 18.

**Table 18: Priority adaptation actions**

No.	Sector	Adaptation Action	IPCC Category
1	Water Resources	# 3. Groundwater recharge using treated wastewater. #8. Reuse of treated wastewater	Physical & Structural Physical & Structural
2	Agriculture & Food Production	# 9. Upgradation and cooling of greenhouse farm facilities with energy efficient cooling technologies, coupled with smart systems for monitoring and process optimization. # 10. Modern vertical and controlled farming practices requiring less amount of freshwater such hydroponic, aeroponic and aquaponic methods. #12. Adoption of advanced water efficient drip, sprinkler, or micro-sprinkler irrigation systems #13. Cultivation of native and climate compatible crop species that require less freshwater. #14. Crop production using drought-resistant, salinity-tolerant seed varieties or those that can use lower quality water (treated wastewater) #21. Climate-controlled housing to protect animals from heat by installing energy efficient cooling technologies. #22. Improved animal health and husbandry practices (advanced vaccines, supplements, medicines etc.) to reduce the incidence and impact of diseases, parasites, and insect burdens.	Physical & Structural Physical & Structural Institutional Institutional Institutional Physical & Structural Institutional
3	Ecosystem Services & Biodiversity	#25. Restoration of mangrove forests #28. Enhance shoreline protection and fish-rearing habitats.	Physical & Structural Institutional
4	Urban Development	#37. Increase afforestation and create greenbelts around urban centers to reduce wind speeds, dust pollution and desertification.	Physical & Structural

A review of the 12 priority adaptation actions indicates that:

- The prioritized actions are a mix of adaptation actions that are categorized by the IPCC as “Physical and Structural” (i.e., those that involve structural and engineering options, the application of discrete technologies, the use of ecosystems and their services) and “Institutional” (i.e., economic, social and policy measures or regulations).
- The 7 actions categorized as “Physical and Structural” are adaptation actions such as restoring mangrove ecosystems and constructing infrastructure for the reuse of treated wastewater.
- The remaining 5 actions categorized as “Institutional” are adaptation actions such as development of new policy initiatives, implementation of new regulations and incentives to accelerate climate resilient farming practices.
- A number of the prioritized actions such as climate-controlled farming and climate-proofing livestock facilities are cross-cutting actions having strong climate mitigation co-benefits.
- A number of the proposed actions in the municipal water supply and climate resilient buildings sub-sector have either been implemented or are currently under implementation by the respective ministries and hence not included in the list of priority adaptation actions.
- Most of the actions are at a preparatory stage and will require further development to reach the financing stage.

## 4.0 INVESTMENT CONCEPT NOTES

Development of climate adaptation projects is a complex process involving multiple stakeholders from various government ministries. The preparation of the investment concept notes is an essential first step in the process and is needed to:

- Identify and assess potential climate adaptation investment projects by providing a high-level overview of the project, including the problem it is addressing, the solution it proposes, and the potential benefits and risks.
- Communicate the value of climate adaptation investment projects to potential investors by providing evidence of the need for the project and the potential benefits of the project.
- Mobilize private capital for climate adaptation investment projects by providing potential investors with a clear and concise overview of the investment opportunity.
- Build partnerships and alliances to support climate adaptation investment projects by providing a common understanding of the project and its goals.

For the NAIP, six sectoral investment concept notes with a total investment requirement of approximately BHD 605 million have been prepared addressing the 12 prioritized climate adaptation actions in the four key sectors most vulnerable to the threat of climate change. The development of these investment concept notes was carried out in close coordination and direct consultation with the technical experts from the respective government departments.

**Table 19: Investment concept notes**

No.	Sector	Title	Investment Amount (BHD million)
1	Water Resources	Scaling Wastewater Reuse for Climate Resilience	~245.0
2	Agriculture & Food Production	Accelerating Climate Resilience in Agriculture and Crop Production	~21.0
3		Climate Resilient Livestock & Poultry Development	~20.0
4		Climate Resilient Fisheries and Aquaculture Development	~23.0
5	Ecosystem Services & Biodiversity	Restoration of Mangrove Ecosystems for Climate Resilience	~205.0
6	Urban Development	Afforestation & Nursery Development	~91.0
<b>Total investment requirement</b>			<b>~605</b>

By providing a clear and concise overview of the investment opportunity, the concept notes can help identify and mobilize the capital needed to implement these projects.

# 4.1

## Scaling Wastewater Reuse for Climate Resilience



## 4.1 Scaling Wastewater Reuse for Climate Resilience

Bahrain has 13 major wastewater treatment plants that are owned and operated by the Ministry of Works with a total capacity of about 352,770 m<sup>3</sup>/day (Table 20). The main wastewater treatment facility is the Tubli Water Pollution Control Centre (Tubli WPCC) with tertiary treatment level and is the only plant that has a transmission network for its tertiary Treated Sewage Effluent (TSE) for reuse. Almost all the high-quality TSE produced at Muharraq Sewage Treatment Plant (STP) is currently discharged to the sea. However, plans for constructing a new TSE network to serve the Muharraq area and the main Transmission Network are well advanced. Currently, a very limited volume of tertiary TSE from the Muharraq plant is being used (about 2,000-3,000 m<sup>3</sup>/day) and is delivered to the users by tankers.

**Table 20: Major Wastewater Treatment Plants in Bahrain**

No.	Plant	Year	Level of Treatment	Population Served	Design Flow m <sup>3</sup> /day	Actual Flow m <sup>3</sup> /day	Average TSE Produced (m <sup>3</sup> /day)	Average Discharge to Sea (m <sup>3</sup> /day)
1	Tubli WPCC	1982	Tertiary	700,000	200,000 Being expanded to 400,000 m <sup>3</sup> /day	328,222	100,000 to 145,000 (fluctuates)	175,000 - 220,000 (fluctuates)
2	North Sitra	2008	Tertiary	72,500	16,500	13,322	13,322	13,322
3	Askar	1997	Secondary	1,250	288	410	0	410
4	Hidd Industrial Area	2005	Tertiary	N/A	2325	1860	0	1860
5	Jasrah	2006	Tertiary	1,500	340	1072	0	1072
6	Bahrain University	1985	Tertiary	1,679	504	300	300	0
7	Jaow	1992	Secondary	1,500	408	307	0	307
8	South Alba	1994	Tertiary	14,800	900	1205	1205	1205
9	Al-Dur	2003	Tertiary	250	70	55	0	55
10	Hamalah	2015	Secondary	1,500	1,100	850	850	Unknown
11	Ma'ameer	2010	Secondary		2,250	1,931	1,931	1,931
12	Muharraq	2014	Tertiary		100,000 To be expanded to 160,000 m <sup>3</sup> /day	73,700	71,610	~70,000 2000-3000 Reused via tanker
13	Madinat Salman	2018	Tertiary		40,000			

Source: Sanitary Engineering Operation & Maintenance Directorate, Ministry of Works

In addition to the above treated wastewater resources, industrial wastewater is being treated and reused in Bahrain. The total capacity of industrial treatment plants in these three locations is about 25,900 m<sup>3</sup>/d. The main areas of treatment and reuse of industrial wastewater are the

industrial area of Sitra Island, ALBA (Aluminum Bahrain), and Bapco Refining (previously Bahrain Petroleum Company).

### Treated Sewage Effluent (TSE) Demand

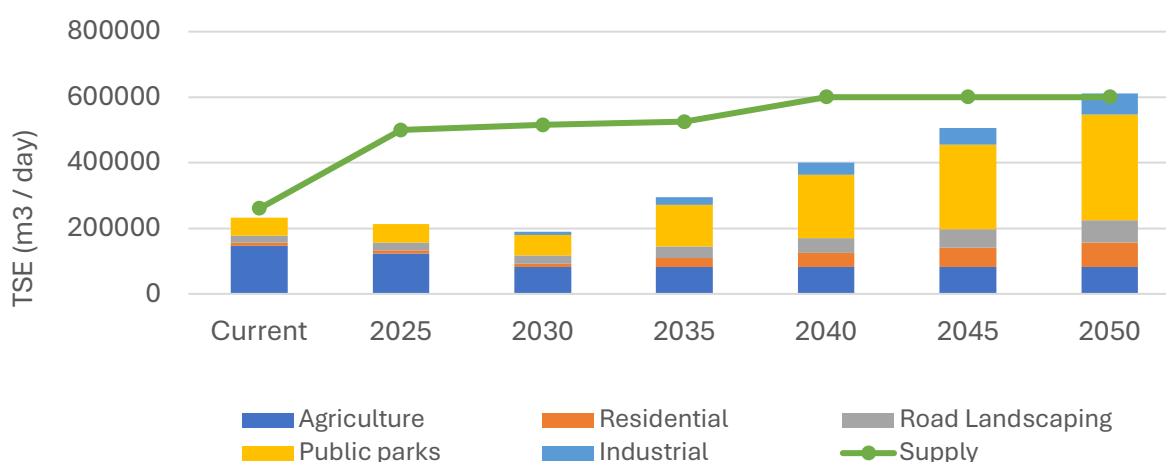
TSE represents a major opportunity for the Kingdom of Bahrain in meeting large percentages of its water requirements under its rapid socio-economic activities, especially since wastewater generation will match its population and urbanization growth rates. TSE demand for each demand type is predicted to increase with the exception for the demand for agriculture. However, uncertainties remain on sustainability of agriculture in the Kingdom and the industrial use which may affect the predicted demand. The predicted demand till 2050 horizon for different demand types are listed in Table 21 and the TSE supply/demand balance is shown in Figure 5.

**Table 21: TSE Demand Summary**

Demand Type	Current (m <sup>3</sup> /day)	2025 (m <sup>3</sup> /day)	2030 (m <sup>3</sup> /day)	2035 (m <sup>3</sup> /day)	2040 (m <sup>3</sup> /day)	2045 (m <sup>3</sup> /day)	2050 (m <sup>3</sup> /day)
Agriculture	147,350	122,195	81,946	81,946	81,946	81,946	81,946
Residential	9,444	9,989	10,861	26,845	42,829	58,813	74,797
Road landscaping	21,500	23,650	24,757	35,436	46,148	56,859	67,570
Public parks	54,342	57,477	62,493	127,778	193,063	258,348	323,633
Industrial	-	-	10,000	23,583	37,165	50,748	64,330
<b>Total</b>	<b>232,636</b>	<b>213,311</b>	<b>190,057</b>	<b>295,588</b>	<b>401,151</b>	<b>506,714</b>	<b>612,276</b>

Source: Final TSE Masterplan Report, Sanitary Engineering Operation & Maintenance Directorate, Ministry of Works

**Figure 6: TSE Supply / Demand Balance**



It is clear from the supply/demand balance that the TSE supply is currently under-utilized, and that supply could be fully utilized to some extent by 2025 - 2030 if sufficient infrastructure can be

put in place in that timeframe. The Sanitary Engineering Affairs department has developed a comprehensive master plan for the period 2020-2050 for wastewater treatment and reuse, with major emphasis on the reuse of TSE. The plan analyzed the development of the treated wastewater demand over the next 30 years and short, medium, and long terms plans to upgrade, extend and expand the TSE conveyance system were developed to provide maximum flexibility to meet future demand scenarios.

## Climate Rationale

Over the last four decades, rapid population growth and urbanization in the Kingdom of Bahrain, coupled with the expansion of irrigated agriculture and industrialization has led to very high-water demand and increasing vulnerability of water supply. In addition to the burgeoning demand, climate change is expected to exacerbate an already vulnerable water supply situation in the country. Direct climate change threats include rising sea levels, lower precipitation, and higher temperatures. Sea level rise is expected to lead to seawater intrusion into fresh groundwater lenses and adverse impacts on inlets/outlets of desalination plants. Lower precipitation could lead to lower groundwater recharge rates. Higher temperatures could lead to unsustainable levels of groundwater and desalinated water use by agriculture, households, and businesses.

Climate change will affect national demand for water as well as the size of Bahrain's freshwater reserves. In terms of demand: increasing temperatures in Bahrain are expected to increase requirements for municipal water use – currently averaging ~248 million m<sup>3</sup> per year – by ~5 million m<sup>3</sup> per year by 2035. Given that municipal use accounts for approximately half of Bahrain's water use, an additional demand of ~5 million m<sup>3</sup> per year can conservatively be expected from other industrial and agricultural users of water (industry and agriculture account for ~5% and ~45% of total water use, respectively). This total extra demand caused by climate change of ~10 million m<sup>3</sup> per year is likely to increase beyond 2030 as temperatures increase further.

As climate change accelerates, and its associated adverse impacts on water resources increase, it is vitally important that the Kingdom of Bahrain invest in water recycling and reuse to build resilience, manage energy demands, support public and environmental health, and ensure Bahrain's economic prosperity. Wastewater reuse is a reliable, climate resilient and local source for water and is central to the national water security strategy.

Sustainable wastewater treatment contributes to water resource management, human and environmental health, water security and climate change adaptation and mitigation strategies. Treating wastewater and reusing it for industrial and agricultural purposes are considered a vital component of adapting to water scarcity. By efficiently repurposing treated sewage effluent for non-potable uses, it conserves freshwater resources, diversifies water sources, and ensures resilience during water shortages, while also combating environmental degradation and reducing GHG emissions such as methane from untreated or inadequate wastewater treatment processes. In addition, treated wastewater is a reliable source of water that often requires lower investment costs and energy use than alternative sources such as desalination or inter-basin water transfers. Treated wastewater is also more resilient to climate impacts.

Applying circular economy and resilience principles to wastewater treatment and reuse has emerged as a response to the current unsustainable linear model of “take, make, consume, and waste.” The benefits of a circular and resilient approach to developing infrastructure and

services, including for wastewater treatment contributes directly to the achievement of SDG 6 (availability and sustainable management of water and sanitation for all) and is linked to several other SDG targets, which are well aligned with the national development agenda of the Kingdom of Bahrain.

Wastewater reuse investments have proven to be a multi-benefit solution that:

- (i) Compare favorably to other options for providing new water supplies by often using less energy, imposing a smaller carbon footprint, and generating fewer air pollution emissions.
- (ii) Ensure reliable and resilient water supplies in the face of increasingly frequent, severe, and prolonged droughts, and other climate-related risks by drawing on a stable, locally generated, and controlled water source.
- (iii) Protect the already stressed groundwater resources by reducing extractive water demands, reducing nutrient and other pollutant loads, and providing high-quality water for replenishing groundwater sources.
- (iv) Support sustainable economic prosperity, advanced clean manufacturing, and well paying high-skill employment opportunities by providing business and industry with a reliable, long-term supply of water.

## Project Description

The project development objective is to increase the utilization of Treated Sewage Effluent (TSE) for productive use and enhance the water security in the country by significantly increasing the contribution of TSE to the total water supply.

The project will address the main challenges that are preventing the Kingdom from maximizing the utilization of the TSE; particularly the limitations of the current distribution network and the quality needs to be utilized in various sectors.

The project consists of three investment components to achieve the project development objective and to increase the utilization of TSE, namely (1) expansion of TSE transmission and distribution network; (2) upgradation of feedwater treatment systems for industrial use; and (3) artificial groundwater storage and recovery; and (4) technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Expansion of TSE transmission and distribution network*

Despite significant capacity of TSE of tertiary level quality being available in the country, less than 10% is utilized for productive use. This is due to the lack of an effective TSE transmission network to pump the water to the demand sectors. The Kingdom of Bahrain plans to implement the TSE network expansion in two phases: Phase 1 (2020-2025) – Short Term and Phase 2 (2026-2045) – Medium and Long Term.

Phase 1 (Short Term) consists of the following:

- Utilize new flows from two Sewage Treatment Plants (STPs): Muharraq (100,000 m<sup>3</sup>/day) and North Sitra (14,500 m<sup>3</sup>/day).
- Implement Transmission Network projects to utilize additional flows.
- Provide TSE connections based on requests received.
- The projects will cost approximately BHD 23.0 million as detailed in Table 22.

**Table 22: Phase 1 (Short Term) Projects**

No.	Project	Length (km)	Cost (BHD million)
1	Phase 3A - Muharraq TSE Line (MSTP to Diyar)	6	2.5
2	Phase 3B - Muharraq TSE Line to North Sitra Connection	9	6.5
3	Phase 3C (B) - Part 2 – Avenue 13 (Tubli STP to Mahooz)	3	2.5
4	Phase 3H(B) - Part 1 - North Manama Loop (NML)	15	5.5
5	Phase 3H(B) - Part 2 - South Manama Loop (SML)		6.0
<b>Total</b>		<b>33</b>	<b>23.0</b>

Phase 2 (Medium and Long Term) consists of the following:

- Utilize new flows from seven STP: Tubli expansion (200,000 m<sup>3</sup>/day), South Alba Expansion (2,000 m<sup>3</sup>/day), Madinat Salman (40,000 m<sup>3</sup>/day), Muharraq STP expansion (48,000 – 60,000 m<sup>3</sup>/day), Madinat Khalifa (40,000 m<sup>3</sup>/day), East Sitra STP (20,000 m<sup>3</sup>/day), and South West STP (~ 30,000 m<sup>3</sup>/day).
- Additional flow from Tubli WPCP will primarily be utilized for Managed Aquifer Recharge (MAR) and for future developments in the south of the country.
- Flow from Madinat Salman will be utilized to meet the demand in the northern areas of the country.
- Flow from Madinat Khalifa will be utilized to meet the demand in the southeastern areas of the country.
- The projects will cost approximately BHD 80 million as summarized in Table 23.

**Table 23: Phase 2 (Medium and Long Term) Projects**

No.	Project	Length (km)	Cost (BHD million)
1	Phase 3F (C & D) - King Hamad Highway	13.3	9.5
2	Phase 3D (E) - S Link Highway	3.0	2.0
3	Phase 3C (B) - Shaikh Isa Bin Salman Highway (Part 1 - Tubli WPCP to Saar Interchange)	6.0	5.5
4	Phase 3C(A) - Shaikh Khalifa Bin Salman Highway (Saar Interchange to Zallaq)	14.0	12.5
5	Phase 3D(A), 3D(B), 3D(C) and 3D(F) - Northern Loop (Janabiya Budaiya, SIBS and SKBS Highway)	20.5	14.5
6	Phase 3E & 3F (A & B) - East Sitra Link Highway	14.35	8.0
7	Phase 3G(A) - Gulf of Bahrain Avenue	6.0	4.0
8	Phase 3I - Avenue 96, Avenue 49 and Avenue 76	12.0	7.5
9	Phase 3H(A) - Shaikh Khalifa Bin Salman Highway (Budaiya Intersection to Al Farooq Interchange)	5.0	4.0

No.	Project	Length (km)	Cost (BHD million)
10	Phase 3D(D) - W Link Highway	1.5	1.5
11	Phase 3G(A)-P1 and Phase 3G(B) - South Bahrain Loop Road	14.5	8.0
12	Phase 3G(C) and Phase 3F(D)- P1 (South Bahrain Loop Road to King Hamad Highway)	21.5	7.0
<b>Total</b>		<b>131.65</b>	<b>84.0</b>

### *Component 2: Upgradation of feedwater treatment systems for industrial uses*

In general, all industries require water that meets certain quality requirements. Tertiary TSE can be directly utilized for industrial uses that do not require high grade water such as sand washing and cooling. However, to meet the water quality requirements for boiler and process applications (cooling and steam generation), additional water treatment is required to produce higher quality feedwater such as demineralized water.

Utility power plants are ideal facilities for producing higher quality water from tertiary TSE due to their large, demineralized water requirements. Petroleum refineries, chemical plants and metal working facilities are among other industrial facilities that can potentially utilize TSE not only for cooling but for process needs as well. Although these industries currently rely on captive desalination plants and supply from Electricity and Water Authority (EWA) for their freshwater requirements, in the long run, the cost of using tertiary TSE to produce the required quality feedwater is more economically viable.

The most common treatment design consists of pretreatment filtration and chemical addition for removal of particulate matter and conditioning of the water chemistry. This is followed by a membrane process for the bulk reduction of dissolved minerals and a final polishing ion exchange step. Investing in feedwater treatment systems that produce higher quality feedwater will significantly reduce chemical usage and increase the cycles of concentration, improving overall plant efficiency. By upgrading the feedwater treatment systems to produce demineralized and process feedwater from tertiary TSE, a significant part of the annual desalinated water supply (around 6 million m<sup>3</sup>) by Electricity and Water Authority (EWA) can be replaced.

Reusing TSE in the industrial sector is particularly crucial for the future planning of water resources in the Kingdom. This is due to that the agricultural sector demands for treated wastewater are expected to reach steady levels (if not reduced) with the limitation of expansion in agricultural lands and current trends of agricultural lands transfer into urban areas, and hence, surplus TSE would be available.

### *Component 3: Artificial groundwater storage and recovery*

Heavy dependence on groundwater from the Dammam aquifer since the 1970s, particularly for the development of the agricultural and municipal sectors, has increased groundwater abstraction rates to more than twice the recommended groundwater safe yield. This has resulted in a severe decline in the aquifer water levels, leading to the cessation of flows from these springs and the loss of an environmentally and culturally significant resource to Bahrain. More

dangerously, it has led to the deterioration of the quality of the aquifer water due to seawater intrusion and brackish water up-flow.

In recent years, strenuous restoration efforts on the Dammam aquifer by the water authorities have been successful in reducing the abstraction rates to be close to the recommended safe yield rates. Enhanced artificial recharge by storm runoff water has been practiced since 1999, where storm runoff is diverted to depressions to recharge groundwater by gravity wells. In addition to this, the expansion of the reuse of treated wastewater to increase the groundwater recharge is currently under study by the Ministry of Works.

Under this component, a Managed Aquifer Recharge (MAR) pilot for the Dammam aquifer system using tertiary TSE from the Muharraq plant will be implemented by 2025. The targeted aquifer unit for the pilot phase is the Khobar member of the Dammam aquifer system. In the subsequent phases (2026-2045), Managed Aquifer Recharge (MAR) projects will be scaled up across the Dammam aquifer system by building wells to inject tertiary TSE into the stressed aquifer.

The Kingdom of Bahrain plans to implement the MAR projects in two phases: Phase 1 (2020-2025) – Short Term and Phase 2 (2026-2045) – Medium and Long Term. The Phase 2 projects are dependent on the findings of the Phase 1 - Muharraq pilot.

**Table 24: Managed Aquifer Recharge (MAR) Projects**

No.	Project	Description	Cost (BHD million)
1	Muharraq pilot (Phase 1)	Pilot Implementation - Assess Aquifer Storage and Recovery (ASR) and barrier well field options.	0.5
2	Muharraq well field development (Phase 2)	Muharraq ASR field development for seasonal storage and/or barrier wells.	30.0
3	Tubli WPCCC pilot (Phase 2)	Tubli WPCCC Pilot to establish recharge and extraction rates. (Assumes Tubli TSE quality has been achieved through Tubli Extension project).	10.0
4	Tubli WPCCC ASR Well field development (Following pilot study)	ASR (vertical wellfield). Maximum recovery minimum retention to avoid impact on potable water wells.	60.0

By replenishing the Dammam aquifer, this investment component will restore water supply, prevent saltwater intrusion, and mitigate land subsidence related to aquifer withdrawals in Bahrain. The MAR will provide an initial demand until the ground water level recovers, but in the long term it will not create a permanent additional demand. Rather it will provide good seasonal storage, preventing future wastage of TSE in winter and ensuring there is enough TSE during peak summer demand periods.

It should be noted that the Dammam aquifer system in Bahrain represents a small part of the Eastern Arabian aquifer, which extends from central Saudi Arabia to the Arabian Gulf waters, including Bahrain. Therefore, it is important that there is effective cooperation between Bahrain and Saudi Arabia in the development and management of the Dammam Aquifer System.

#### *Component 4: Technical Support and Project Management*

This component will support the establishment of a Project Implementation Unit (PIU) to oversee the implementation of the project components with following main objectives: (i) ensuring effective strategic and operational planning, implementation, and monitoring & evaluation (M&E) of the project, beginning with a baseline assessment to measure the project's progress and impacts; (ii) ensuring that all project funds are used efficiently, and coordinating project actions implemented by participating stakeholders and partners; (iii) evaluating the project's mid-term and final results, outcomes, and impacts on beneficiaries; (iv) supporting and ensuring efficient knowledge management; and (v) preparation and implementation of a communication strategy to support effective communication to various public and private entities on project activities, outcomes, best practices, and lessons learned.

### Investment & Financing Plan

The project is estimated to cost BHD 245 million (2023 prices).

**Table 25: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Expansion of TSE transmission and distribution network	107.0	44%
	Component 2: Upgradation of feedwater treatment systems for industrial uses	10.0	4%
	Component 3: Artificial groundwater storage and recovery	100.5	41%
	Component 4: Technical Support and Project Management	5.0	2%
	<b>Subtotal (A)</b>	<b>222.5</b>	<b>91%</b>
<b>B</b>	<b>Contingencies</b> (assumed at 10% of base cost)	22.5	9%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>245.0</b>	<b>100%</b>

#### *Component 1: Expansion of TSE transmission and distribution network*

This project component is a large-scale infrastructure project with high risk profile as the technical challenges of implementing a separate TSE transmission and distribution network in dense urban and semi-urban areas are high. As a result, such type of projects are well-suited to be directly implemented by the government and the financing involves a mix of debt financing instruments from many funding sources as listed below:

Financing Instrument	Funding Sources	Key Requirements
Government funds	National budget	New taxes and usage fees are required to service the debt funding raised from capital markets, multilateral, and regional financial institutions.
Green bonds/sukuk (sovereign)	Capital markets	
Concessional Debt (sovereign)	Multilateral Financial Institutions Regional Development Banks/Funds	

To enable private capital, this project can be implemented as a PPP project where the project risks taken by the private sector sponsors is mitigated by a well-structured and commercially viable cost-plus TSE water tariff as well as other project implementation and contractual structures. A detailed PPP feasibility study is required to assess the enabling factors for attracting private capital. The GCF NAP Readiness Program is well suited to conduct such feasibility studies.

### *Component 2: Upgradation of feedwater treatment systems for industrial use*

The commercial potential for upgrading feedwater treatment systems towards using TSE is significant, as it can help businesses to reduce their costs, improve their environmental performance, and increase their resilience to water scarcity. The benefits include:

- **Reduced costs:** TSE is often less expensive than traditional water sources, such as municipal water supply from desalination plants. This is because the cost of treating wastewater has decreased significantly in recent years, due to advances in technology and economies of scale.
- **Improved environmental performance:** Using TSE can help businesses to reduce their environmental impact in several ways. First, it helps to conserve freshwater resources. Second, it reduces the amount of wastewater that needs to be discharged into the environment. Third, it can help to improve the quality of wastewater discharges, by removing pollutants and nutrients.
- **Increased resilience to water scarcity:** Using TSE can help businesses to become more resilient to water scarcity. This is because treated wastewater is a reliable and sustainable source of water. It is also less susceptible to drought and other climate-related impacts than traditional water sources.

In addition to these direct benefits, upgrading feedwater systems to use TSE can also lead to indirect benefits, such as improved public relations and increased customer loyalty. Businesses that are seen as leaders in sustainability are often more attractive to customers and investors. As a result, this project component has the potential of realizing significant direct and indirect benefits for industries as the water tariff from carbon intensive desalination plants is expected to become cost reflective. The commercial potential of this project component could be high enough to attract commercial equity and debt capital from the private sector.

Financing Instrument	Funding Sources	Key Requirements
Equity & debt capital	Private sector including commercial banks, climate impact/venture funds, etc.,	The quality of TSE needs to be of an acceptable quality and consistency for the feedwater treatment systems to be effective.  Matching grants or other financial incentives from the government of Bahrain.

### *Component 3: Artificial groundwater storage and recovery*

Artificial groundwater storage and recovery can help businesses and governments to increase water supply, reduce the risk of water shortages and increase the value of water resources. The commercial potential depends on the specific design and implementation of the project, the ownership and management of the project, and the benefits that the project provides to society. Since the primary objective of this project component is to ensure the water security for the country, the project is most likely to be directly implemented by the government and the financing involves a mix of debt financing instruments from many funding sources as listed below:

Financing Instrument	Funding Sources	Key Requirements
Government funds	National budget	New taxes and usage fees are required to service the debt funding raised from capital markets, multilateral, and regional financial institutions.
Green bonds/sukuk (sovereign)	Capital markets	
Concessional Debt (sovereign)	Multilateral Financial Institutions  Regional Development Banks/Funds	

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. Project implementation organizations and their roles and responsibilities are proposed in the following table, based on each institution's mandate.

**Table 26: Project Management**

<b>Project Implementation Organizations</b>	<b>Roles and Responsibilities</b>
Ministry of Works	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>
Electricity and Water Authority Ministry of Industry and Commerce	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development and implementation of relevant policies and regulations.</li> </ul>
Project Management Office (To be established by the Ministry of Works)	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

# 4.2

## Accelerating Climate Resilience in Agriculture and Crop Production



## 4.2 Accelerating Climate Resilience in Agriculture and Crop Production

Natural access to fresh water has made agriculture a very important sector in Bahrain. Along with fishing, it was the primary source of livelihood for many communities. Historically, date cultivation was the pre-eminent activity. However, since the 1970's, agriculture in Bahrain has faced various challenges that limited its role in further contributing to domestic crop production. These challenges include urbanization at the expense of arable land, soil salinization, restricted water resources, limited size of farm holdings and a decreased number of people interested in the agricultural sector. All these factors are further exacerbated by climate change. The Government has reported that the 4,500 hectares classified as agricultural land in 2011 shrank to 2,175 hectares in 2019, which is around 3% of total land area.

The Gross Value Added (GVA) of agricultural sector, both crop production, fisheries, and livestock, amounted to BHD 38.2 million (2021), with a contribution of 0.3% to Real GDP (2021). The value of food imports amounts to more than BHD 4 billion. The main agricultural imports include fruits, vegetables, meat, cereals, legumes, and dairy products. While most of the country's food demand is imported, there is a potential for increasing the contribution of the domestic food production sector, while promoting efficient use of limited water resources and arable land.

### Crop Production

The crop production sector is a combination of traditional agriculture, protected agriculture, and hydroponic production. The Government estimates around 660 farmer households involved in agricultural production on their owned and leased agricultural lands. Most of the farms are concentrated in the Northern Governorate. The Ministry of Municipalities Affairs and Agriculture oversees six government farms devoted to agricultural research.

The main crops produced in Bahrain are dates and a wide range of vegetables. Modern methods of agriculture and irrigation have proven successful in conserving resources and the environment. This has also demonstrated high economic returns and increased employment opportunities. Vegetable production currently covers around 11% of national consumption needs, and Bahrain has exported around 92 tons of domestically produced fruits and vegetables in 2019 (dates, date molasses, tomatoes, pepper and lettuce).

Due to limited availability of land and water, many farmers and investors are turning into hydroponic production as the yields are higher, there is no need for extensive land and the technology allows for reduced water consumption. This is making locally grown vegetables and salad greens increasingly available on the market. Hydroponic production has a very good potential in expanding domestic production in Bahrain and contributing to food security and improved nutrition. The main crops being produced through this approach include tomatoes, cucumber, melons, peppers, lettuce and other greens.

### National Initiative for Agricultural Development (NIAD)

The Government of Bahrain is encouraging further investments in domestic food production through focusing on innovation and non-conventional agriculture and has also put in place

several training and mentoring programs, as well as awarding initiatives that help advance the sector, such as the King Hamad Prize for Agricultural Development. A main national institution to support all those efforts is the National Initiative for Agricultural Development (NIAD) which is developing future entrepreneurial capacities to help expand domestic production and enhance food security. The NIAD is working on a number of projects that contribute to the support of agricultural workers, stimulate and support agricultural manufacturing industries, and increase expertise in agriculture through education and training. These include:

- **AgroBH:** Bahrain's first digital agricultural database, used to assist existing agricultural organizations and businesses in Bahrain, as well as advise and support potential international investors and companies; providing all stakeholders with accurate and up-to-date agricultural information.
- **Agricultural Incubator Centre:** The incubation centre in Hoorat A'ali is dedicated to agricultural entrepreneurs and the development of their pioneering ideas to start projects using modern agricultural techniques to grow crops with high economic returns. The centre provides support services including management, expertise, and access to technical and financial support programs.
- **Farmers market:** In collaboration with the Agriculture and Animal Wealth Affairs, NIAD – as an official partner and committee member in the project – provides support for the farmers market every agricultural season, through help in maintenance, promotional campaigns and services, and other supporting market activities.
- **Agricultural greenhouses:** NIAD has established several high-quality greenhouses with the latest technologies in cooperation with several government institutions, civil society organizations and educational institutions, to spread agricultural skills across various levels.
- **Agricultural awareness:** In collaboration with the Bahrain Training Institute (BTI), NIAD has launched an agricultural diploma to ensure the availability of qualified graduates entering the labour market, so as to support the development of local expertise in formulating and implementing agricultural strategies and solutions.

Although the recent years have witnessed an increase in locally produced fruits and vegetables, there are several challenges that still face producers and the crop production sector. To offset some of those challenges, the following actions would need to be considered:

- Diversify investments beyond primary production to include other levels of the food supply chain (post-harvest handling, transportation, cooling, processing, and marketing) to minimize food losses and economic damages to producers.
- Support investments in agro-processing facilities that help extend shelf-life, add value to the produce and stimulate export/re-export potential.
- Revitalize the date palm sector through increasing productivity and support the replacement of poorly performing date palms with high yielding varieties.
- Diversify crop varieties and identify differentiated high value crops that present further opportunities for the local and export markets.

- Extend growing seasons by adopting agricultural technologies, enhancing indoor environments in protected farming facilities, seed resilience and irrigation techniques.

## Climate Rationale

Among the different phenomena related to climate change, the agriculture sector is particularly exposed to rising sea levels, soil salinization, and increasing temperatures.

Based on the Kingdom's latest coastal resilience study, there are 21 potential flood zones where food and agriculture related assets are located and are vulnerable to SLR impacts. Under the L3 scenario (i.e., present day risk of flooding from storm surge events/storm with probability of once every 500 years), 16 food and agriculture related assets are expected to be at risk with estimated damages of 817k BHD. However, under the L5 scenario (i.e., a 0.5 m increase in sea level after 2050 and a storm surge event with probability of once every 500 years), 168 food and agriculture related assets are expected to be at risk with estimated damages of 23.6M BHD.

In addition to sea level rise, air temperatures have been steadily increasing over the last 50 years. Considering that traditional agriculture takes place outdoors, farmers are vulnerable to climate-related diseases, and reduced productivity. Moreover, higher temperatures could also lead to increased groundwater and desalinated water use by the agriculture sector, exacerbating an already unsustainable water situation.

Climatic conditions create significant food security challenges for the Kingdom of Bahrain, which is characterized by water scarcity and a lack of arable land. To be able to increase domestic food production in Bahrain, optimize use of available water, and safeguard natural resources, there is an urgent need in finding long-term, cost-effective solutions and actions to ensure sustainability of local production and mitigate the adverse impact of climate change on essential imported food commodities. Some of these actions include:

- Adopt further innovative sustainable and resilient agricultural approaches (such as climate-smart agriculture), taking into consideration water and water-use efficiency, soil quality, and further research relating to stress-tolerant crops.
- Invest in innovative crop production, water-efficient and renewable energy technologies to ensure sustainability and identify potential for high-value crops that have better yield per drop of water.
- Ensure that climate change and resource management are factored into policymaking, research and practices to ensure sustainability.
- Undertake further analysis to better understand the impacts of climate change on food markets (especially wheat and rice), considering relevant global studies, and diversify imports accordingly.

Responding to the challenges posed by climate change on food security requires an integrated, cross-sectoral approach, guided by multi-stakeholder dialogue and partnerships.

## Project Description

The project development objective is to enhance the resilience of agricultural production to climate risks and accelerate the adoption of climate-smart agricultural systems in the Kingdom of Bahrain.

The project consists of the following two investment components and a supporting implementation unit: (1) promotion of climate-smart agricultural systems; (2) promoting cultivation of native and climate compatible crops; and (3) technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Promotion of climate-smart agricultural systems*

The objective of this component is to strengthen the adaptive capacity of the agricultural enterprises to adjust and modify their production systems to moderate potential future impacts from climate events. The component builds climate-resilience in agricultural production systems through modern agri-tech solutions at farm level, complemented by actions in efficient use of groundwater water resources. The objective is to enhance climate resilience beyond farm gate and provide end-to-end solutions in value chains for agricultural commodities.

This component supports: (i) scaling-up the adoption of climate-resilient agricultural technologies and farming practices aimed at improving soil health, water-use efficiency and crop productivity, including in the areas affected by high salinity levels; (ii) upgrading irrigation and water management infrastructure to promote a more efficient use of surface water for agriculture, complemented with a more sustainable use of groundwater, and ultimately improve the availability and quality of water at farm level; (iii) developing inclusive value chains (drying, processing, and storage facilities) for climate-resilient post-harvest management; (iv) strengthening the infrastructure for agricultural quality and safety testing; and (v) promoting renewable energy (biodigesters and use of solar energy) to reduce GHG emissions.

This component contributes directly to the project development objective by promoting climate resilient technologies and agronomic practices aimed at: improving water-use efficiency and water productivity at farm level; reducing climate vulnerability in crop production; and scaling up the adoption of advance farming practices (hydroponic, aeroponic, and aquaponic method) practices and agricultural technologies to enhance climate resilience in farming. To complement these on-farm activities, this component also supports investments to improve the sustainable management of groundwater resources for agriculture. This component may also build on existing initiatives such as the Agricultural Incubator Centre in Hoorat A'ali that aims to enhance technical capabilities to contribute to local agricultural production.

### *Component 2: Promoting cultivation of native and climate compatible crops*

The objective of this component is to strengthen the cultivation of native and climate-resilient high-protein crop varieties. To ensure successful cultivation of native and climate resilient crops, this component supports overcoming constraints in the seed supply chain by addressing constraints with the volume, quality, availability, affordability, and access of seed varieties with climate-resilient features (e.g., short duration cycle, drought-, salinity- or heat-tolerant).

Under this component, a seed bank will be established to advance efforts in preserving the Kingdom’s native plants and to study the use for commercial purposes. The seed bank will preserve local native plants through four modalities; live plants, dried plants, seeds, as well as preserving genes through scientific methods, providing genetic material and information for various breeding programs, and exchanging information related to genetic resources with local and foreign gene banks. The seed bank will feature laboratories – environmental, microscopic, and analysis – in addition to rooms for preserving and drying seeds, and refrigerators for seed preservation.

### *Component 3: Technical Support and Project Management*

This component will support the establishment of a Project Implementation Unit (PIU) to oversee the implementation of the project components with following main objectives: (i) ensuring effective strategic and operational planning, implementation, and monitoring & evaluation (M&E) of the project, beginning with a baseline assessment to measure the project’s progress and impacts; (ii) ensuring that all project funds are used efficiently, and coordinating project actions implemented by participating stakeholders and partners; (iii) evaluating the project’s mid-term and final results, outcomes, and impacts on beneficiaries; (iv) supporting and ensuring efficient knowledge management; and (v) preparation and implementation of a communication strategy to support effective communication to various public and private entities on project activities, outcomes, best practices, and lessons learned.

## Investment & Financing Plan

The project is estimated to cost BHD 21 million (2023 prices)

**Table 28: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Promotion of climate-smart agricultural systems	16.0	77%
	Component 2: Promoting cultivation of native and climate compatible crops	2.0	10%
	Component 3: Technical Support and Project Management	1.0	5%
	<b>Subtotal (A)</b>	<b>19.0</b>	<b>91%</b>
<b>B</b>	<b>Contingencies</b> (assumed at approx. 10% of base cost)	1.9	9%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>21</b>	<b>100.0%</b>

### *Component 1: Promotion of climate-smart agricultural systems*

Climate-smart agricultural systems (CSA) have the potential to generate significant commercial value for farmers and businesses. By increasing productivity, resilience, and reducing greenhouse gas emissions, CSA can help farmers increase crop yields, reduce production costs and improve market access. CSA can also generate a number of indirect commercial benefits by

reducing food losses and waste, improving environmental quality and creating new jobs and businesses. As a result, the commercial potential of this project component could be high enough to attract private finance.

Financing Instrument	Funding Sources	Key Requirements
Equity & debt capital	Private sector including commercial banks, climate impact/venture funds, etc.,	Enabling policies and economic incentives is required to strengthen the business case for CSA systems.  Grants/ subsidies or other financial incentives from the government of Bahrain.

### *Component 2: Promoting cultivation of native and climate compatible crops*

This project component seeks to enhance the research and development of native and climate compatible crops. As with most R&D initiatives, the outcome is uncertain. As a result, there is no near-term commercial potential for this project component and grant funding from the government or philanthropic organizations is most suitable.

Financing Instrument	Funding Sources	Key Requirements
Grant	Philanthropic organizations  CSR contributions	Alignment with donor priorities  Matching grants or other financial incentives from the government of Bahrain.

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. Project implementation organizations and their roles and responsibilities are proposed below, based on each institution's mandate:

**Table 29: Project Management**

Project Implementation Organizations	Roles and Responsibilities
Ministry of Municipalities Affairs and Agriculture	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>

Project Implementation Organizations	Roles and Responsibilities
<p>Supreme Council of Environment</p> <p>Ministry of Municipalities Affairs and Agriculture (Agriculture Affairs and Marine Resources Directorate)</p>	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development and implementation of relevant policies and regulations.</li> </ul>
<p>Project Management Office</p> <p>(To be established by Ministry of Municipalities Affairs and Agriculture)</p>	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

# 4.3

## Climate Resilient Livestock & Poultry Development



### 4.3 Climate Resilient Livestock & Poultry Development

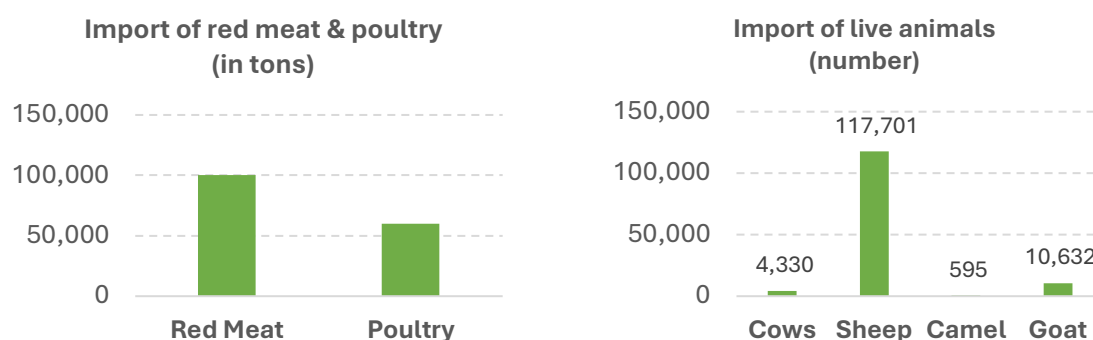
Bahrain has relatively minor livestock resources, consisting mainly of sheep, goats, and cattle, with a few horses and camels. These resources only fulfil around 12% of national consumption needs. In total, there are about 1000 farms with a population of 108,000 sheep, goats, and cattle. The total livestock population in the Kingdom of Bahrain is detailed in Table 30.

**Table 30: Livestock Population**

Governorate	No. of Farms	No. Cattles	No. Sheep	No. Goats
Muharraq	83	379	744	1,036
Capital	264	1,895	3,585	3,994
Northern	535	4,592	11,414	7,364
Southern	149	1,020	24,987	7,117
<b>Total</b>	<b>1,031</b>	<b>7,886</b>	<b>40,730</b>	<b>19,511</b>

Driven by high purchasing power, there is a high demand for red meat and poultry in the country. Bahrain depends largely on imports for its supply of live animals and frozen meat to supply national demand. The average red meat, poultry, and live animal imports of Bahrain is summarized in Figure 7.

**Figure 7: Average red meat, poultry, and live animal imports**



Considering the economic and financial viability of relevant choices to ensure the national food security, the Kingdom of Bahrain has taken a strategic decision to focus on poultry and egg production. Modern, “high-tech” broiler farms with high-yielding breeds have been established. There are currently five farms for eggs and 20 poultry farms. This currently contributes to 25% of national consumption needs for poultry and 20% for eggs (83 million eggs). With expected population growth, demand for meat and poultry will increase and the Government’s objective is to reach 40% self-sufficiency for poultry and 35% self-sufficiency for eggs (120 million eggs) by 2022.

The Kingdom of Bahrain has an effective food safety system, which is also applied to livestock imports to guard the health of its citizens. To further enhance national food security, the Government of Bahrain has committed to advancing intersectoral collaboration across human-animal-environment sectors, in alignment with WHO’s One Health approach. This approach aims

to holistically consider the health of people, animals and the environment. Bahrain has demonstrated its commitment towards advancing collaboration across human-animal-environment sectors by investigating intersectoral collaboration in this field and exploring the establishment of a formal One Health mechanism.

## **Climate Rationale**

Climate change impacts livestock and poultry production in two broad ways; directly, through heat stress, and indirectly, through disease-causing pathogens and vectors. Moreover, climate change can exacerbate disease in livestock, and some diseases are especially sensitive to climate change. The main zoonotic diseases for the animal health sector in Bahrain are brucellosis, glanders, MERS-CoV, rabies, tuberculosis, sheep & goat pox, lumpy skin, IBR, HPAIV, etc. These climate change impacts are further elaborated below.

### **Heat stress**

All animals have a thermal comfort zone which is beneficial to their physiological functions. When the ambient environmental temperature exceeds the upper critical threshold, it leads to heat stress, metabolic disorder, and immune suppression among the livestock, resulting in an increased propensity for disease incidence and death. Chronic exposure to heat stress has been demonstrated to impair immune response in poultry and calf, hamper the efficacy of vaccinations and impair function of neutrophils that are important for defense against bacteria. Studies also report that cases of mastitis, a major health problem in the dairy industry worldwide, increase during summer and have a significant correlation with heat stress due to suppressed immunity, thermal injury of the udder and spread of pathogens in the summer.

### **Vector-factor**

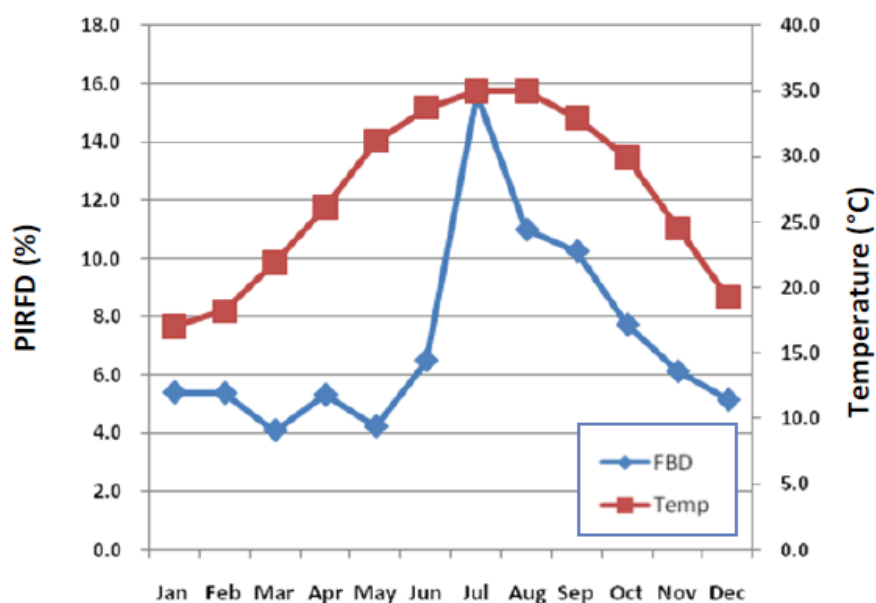
Some of the effects of climate change are less apparent but have much greater impact on livestock disease transmission. Vector-borne diseases are especially sensitive to climate change. A rise in temperature, precipitation intensity and humidity increase pathogens or vectors' metabolic processes, reproductive rates, resulting in enhanced vector-pathogen-host contact and, therefore, the risk of disease. Arthropod vectors such as mosquitoes, ticks, mites, lice, etc., tend to be more active at higher temperatures. They therefore feed more regularly to sustain the increase in their metabolic functions, enhancing the chances of infections being transmitted between hosts.

### **Food-borne Diseases**

Livestock diseases also have impacts on human health. Over 60% of human pathogens are zoonotic, or transmissible from animals. The most important are food-borne zoonoses, which cause millions of cases of illness each year. Other important zoonoses acquired by direct contact or food include bovine tuberculosis, brucellosis, and leptospirosis. Additionally, inappropriate use of antibiotics in livestock production will reduce capacity to treat animal diseases and has been linked to antimicrobial resistance (AMR) in humans, presenting a daunting challenge to the fight against infectious diseases.

In Bahrain, studies have found a greater prevalence of food-borne diseases in humans in hot weather. Between 2001-2008, the Arabian Gulf University tracked Proportional Incidence Rates of Food-borne Diseases (PIRFD) in humans and average monthly temperatures, and found a notable correlation between increased food-borne diseases and high temperatures throughout this period (Figure 8). With even higher temperatures predicted in the summer months due to climate change, this represents an important finding that can guide subsequent adaptation planning.

**Figure 8: Average temperature and food-borne incidence in Bahrain, 2001-2008**



To address climate change impacts on the livestock and poultry sector and the resulting food-borne diseases, the following measures are recommended.

- Improve disease surveillance and response to detect changes in disease in a timely way, thus dramatically reducing the costs of response.
- Improve animal health service delivery by investing in the public sector and supporting innovations in the private sector.
- Support eradication of priority diseases by developing effective diagnostics, vaccines and promoting adoption of good practices and strengthening biosecurity.
- Increase the resilience of livestock systems by promotion of species and breeds that are more resistant to disease and climate change.

## Project Description

The project development objective is to improve the climate resilience, productivity, and commercialization of livestock and poultry production in Bahrain. The project consists of the following two investment components and a supporting implementation unit: (1) institutional strengthening for enhancing the surveillance, diagnostic and control of animal diseases; (2) development of climate-resilient and low-carbon livestock and poultry value chain; and (3)

technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Institutional strengthening for enhancing the surveillance, diagnostic and control of animal diseases*

The Animal Wealth Assistance Agency has proposed several regulations and procedures to enhance the livestock and poultry sector's legal framework and capacity. The implementation of effective biosecurity regulations across the food chain has become increasingly vital to control the spread of livestock diseases and ensure the wellbeing of animals and humans alike around the world. The main prerequisite for such policies is livestock identification, which includes cow ear tags and other livestock ID ear tags, as this enables the tracking and monitoring of all livestock movement over their lifetime. This component will support the implementation of the proposed biosecurity regulations as well as implementing procedures for granting licenses for the establishment of livestock and poultry farms, veterinary health, environmental, and infrastructure requirements for the operating livestock and poultry production units.

In addition, this component will strengthen the active surveillance systems for zoonotic and major contagious animal diseases and scale-up vaccinations against major diseases. It will provide support to pre-defined disease control strategies including vaccination campaigns and progressive zoning approach, in collaboration with the private sector. In partnership with the Food and Agricultural Organization (FAO), the Animal Wealth Directorate seeks to effectively control animal diseases and zoonosis and conservation of animal genetic resources in the Kingdom.

Effective control of animal diseases would support the smallholders to join livestock value chains, market their local dairy and poultry products and increase their income and living standards. The component will also contribute to a reversal of the ongoing trends of erosion and underutilization of Animal Genetic Resources for food security, sustainable agriculture, and human well-being. It will strengthen the capacity of national partners and design a strategy to improve production and productivity of local breeds through the utilization of modern techniques in genetic improvement, improved health care, feeding, husbandry management while improving the cost structure of locally produced animals and animal products.

### *Component 2: Development of climate-resilient and low-carbon livestock and poultry value chain*

This component builds on improvements in productivity arising from investments under component 1 (improved breeds, animal health) to expand overall production of meat, milk, eggs and reduce imports of those commodities. To that end, it will enhance and modernize the value chain for livestock and poultry products, promote a stronger commercial/market orientation among small and medium producers, and encourage increased private investment in priority segments of the value chain, while mainstreaming climate change adaptation and mitigation measures. In addition to augmenting national production, these activities will build more resilient livelihoods, create jobs, promote rural economic growth, and improve food safety.

In collaboration with commercial banks, a credit line will be established to support the following activities to develop a climate-resilient and low-carbon meat and poultry industry in Bahrain.

- (i) Boosting efficiency of livestock production and resource use - Extensive and labor-intensive ruminant systems with low productivity are targets for low carbon investments. Technological innovations such as improved feeding, genetics, animal health, general husbandry and information technology are driving up productivity, making resource use more efficient with potential to reduce environmental impact.
- (ii) Intensifying recycling efforts and minimizing losses for a circular bioeconomy - Promoting a circular bioeconomy involves recycling resources at every possible step in agrifood systems and closing systems to minimize the loss of resources and nutrients. Manure and slaughterhouse waste can be used to generate fertilizer and biogas as a source of renewable energy.

This component will enable market linkages and market development among small and medium producers so that producers capture a fair share of the product value through appropriate value addition at the farm level through primary processing (bulking, cooling, sorting, packing, and so on) to increase profits and reduce food loss and waste. Concurrently it will raise producers' awareness of modern, climate-smart production technologies to increase efficiency while reducing emissions and mitigating the negative ecosystem effects of livestock production.

### *Component 3: Technical Support and Project Management*

This component will support the establishment of a Project Implementation Unit (PIU) to oversee the implementation of the project components with following main objectives: (i) ensuring effective strategic and operational planning, implementation, and monitoring & evaluation (M&E) of the project, beginning with a baseline assessment to measure the project's progress and impacts; (ii) ensuring that all project funds are used efficiently, and coordinating project actions implemented by participating stakeholders and partners; (iii) evaluating the project's mid-term and final results, outcomes, and impacts on beneficiaries; (iv) supporting and ensuring efficient knowledge management; and (v) preparation and implementation of a communication strategy to support effective communication to various public and private entities on project activities, outcomes, best practices, and lessons learned.

## Investment & Financing Plan

The project is estimated to cost BHD 20 million (2023 prices)

**Table 31: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Institutional strengthening for enhancing surveillance, diagnostic and control of animal diseases	1.0	5%
	Component 2: Development of climate-resilient and low-carbon livestock and poultry value chain	16.0	77%
	Component 3. Technical Support and Project Management	1.0	5%

Item		Amount	%
	<b>Subtotal (A)</b>	<b>18.0</b>	<b>86%</b>
<b>B</b>	<b>Contingencies</b> (assumed at 10% of base cost)	1.8	8.8%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>20.0</b>	<b>100.0%</b>

*Component 1: Institutional strengthening for enhancing the surveillance, diagnostic and control of animal diseases.*

The goal of animal disease surveillance, diagnosis and control project component is to improve public health and not to generate revenue. However, generating revenue can help to ensure the sustainability of this component and allow it to reach more beneficiaries. Some specific examples of revenue-generating activities that the project could undertake are:

- Provide diagnostic testing services to farmers and veterinarians.
- Offer training on animal disease diagnosis and control to veterinary professionals.
- Develop and sell new diagnostic kits and vaccines for animal diseases.
- Provide consultancy services to businesses on animal disease surveillance and control.
- Develop and sell educational materials on animal disease surveillance, diagnosis and control to farmers and veterinarians.

Considering the low commercial potential of this project component, grant funding from the government or philanthropic organizations is most suitable.

Financing Instrument	Funding Sources	Key Requirements
Grant	Philanthropic organizations CSR contributions	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.

*Component 2: Development of climate-resilient and low-carbon livestock and poultry value chain*

The commercial potential of developing a climate-resilient and low-carbon livestock and poultry value chain is significant. As the world transitions to a more sustainable food system, there is a growing demand for climate-friendly meat and poultry products. Some of the ways in which climate-resilient and low-carbon livestock and poultry value chains can generate commercial value:

- **Increased access to premium markets:** Consumers are increasingly willing to pay a premium for sustainable and climate-friendly meat and poultry products. This is creating new opportunities for farmers and businesses to access high-value markets.

- **Reduced costs:** Climate-resilient and low-carbon livestock and poultry production practices can help to reduce costs for farmers. For example, using renewable energy to power livestock and poultry farms can reduce energy costs.
- **Improved efficiency:** Climate-resilient and low-carbon livestock and poultry production practices can also help to improve efficiency. For example, using precision agriculture techniques to manage livestock and poultry feed can help to reduce waste and improve feed conversion efficiency.
- **Increased productivity:** Climate-resilient and low-carbon livestock and poultry production practices can also help to increase productivity. For example, using climate-tolerant breeds of livestock and poultry can help to reduce losses due to extreme weather events.
- **Improved brand reputation:** Businesses that produce and sell climate-resilient and low-carbon livestock and poultry products can improve their brand reputation and attract new customers. This is because consumers are increasingly looking to support businesses that are socially and environmentally responsible.

As a result, the commercial potential of this project component could be high enough to attract private finance.

Financing Instrument	Funding Sources	Key Requirements
Equity & debt capital	Private sector including commercial banks, climate impact/venture funds, etc.,	<ul style="list-style-type: none"> <li>* Enabling policies and economic incentives is required to strengthen the business case for climate-resilient and low-carbon livestock and poultry value chain.</li> <li>* Grants/subsidies or other financial incentives from the government of Bahrain.</li> </ul>

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. The proposed roles and responsibilities are in line with the institutions mandate as summarized below:

**Table 32: Project Management**

Project Implementation Organizations	Roles and Responsibilities
Ministry of Municipalities Affairs and Agriculture	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>

<b>Project Implementation Organizations</b>	<b>Roles and Responsibilities</b>
<p>Supreme Council of Environment</p> <p>Agriculture Affairs &amp; Marine Resources (Animal Health)</p>	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development and implementation of relevant policies and regulations.</li> </ul>
<p>Project Management Office</p> <p>(To be established by Ministry of Municipalities Affairs and Agriculture)</p>	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

# 4.4

## Climate Resilient Fisheries and Aquaculture Development



## 4.4 Climate Resilient Fisheries and Aquaculture Development

The fisheries sector is a very promising sector for Bahrain and has a great potential to contribute to food security. Fish resources in Bahrain supply around 50% of national consumption needs, and the rest is imported. The annual level of production in 2022 amounted to 12,000 metric tons of fish and crab of which the local consumption accounts for 6,000 metric tons and the rest is exported. In addition to the local production, Bahrain imported around 6,000 metric tons of fish and shrimps in 2022.

There are several factors negatively affecting the marine environment and reducing fish stocks including habitat destruction, discarded brine from desalination plants, overfishing and climate change. To address the deficit in fish production, the Government has been investing in aquaculture to enhance food security and self-sufficiency, as well as develop exports. However, there are several challenges facing aquaculture development in Bahrain that need to be addressed to ensure sustainable development of the fisheries sector.

- (i) There is no thorough assessment of the diversity of fish species to cultivate and the production is currently carried out without a sustainable strategy. If the environmental carrying capacity is not respected, the fish production will face a disease outbreak.
- (ii) The local production of fish feed in the country is limited and mostly imported from Saudi Arabia. It is important to encourage private companies to invest in fish feed production.
- (iii) Loss and waste in the fishing industry is generally high, with nearly 40 percent lost or wasted between catch and consumption. This loss is due to limited investments in handling, transport, storage, and processing facilities.

To achieve climate resilient development of the fisheries and aquaculture sector, the government has initiated several actions aimed at decreasing pressure on marine resources, preserving marine wealth, and allowing the recovery of fish stocks. With steps taken to promote more sustainable use of fishery resources, the fisheries sector has a promising potential to contribute to food security, enhance productivity and provide prospects for innovation, value addition and exports. To better capitalize on this development, steps may be taken to:

- (i) Strengthen the implementation and enforcement of current regulations to protect marine resources, respect maximum sustainable yields and avoid depletion of fish stocks.
- (ii) Promote responsible development of aquaculture through a sustainable aquaculture strategy based on ecosystem-based management approach to enhance adaptive capacity to climate change and ensure that environmental carrying capacity is not exceeded.
- (iii) Ensure the high quality of coastal water near aquaculture operation sites and areas with potential for aquaculture.
- (iv) Explore investments along the fish value chain (handling, transport, storage and processing) through transfer of adapted technologies to minimize loss and waste.

- (v) Develop local capacities for SME aquaculture entrepreneurs, promote the quality of fingerlings and the safety of farmed fish.
- (vi) Improve and raise the level of production in the fish farming sector, including on feed and the establishment of hatcheries covering the needs of companies for fish farming.

## Climate Rationale

Climate change, along with other phenomena that affect climate variability, such as extreme weather events, are affecting the abundance and distribution of fisheries resources and the suitability of geographical locations for aquaculture systems. Although the fisheries and aquaculture sector is less vulnerable to the seasonal risks that affect crop production, the sector is nevertheless threatened by long-term stresses from climate change. Increases in water temperatures due to climate change alter the ecosystem fishers rely on for their catch, while economic growth and human activity irrevocably alter fish habitats.

The coastal areas of Bahrain support several important ecosystems including, mangroves, seagrass beds, coral reefs, and intertidal mudflats. These habitats provide a variety of ecosystem services to the country and its economy, including the fisheries sector. Seagrass beds, which occupy approximately 33,700 ha of Bahrain's coastal waters, constitute a rich habitat for commercial fisheries, mollusks, and crustaceans. Coral reefs maintain a large diversity of fish, supporting over 230 species and numerous shellfish species. They also constitute the nurseries for commercial fish species and account for most of the annual fish yield.

Under a high emissions global warming scenario (RCP 8.5), Bahrain is projected to experience a decline in the maximum potential catch in marine species currently being exploited compared to other countries located around the Arabian Gulf (See Table 6). While species may adapt by moving deeper, the Arabian Gulf's shallow depth limits species' ability for such relocation. Climate-driven perturbations in local and regional environmental conditions will make most of the southern Gulf unsuitable for certain species. This calls for the development and effective implementation of an ecosystem-based management approach to enhance the adaptive capacity of marine social-ecological systems to climate change.

Improving the general resilience of fisheries and aquaculture systems can reduce their vulnerability to the impacts of climate change and climate variability on resources and to severe weather episodes. Some of the key climate resilience measures include:

- (i) Strengthening the implementation and enforcement of current regulations to protect marine resources and ensure the high quality of coastal water near fisheries operation sites and areas with potential for aquaculture.
- (ii) Promote responsible development of the fisheries sector based on ecosystem-based management approach to enhance adaptive capacity to climate change and ensure that environmental carrying capacity is not exceeded.
- (iii) Climate proofing investments along the fisheries value chain (handling, transport, storage and processing) to build the adaptive capacity of the sector to climate change.
- (iv) Ensure that climate change and resource management are factored into fisheries policymaking, research, and practices to ensure sustainability.

## Project Description

The project development objective is to increase the climate resilience and sustainability of the coastal and marine fisheries and to promote public and private sector collaboration to rapidly scale-up climate action in the country. The project consists of two investment components and a supporting implementation unit: (1) enhancing resilience of fish habitats; (2) development of climate-resilient fisheries and aquaculture value chain; and (3) technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Enhancing resilience of fish habitats*

This component targets enhancing the management of priority ecosystems and fisheries to reduce the likelihood of their continued decline and to build their resilience to underlying climate change threats. The types of resilience actions and the associated activities are listed below:

- **Protecting coastal habitats:** Coastal habitats, such as mangroves, seagrasses, and coral reefs, are important for fish spawning, nursery, and feeding grounds. These habitats are also vulnerable to climate change impacts such as sea level rise and storm surges. Restoring and protecting coastal habitats can help to improve their resilience to climate change and provide fish with the habitat they need to survive and thrive.
- **Creating fish passageways:** Climate change is causing changes in water temperature, salinity, and oxygen levels. These changes can make it difficult for fish to move between different habitats, which can disrupt their spawning, nursery, and feeding cycles. Creating fish passageways can help fish to move freely between different habitats, even when conditions change.
- **Planting heat-tolerant vegetation:** Rising water temperatures are one of the most significant impacts of climate change on fish habitats. Heat-tolerant vegetation can provide shade and cover for fish, helping them to cope with rising water temperatures.
- **Managing fishing sustainably:** Overfishing can reduce fish populations and make them more vulnerable to climate change impacts. Sustainable fishing practices, such as setting catch limits and closing spawning areas, can help to protect fish populations and make them more resilient to climate change.

In addition to these general climate adaptation actions, there are a number of specific actions that can be taken to protect fish habitats in the Arabian Gulf. These include:

- Developing and implementing climate change adaptation plans for specific fish habitats. These plans should identify the specific threats that each habitat faces and develop strategies to mitigate those threats.
- Monitoring fish habitats and fish populations to assess the effectiveness of climate adaptation actions. This information can be used to improve climate adaptation plans over time.
- Raising awareness of the importance of fish habitats and the threats they face from climate change. This can help to build support for climate adaptation actions.

In the first phase, the resilience enhancing actions will be piloted at a densely populated and vulnerable shoreline in Bahrain. In the subsequent phases, the resilience enhancing measures may be extended to other major marine protected areas in the country as listed below:

- **Hawar Islands** – An archipelago covering a surface area of 5,200 ha consisting of 36 pristine small islands, surrounded by seagrasses. Hawar Islands host the largest breeding colony of Socotra cormorants, the largest herd of dugongs (following Australia), as well as populations of greater flamingo, black-head gull and marine turtles.
- **Tubli Bay** – A semi-confined bay located in the northeastern part of Bahrain, covering a surface area of 1,610 ha. Tubli Bay is home to a variety of marine life, including mangroves, fish, and birds. Tubli Bay harbors intertidal mud and sand flats and is also a nursery for commercially important prawns and fishes.
- **Mashtan Island** – An island located in the southern part of Bahrain and covers a surface area of 250 ha. It is home to a variety of marine life, including coral reefs, seagrass beds, dugongs, and sea turtles.
- **Arad Bay** – A reserve located in the northwestern part of Bahrain, covering an area of 44 ha that acts as a nursery for small fish, plankton and seaweed. The area also an important environment for multiple species of resident and migratory birds.
- **Northern Oyster Beds Site** – Consists of three oyster beds namely Hayr Bul Thamah, Hayr Shtayyah and Hayr Bu Am'amah located in the north-east of Bahrain. Collectively, these oyster beds cover a total area equal to 1347.2 km<sup>2</sup> in the sea.

### *Component 2: Development of climate-smart fisheries and aquaculture value chain*

This component seeks to create an enabling environment for sustainable growth in the fisheries and aquaculture sector by financing the development of critical infrastructure and related facilities to stimulate value addition, develop market strategies and improve the business climate for viable private sector investments. The focus is on modernizing fish farming operations, processing and cold storage facilities as well as providing adaptation co-benefits by reducing fish waste and losses. In alignment with the Kingdom of Bahrain's commitment to reduce greenhouse gas (GHG) emissions, this component will support investments that result in:

- Reduced GHG emissions per unit of output and a lower intensity than the national average for GHG emissions per unit of output.
- Improved productivity by adopting innovative technologies such as aquaponics to improve the efficiency of the fish farming operations.
- Reduced feed losses in the operations, as well as food losses across the supply chain, where possible or feasible.
- Effective waste management that seeks to reduce its climate impact.

### *Component 3: Technical Support and Project Management*

This component will support the establishment of a Project Implementation Unit (PIU), which would include research and study activities geared to an improved understanding of marine habitat restoration and the public good services provided by such restoration. This would also help gain a better understanding of the public and private funding requirements of marine habitat restoration activities. A monitoring and evaluation system that includes, for example, fish stock status index, marine trophic index and fish caught by trawling, will be established to assess the project's environmental and socio-economic impact and to monitor project performance and achievement of project objective.

## Investment & Financing Plan

The project is estimated to cost BHD 23 million (2023 prices)

**Table 33: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Enhancing resilience of fish habitats	4.0	17%
	Component 2: Development of climate-resilient fisheries value chain	16.0	69%
	Component 3: Technical Support and Project Management	1.0	4%
	<b>Subtotal (A)</b>	<b>21.0</b>	<b>91%</b>
<b>B</b>	<b>Contingencies</b> (assumed at 10% of base cost)	2.1	9%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>23.0</b>	<b>100.0%</b>

### *Component 1: Enhancing resilience of fish habitats*

The revenue potential of a project to enhance the resilience of fish habitats can vary depending on the specific project, the location, and the target audience. However, there are several ways to generate revenue from a fish habitat restoration project, as noted below.

- **Sale of fish and seafood:** Fish habitat restoration projects can lead to increased fish populations, which can benefit commercial and recreational fisheries. The sale of fish and seafood can generate revenue for the project, as well as for the fishers and seafood businesses that benefit from the increased fish populations.
- **Ecotourism:** Fish habitat restoration projects can also attract ecotourists, who are interested in experiencing and supporting healthy ecosystems. Ecotourists may be willing to

pay for activities such as fishing, kayaking, and birdwatching in areas where fish habitats have been restored.

- **Carbon credits:** Fish habitats can sequester carbon dioxide from the atmosphere. This can help to mitigate climate change and generate revenue for the project through the sale of carbon credits.
- **Ecosystem service payments:** Governments and businesses may be willing to pay for the ecosystem services that fish habitats provide, such as water quality regulation and coastal protection.

Currently, the enabling environment does not exist for generating revenue and attracting private finance. As a result, there is no near-term commercial potential for this project component and grant funding from the government or philanthropic organizations is most suitable.

Financing Instrument	Funding Sources	Key Requirements
Grant	Philanthropic organizations CSR contributions	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.

### *Component 2: Development of climate-smart fisheries and aquaculture value chain*

The commercial potential of climate-smart fisheries and aquaculture is significant. As the world transitions to a more sustainable food system, climate-smart fisheries and aquaculture are expected to play a major role. By increasing productivity and resilience, while reducing greenhouse gas emissions, climate-smart practices can help businesses to:

- **Reduce costs:** Climate-smart practices can help businesses to reduce their input costs, such as energy, water, and feed. For example, using renewable energy to power fishing vessels and aquaculture facilities can reduce energy costs.
- **Increase revenue:** Climate-smart practices can help businesses to increase their revenue by producing more fish and seafood, and by accessing new markets and premium prices. For example, businesses that produce climate-smart fish and seafood products can access new markets and premium prices from consumers who are looking for sustainable and environmentally friendly products.
- **Improve brand reputation:** Businesses that invest in climate-smart practices can improve their brand reputation and attract new customers. This is because consumers are increasingly looking to support businesses that are socially and environmentally responsible.

As a result, the commercial potential of this project component could be high enough to attract private finance.

Financing Instrument	Funding Sources	Key Requirements
Equity & debt capital	Private sector including commercial banks, climate impact/venture funds, etc.,	<p>Enabling policies and economic incentives is required to strengthen the business case for climate-smart fisheries and aquaculture value chain.</p> <p>Grants/subsidies or other financial incentives from the government of Bahrain.</p>

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. The proposed roles and responsibilities are in line with the institutions mandate as summarized below:

**Table 34: Project Management**

Project Implementation Organizations	Roles and Responsibilities
	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>
Supreme Council of Environment (Fish Stock Protection and Development Directorate)	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development and implementation of relevant policies and regulations.</li> </ul>
Project Management Office	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

# 4.5

## Restoration of Mangrove Ecosystems for Climate Resilience



## 4.5 Restoration of Mangrove Ecosystems for Climate Resilience

Mangrove ecosystems have a significant ecological and socioeconomic value wherever they are found in the world's coastal areas. They form the foundation of highly productive and biologically rich habitats for a broad range of marine and terrestrial species. In Bahrain, dense mangrove forests are found in Tubli Bay and are distributed across other major areas such as Sitra, Arad Bay and Ras Sanad. These mangroves provide a range of vital ecological and ecosystem services such as:

- **Regulating services:** These include the protection of beaches and coastlines from storm surges, waves, and floods; reduction of beach and soil erosion; stabilization of land by trapping sediments; and water quality maintenance.
- **Provisioning services:** The most pertinent provisioning service is commercial fisheries as Tubli Bay acts as a nursery site for commercial shrimp.
- **Supporting services:** These include cycling of nutrients; maintenance of hydrologic balance, habitats for species; and pollutant processing. Each of these is relevant to Tubli Bay, mainly resting and feeding habitats for resident and migratory birds.
- **Tourism services:** These include recreational activities, as well as intrinsic services associated with cultural heritage and support of societal values. The Bahrain Tourism and Exhibitions Authority (BTEA), in collaboration with the Supreme Council for Environment, launched mangrove tourism in Tubli Bay in 2018 as a way of enhancing public awareness of their ecological and cultural value.

Since the 1970s, the mangrove forest areas in the Kingdom of Bahrain have been adversely impacted resulting in the loss of more than 75% of its natural mangrove cover, from 330 ha in 1967 to 80 ha in 2020. As per the Third National Communication, three main anthropogenic factors have adversely impacted Bahrain's mangrove forests, leading to sharp reductions in their spatial extent and health. First, extensive land reclamation has been conducted along the coasts of the country which has affected large areas of mangroves. Second, slurry discharge from sand washing plants has led to excessive siltation that has damaged the fragile mangrove root system. Third, treated wastewater is discharged from the Tubli wastewater treatment plant, leading to high levels of nitrogen and phosphorus in the Bay, that adversely alter the nutrition of mangroves. This is further compounded by frequent illegal dumping of municipal solid wastes by tankers. These factors have led to the loss of about a third of the total mangrove area in Tubli Bay.

The Government of Bahrain is taking bold steps to revert mangrove losses and rehabilitate degraded or deforested mangrove areas. The mangrove planting project started in 2013 with the Supreme Council of Environment and has now grown into a national project. In 2022, the government launched the National Afforestation Plan, with the goal of increasing the mangrove area by four times by 2035. To start off, the government, in collaboration with UN-Habitat and HSBC, launched a project to support the rehabilitation and restoration of mangrove habitats situated along the urban fringes of Bahrain's capital city of Manama. The project supports ongoing efforts of the government to increase the mangrove area, extending the benefits of the current work of the Supreme Council for the Environment and the Ministry of Municipalities Affairs and

Agriculture to restore mangrove ecosystems, and constructing of a visitor center at Ras Sanad in Tubli Bay.

## Climate Rationale

Sea level rise (SLR) is one of the primary and most significant effects of climate change. As with all small low-lying states, sea level rise represents a significant climate risk to Kingdom of Bahrain. A recent study conducted by the SCE assessed this threat and quantified the extent of potential inundation throughout the Kingdom under a range of sea level rise scenarios. The results confirm that significant inundation impacts are projected for certain land use categories, even at small levels of rising seas. Some key national implications of the assessment are outlined below:

- The risk after 2050 is greater for several locations, predominantly in the North-west of Bahrain, such as Muharraq and Manama, which host significant numbers of critical infrastructure assets.
- The assessment shows that Muharraq has by far the most significant damages in the L5 scenario (1 in 500 years surge event following 0.5m SLR).
- For the L3 (1 in 500 years surge event today) and L1 (0.5m SLR only) scenarios, Muharraq still has the highest damages, however, the distribution is spread more evenly amongst other coastal areas.
- A total of over 18,000 assets are exposed to flood risk if the severe (but unlikely) L5 scenario occurs, with the majority of those being residential properties.
- The potential scale of economic damage from the single occurrence of the L5 SLR scenario is estimated at ~BHD 1.4 billion. The implementation costs of physical interventions to mitigate the impact of the L5 scenario are estimated to be in the range of BHD 122-161 million.

The development of natural adaptive measures such as mangroves ecosystems are considered natural infrastructure options to mitigate the impact of inundation from sea level rise and help protect nearby populated areas by reducing erosion. Their dense roots help bind and build soil. Their above-ground roots slow down water flows and encourage sediment deposits that reduce coastal erosion. The complex mangrove root systems filter nitrates, phosphates, and other pollutants from the water, improving the water quality flowing into the ocean environment.

The other major benefit of mangrove ecosystems is their enhancement of biodiversity. Mangrove forests provide habitat and refuge to a wide array of wildlife such as birds, fish, invertebrates, mammals, and plants. Habitats with coastal mangrove shorelines and tree roots are often important spawning and nursery territory for juvenile marine species including shrimp, crabs, and many commercial fish species. Therefore, the protection provided by mangrove forests is an essential component of coastal resilience, with their conservation and restoration necessary to safeguard both coastal communities and the natural environment.

The mangrove forest restoration process has the potential of contributing to the Kingdom's wider national socioeconomic development. This includes providing an important biological habitat for

crustaceans, marine organisms, and birds; enhancing fish rearing habitats; providing shoreline protection against sea level rise; increasing ecotourism revenues; improving respiratory health, encouraging physical activity and interaction with greenspaces.

## Project Description

The project development objective is to contribute to the long-term resilience of Kingdom of Bahrain from climate change by rehabilitating mangrove ecosystems and promoting a nature-based solutions approach towards sustainable development of the coastal areas.

The project consists of the following three investment components and a supporting implementation unit: (1) strengthening policy and institutions for mangrove management; (2) restoring and promoting sustainable mangrove ecosystems; and (3) developing a blue carbon market; and (4) technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Strengthening policy and institutions for mangrove management*

More than 80% of Bahrain's coastline has extensively been modified due to land reclamation activities. Land reclamation affects suspended sediments, turbidity, ocean currents and water movements as well as salinity. This has resulted in the large-scale disappearance of mangrove ecosystems and the loss of many productive intertidal habitats. It has also greatly increased the turbidity in the waters surrounding both reclaimed and dredged sites.

An analysis of the conservation status of the existing ecosystems and their habitats in the Kingdom of Bahrain has shown that some of the highest threat values are recorded for the mangrove forest areas and related ecosystems. The national priority actions proposed for biodiversity conservation that are related to mangrove ecosystems include:

- (i) Take necessary measures to stop illegal activities and violations.
- (ii) Reinforce the management program for the restoration and plantations of mangroves.
- (iii) Develop a communication strategy to raise awareness on the importance of mangroves.

Component 1 aims to address national priority actions by strengthening policies and institutions to improve the management of mangrove ecosystems. The main activities under this component are: (i) development of national regulations and action plan for sustainable mangrove management; (ii) improvement of institutional capacity in mapping mangroves and provision of related infrastructure; (iii) design and implementation of a monitoring system, including, a comprehensive monitoring methodology and its governance mechanism; and (iv) conduct strategic communications campaigns.

### *Component 2: Restoring and promoting sustainable mangrove ecosystems*

Since the 1970s, the mangrove forest area has decreased by over 75% due to various urban development factors. Component 2 aims to rehabilitate and restore mangrove forests through a landscape approach. Led by the Ministry of Municipalities Affairs and Agriculture, in close coordination with the Biodiversity Directorate of the Supreme Council for Environment (SCE), this

component will build on the ongoing restoration activities with an objective of quadrupling the current mangrove forest coverage. Between 2023 and 2035, the goal is to plant 230,000 mangrove trees per year and restore the mangrove forest cover in the targeted areas following global best practices. On June 5, 2023, World Environment Day, His Royal Highness the Crown Prince, and Prime Minister announced that 2023's annual mangrove plantation is doubled from 230,000 to 460,000.

Restoration actions consist of works and activities carried out by specialized professionals as described below:

- **Desilting water passages:** Road construction is one of the main causes of hydrological changes in mangroves. Water passages usually designed in construction works are ineffective as they do not allow the free exchange of water. Therefore, it is necessary to build channels or alter the existing channels to connect the wetland, or conserved area, with the disturbed mangrove area to allow a free flow of water between them.
- **Relocation of organic material:** As a result of natural events and the impact of anthropic activities, remains of dead vegetation and other debris may likely exist in the site to be restored. Such materials could limit or restrict the free flow of surface water through the desilted or rehabilitated channels and will have to be removed and relocated. The organic material removed should be relocated somewhere within the area being restored so that its decomposition process can continue and provide nutrients to the soil, but without obstructing water flow.
- **Desilting natural tidal channels:** Once the natural tidal channels of the site have been identified through the analysis of satellite images, photographs, prospecting and field sampling, or the topographic survey, desilting activities will begin. The width and depth of these channels should mimic the natural configuration of each site to provide heterogeneity and mitigate the erosion of walls from ebb and flow of water, thus reducing the frequency of maintenance works. Efforts should be made to follow the original zigzag paths of channels to improve water circulation and reduce maintenance costs.
- **Enabling new channels:** Works for building new channels consider water exchange efficiency so that the water residence time is determined by both the tides and the freshwater runoff. Ensuring the free circulation of water increases the chances that the new channels will work properly. Sediment removed during the construction or rehabilitation of channels must be raked towards the ends or used to fill up low-laying sites or to construct dispersal centers.
- **Conditioning dispersal centers:** Dispersal centers (DC) are areas that have been delimited and topographically modified to raise up their level by accumulating sediment and form mounds that are stabilized using mesh or other materials. The main objective of DCs is to promote adequate flooding conditions for the successful establishment of seedlings. Dispersal centers possess hydrological and sediment conditions that are suitable for the successful establishment of seedlings.

The number, density, and location of dispersal centers is decided based on the size and initial conditions of the area to be restored, considering the topography and preferential flows. Dispersal centers also function as reforestation centers that will contribute, through active restoration, to accelerate the recovery of vegetation structure.

- **Reforestation:** Reforestation is the technique which accelerates the recovery of the structure and functions of mangrove forests. The mangrove seedlings are planted at least 0.5 m from each other to include greater genetic diversity and to avoid collecting several propagules from a single parent plant.

In addition to the restoration activities, this component will support: (i) establishment of mangrove management field school groups; (ii) assessment and selection of mangrove restoration sites; (iii) training of local facilitators on mangrove restoration; (iv) development of governorate-level mangrove restoration plans; and (v) monitoring and mid-term corrections of restored sites.

### *Component 3: Developing a blue carbon market*

Mangrove forests are known to sequester significant amounts of carbon from the atmosphere and store it in their roots and soil, making them effective carbon sinks. However, when degraded or destroyed, these mangrove ecosystems emit the carbon they have stored for centuries into the atmosphere and oceans and become sources of greenhouse gases. In the Kingdom of Bahrain, the potential carbon sequestration due to the loss in mangrove forest coverage is estimated to have decreased from 128 Gg CO<sub>2</sub>e per ha in 1967 to 19 Gg CO<sub>2</sub>e per ha in 2020. This implies that ~109 Gg CO<sub>2</sub>e is released and thereby turning a natural carbon sink into a carbon source.

Considering the significant potential for carbon sequestration and greenhouse gas offsets, blue carbon ecosystems, such as mangrove forests have gained global prominence for climate mitigation as a nature-based solution. Blue carbon markets are relatively new compared with markets for carbon sequestration on land, such as tree planting. But they are expected to have great potential as part of the global demand for carbon credits that is projected to increase fifteen-fold from 2020 levels and to be worth up to US\$50bn by 2030.

The objective of this component is to enable the development of a blue carbon market for making emissions reductions generated from the restored mangrove forests eligible for carbon offset payments. This component will support: (i) national-level accounting of carbon stocks and emissions from blue carbon ecosystems; (ii) development of blue carbon regulatory framework, and (iii) capacity building for blue carbon finance readiness.

### *Component 4: Technical Support and Project Management*

This component will support the establishment of a Project Implementation Unit (PIU), which would include cross-cutting activities designed to strengthen coordination, communication, management, and monitoring of implementation of all components. It will aim to ensure project efficiency by establishing a robust management system and maintaining the project's participatory structures. It will finance the costs associated with day-to-day management and supervision of overall project implementation. A strong monitoring and evaluation system will be set up under the project to monitor project performance, achievement of project objective, and assess the project's environmental and socio-economic impact.

## Investment & Financing Plan

The project is estimated to cost BHD 204.0 million (2023 prices)

**Table 35: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Strengthening policy and institutions for mangrove management.	2.5	1.2%
	Component 2: Restoring and promoting sustainable mangrove ecosystems.	180.0	88.2%
	Component 3: Developing a blue carbon market	2.5	1.2%
	Component 4. Technical Support and Project Management	1.0	0.5%
	<b>Subtotal (A)</b>	<b>186.0</b>	<b>91.1%</b>
<b>B</b>	<b>Contingencies</b> (assumed at 10% of base cost)	18.0	8.9%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>204.0</b>	<b>100.0%</b>

### *Component 1: Strengthening policy and institutions for mangrove management.*

This project component involves capacity building and related technical assistance activities for enabling policies and institutions for mangrove management. Considering that this project component has no direct revenue potential, grant funding from the government or philanthropic organizations is most suitable.

Financing Instrument	Funding Sources	Key Requirements
Grant	Government funds Philanthropic organizations CSR contributions	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.

### *Component 2: Restoring and promoting sustainable mangrove ecosystems*

The commercial potential of restoring and promoting sustainable mangrove ecosystems is significant. Mangroves provide a wide range of valuable ecosystem services, and there are several ways to generate commercial revenue through a variety of direct and indirect means, such as:

- **Ecotourism:** Mangrove forests are popular tourist destinations, offering opportunities for activities such as birdwatching, kayaking, and fishing. Businesses that develop and manage ecotourism activities in mangrove forests can generate revenue from tourists.
- **Carbon credits:** Mangrove forests sequester carbon dioxide from the atmosphere, which can help to offset carbon emissions. Businesses and organizations can purchase carbon credits to offset their emissions, which can generate revenue for mangrove restoration and promotion projects.
- **Ecosystem service payments:** Governments and businesses are increasingly willing to pay for the ecosystem services that mangroves provide. For example, governments may pay mangrove restoration and promotion projects to reduce the risk of coastal flooding. Businesses may pay mangrove restoration and promotion projects to improve water quality in areas where they operate.

Currently, the enabling environment does not exist for generating revenue and attracting private finance. As a result, there is no near-term commercial potential for this project component and grant funding from the government or philanthropic organizations is most suitable. Over the long term as Bahrain creates the enabling environment to incentivize private sector participation, there is potential to mobilize commercial capital.

Financing Instrument	Funding Sources	Key Requirements
Government funds	National budget	New taxes and usage fees are required to service the debt raised from capital markets, multilateral, and regional financial institutions.
Green bonds/sukuk	Capital markets	
Concessional debt	Regional and multilateral development banks and funds	
Grants	Philanthropic organizations CSR contributions	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.
Sale of tourism development rights	Private sector	Enabling policies and economic incentives is required to strengthen the business case for restoring mangrove forests.
Sale of blue carbon credits	Private sector	

### *Component 3: Developing a blue carbon market*

This project component involves capacity building and related technical assistance activities for enabling policies and institutions for developing a blue carbon market. Some of the challenges that need to be addressed in order to develop a successful blue carbon market include:

- **Developing robust carbon accounting methodologies:** It is important to develop robust carbon accounting methodologies to measure the amount of carbon that is sequestered and stored by blue carbon ecosystems. This will be necessary to ensure that blue carbon credits are credible and can be traded on a carbon market.
- **Addressing land tenure and access rights:** It is important to address land tenure and access rights issues for blue carbon ecosystems. This is necessary to ensure that blue carbon projects are developed and managed in a way that is equitable and benefits local communities.
- **Raising awareness of blue carbon:** It is important to raise awareness of blue carbon and the benefits of investing in blue carbon markets. This will be necessary to attract buyers and sellers of blue carbon credits.

Considering that this project component has no direct revenue potential yet, grant funding from the government or philanthropic organizations is most suitable.

Financing Instrument	Funding Sources	Key Requirements
Grant	Government funds Philanthropic organizations CSR contributions	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. The proposed roles and responsibilities are in line with these institutions mandate as summarized below:

**Table 36: Project Management**

Project Implementation Organizations	Roles and Responsibilities
Ministry of Municipalities Affairs and Agriculture	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>
Biodiversity Directorate of Supreme Council of Environment	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development of relevant policies and</li> </ul>

	implementation of mangrove forests restoration and management.
<p>Project Management Office</p> <p>(To be established by Ministry of Municipalities Affairs and Agriculture)</p>	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

# 4.6

## Afforestation and Nursery Development



## 4.6 Afforestation and Nursery Development

The green areas in the Kingdom of Bahrain have been decreasing mainly due to two inter-related factors. The first is the salinization of the land due to the deterioration of groundwater quality and the second is the encroachment of green areas due to rapid urban development.

In November 2021, at the 26th United Nations Climate Change Conference of the Parties (COP26), His Royal Highness Prince Salman bin Hamad Al Khalifa, the Crown Prince and Prime Minister, announced a target of doubling the Kingdom's tree coverage by 2035. This target is one of the key ongoing climate adaptation actions in the Kingdom. Shortly after its announcement, the National Plan for Afforestation was approved by Cabinet to double the current 1.8 million trees to 3.6 million within the set timeframe.

As part of the preparatory activities for implementing the National Plan for Afforestation, thermal satellite imagery of Bahrain was analyzed to identify the target areas for afforestation, climate-resilient native tree species and vegetation suitable for Bahrain's climatic conditions were identified, and a pilot program was established to test the climate impact of afforestation in target areas. Based on the results of the pilot program, the Supreme Council for the Environment, in cooperation and coordination with the Ministry of Works, Municipalities Affairs and Urban Planning, developed the 'Afforestation and Nursery Development Project' to achieve the goals of the National Plan for Afforestation.

### Climate Rationale

Future climate changes with increasing frequency, intensity, and scales of extreme weather events, for example droughts, heat waves and sandstorms, are expected to further exacerbate the vulnerability and risk of humans and ecosystems to desertification, as drought and aridity are projected to increase in scenarios of 1.5°C to a 2°C global warming. Higher intensity of sandstorms and sand dune movements under climate change can also cause damage to transportation and solar energy generating infrastructures. The interaction of climate change and desertification reduces the provision of terrestrial ecosystem services and lowers ecosystem health, including loss of biodiversity, affecting food security and human well-being.

Afforestation is one of the most effective means of tackling climate change and desertification, particularly when it is designed to rely on green energy and recycled water. This Nature-based-Solution (NbS) reduces the impact of climate change-desertification interactions, supports terrestrial ecosystems, and removes carbon emissions from the atmosphere. Afforestation also contributes to preserving biodiversity hotspots, avoiding soil degradation, and protecting groundwater resources.

In urban centers, belts of trees planted as structural elements can offer protection from harsh climatic conditions and contribute to the reduction of urban heat island effects as well as reduce dust concentration in the air. Within the context of future climate change, with rising temperatures, drier climates, and increasingly frequent heat waves, green areas are becoming increasingly important as they can create a cooling effect that extends into its surrounding areas, improves urban landscape, and encourages urban populations to adopt a healthier lifestyle.

The Kingdom of Bahrain is particularly exposed to adverse weather conditions such as recurring sandstorms and high temperatures, both of which can be mitigated by creating green areas with wind breaking and dust-mitigating native tree species. Planting different trees and plant species will also increase biodiversity and provide habitats for birds, bees, and other native species. As such, the sustainable management of green areas is a particularly effective climate adaptation measure which enhances ecosystems services at a local scale; both by reducing vulnerability to climate change and by preventing biodiversity loss.

## Project Description

The project development objective is to contribute to the long-term resilience of the Kingdom of Bahrain from climate change by enhancing and protecting terrestrial ecosystems through NbS and promoting public and private sector collaboration to rapidly scale-up climate action in the country.

The project consists of the following two investment components and a supporting implementation unit: (1) expansion of green cover in urban areas; and (2) development of climate-smart nurseries for afforestation planning and management; and (3) technical support and project management. The project components are designed to complement and support each other.

### *Component 1: Expansion of green cover in urban areas*

Prior to the tree coverage target set at COP26, a national afforestation campaign was launched under the slogan “Forever Green” in cooperation with the Ministry of Works, Municipalities Affairs, and Urban Planning and the Supreme Council for Environment (SCE) in October 2021. The aim of the campaign is to implement afforestation projects and expand green areas in the Kingdom, in coordination with the public and private sector. The campaign contributes to increasing the per capita share of green space and increasing the Kingdom’s total green area by planting trees around streets, intersections, and facilities such as schools, public parks, etc. This greening initiative also improves air quality and reduces temperatures in the urban areas.

During its first phase (2021-2022), the campaign completed 34 afforestation projects in various governorates in the Kingdom and succeeded in planting nearly 50,000 trees and shrubs on an area of 73,000 square meters and along a length of 23 kilometers. For Phase 2 (2023-2024), the afforestation plan is to plant over 160,000 trees in the provinces. Subsequent phases are to be developed in line with the afforestation target of 3.6 million trees by 2035.

This project component aims to continue the expansion of green cover in urban areas, in line with existing tree-planting initiatives and strategies in the Kingdom. To ensure the sustainability of these green spaces, an irrigation network using treated wastewater with a daily capacity of over 20,000 m<sup>3</sup> to cover an afforested area of over 200 ha will be established.

### *Component 2: Development of climate-smart nurseries for afforestation planning and management*

To achieve the goals of the National Plan for Afforestation of doubling tree coverage to 3.6 million trees by 2035, the nursery infrastructure for supplying trees and seedlings needs to be

significantly enhanced as the existing nurseries are out of date. Much of the equipment requires manual operation and the electric fans are over 35 years old. The lack of proper storage facilities exposes seedlings to heat and humidity, thereby reducing their durability. The inefficient use of space also reduces production capacity and forces nursery operators to move plants early, which reduces the plants' survival rate and resilience.

To improve the survival rates and increase the efficiency of seedling production of various types of plants of required sizes, the Ministry of Municipalities Affairs and Agriculture seeks to modernize the existing Adhari nursery and establish two new climate-smart nurseries in Salman City and Al Maameer to increase the seedling production capacity from the 30,000 to 130,000 seedlings per year. Considering Bahrain's current reliance on tree imports to fulfill afforestation targets, the project is set to yield significant cost savings and advantages, by facilitating an expansion in local tree production and reducing the need for imported trees.

This project component seeks to develop three climate-smart nurseries with modern greenhouses with fold-back roofs, semi-automized irrigation systems using drip irrigation or automatic sprinklers, and intelligent systems for watering, fertigation, lighting, ventilation, and cooling systems to maintain the optimum soil and climatic conditions. The total greenhouse area and seedling production capacity for the three nurseries is summarized in Table 37.

**Table 37: Planned Nurseries**

No	Nursery	Greenhouse Area (sqm)	Annual Seedling Production Capacity
1	Adhari	30,000	60,000
2	Salman City	2,200	25,000
3	Al Maameer	4,000	45,000

Once modernized, the climate-smart nurseries have the potential of becoming an agricultural research and development hub for the region and can be used to showcase the latest agricultural technologies as well as provide training to smaller nurseries in horticulture, nursery management and seedling requirements. In addition, the nurseries can serve as recreational and tourist centers by hosting events and workshops in a variety of multidisciplinary fields.

### ***Component 3: Technical Support and Project Management***

This component will support the establishment of a Project Implementation Unit (PIU), which would include research and study activities geared to an improved understanding of ecological afforestation and the public good services provided by such afforestation. This would also help to gain a better understanding of the public and private funding requirements of ecological afforestation activities. A strong monitoring and evaluation system will be set up under the project to monitor project performance, achievement of project objective, and assess the project's environmental and socio-economic impact.

## Investment & Financing Plan

The project is estimated to cost BHD 91.0 million (2023 prices)

**Table 38: Project Investment Plan (BHD million)**

Item		Amount	%
<b>A</b>	<b>Base Cost</b>		
	Component 1: Expansion of green cover in urban areas	81.0	89.0%
	Component 2: Development of climate-smart nurseries	1.0	1.1%
	Component 3: Technical Support and Project Management	1.0	1.1%
	<b>Subtotal (A)</b>	<b>83.0</b>	<b>91.2%</b>
<b>B</b>	<b>Contingencies</b> (assumed at 10% of base cost)	8.0	8.8%
<b>C</b>	<b>Financing Charges during Implementation</b>	-	
	<b>Total (A+B+C)</b>	<b>91.0</b>	<b>100.0%</b>

### *Component 1: Expansion of green cover in urban areas*

Increasing green cover in urban areas can generate commercial revenue through a variety of direct and indirect means, such as:

- **Carbon credits:** Trees sequester carbon dioxide from the atmosphere, which can help to mitigate climate change. Businesses and organizations can purchase carbon credits to offset their carbon emissions, which can generate revenue for tree planting projects in arid urban areas.
- **Development and management of ecotourism activities:** Trees can provide a variety of opportunities for ecotourism activities, such as birdwatching, nature walks, and hiking. Businesses that develop and manage ecotourism activities in urban areas can generate revenue from tourists.
- **Creation of jobs:** Planting and caring for trees in arid urban areas can create jobs in a variety of industries, such as landscaping, construction, and ecotourism. This can boost the local economy and benefit businesses and communities alike.
- **Improved business image:** Businesses that support tree planting projects in arid urban areas can improve their brand reputation and attract customers who are interested in supporting sustainable and environmentally responsible businesses.

Over the long term, as Bahrain creates the enabling environment to incentivize private sector participation, there is potential to mobilize commercial capital. In this regard, the Central Bank of Bahrain's ("CBB") is currently developing Environmental, Social, and Governance ("ESG") disclosure guidelines to assist companies with ESG integration and reporting against a broad range of environmental, social, and corporate governance factors. Bahrain Bourse has also

recently joined the UN Sustainable Stock Exchanges in 2019 and issued voluntary ESG reporting guidelines in 2020.

At present, the commercial potential is limited to mobilizing grants from government agencies, philanthropic organizations, and corporate social responsibility (CSR) donations from large business.

Financing Instrument	Funding Sources	Key Requirements
Grant	Philanthropic organizations Corporate donations	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.

### *Component 2: Development of climate-smart nurseries for afforestation planning and management*

The commercial potential of developing climate-smart nurseries could be significant. Climate-smart nurseries produce plants that are more resilient to climate change, and they use sustainable practices that reduce their environmental impact. This makes climate-smart nurseries attractive to consumers who are looking for ways to mitigate and adapt to climate change. Some of the specific commercial opportunities for climate-smart nurseries are:

- **Sale of climate-smart plants:** Consumers are increasingly willing to pay for climate-smart plants. This is because climate-smart plants are more resilient to pests, diseases, and extreme weather events. This can save consumers money in the long run.
- **Development and sale of climate-smart nursery products and services:** Climate-smart nurseries can develop and sell climate-smart nursery products and services, such as drought-tolerant plants, water-efficient irrigation systems, and pest control methods that are less harmful to the environment.
- **Consultation and design services:** Climate-smart nurseries can provide consultation and design services for businesses and consumers who are interested in creating climate-resilient landscapes.
- **Educational programs:** Climate-smart nurseries can offer educational programs on climate-smart nursery practices, climate-smart plant selection, and climate-resilient landscaping.

At present, the focus of the Ministry of Municipalities Affairs & Agriculture is to supply seedlings at break-even cost for the National Plan for Afforestation by modernizing the existing Adhari nursery and establishing two new climate-smart nurseries in Salman City and Al Maameer to increase the seedling production capacity from the 30,000 to 130,000 seedlings per year. As a result, grant funding from the government or philanthropic organizations is most suitable. Over the long term, as Bahrain creates the enabling environment to incentivize private sector participation, there is potential to mobilize commercial capital.

Financing Instrument	Funding Sources	Key Requirements
Grant	Philanthropic organizations Corporate donations	Alignment with donor priorities. Matching grants or other financial incentives from the government of Bahrain.
Equity & debt capital	Private sector including commercial banks, climate impact/venture funds, etc.,	Long term supply contract is required for the purchase of seedlings by the national agency implementing the afforestation program. Enabling policies and economic incentives is required to strengthen the business case for climate smart nurseries.

## Project Management Arrangements

The implementation of the project components will require the involvement and contribution of all the stakeholders across the different sectors and levels. The proposed roles and responsibilities are in line with these institutions mandate as summarized below:

**Table 39: Project Management**

Project Implementation Organizations	Roles and Responsibilities
Ministry of Municipalities Affairs and Agriculture	<ul style="list-style-type: none"> <li>• Executing agency for the project.</li> <li>• Overall implementation, administration, and monitoring of the project.</li> </ul>
Supreme Council of Environment Agriculture Affairs & Marine Resources (Vegetation)	<ul style="list-style-type: none"> <li>• Provide technical guidance in the development of relevant policies and implementation of mangrove forests restoration and management.</li> </ul>
Project Management Office (To be established by Ministry of Municipalities Affairs and Agriculture)	<ul style="list-style-type: none"> <li>• Day-to-day project implementation, planning and budgeting, procurement, disbursement, monitoring, reporting.</li> <li>• Coordinate and provide guidance on project implementation to local government and other relevant agencies.</li> <li>• Conduct all environmental and social safeguard monitoring and compliance.</li> <li>• Carry out administrative, technical, and financial management and reporting at central level.</li> </ul>

## 5.0 COORDINATION & IMPLEMENTATION

The National Adaptation Investment Plan (NAIP) seeks to support the coordination of climate change adaptation actions at the national level, and to accelerate strategic investments in climate-resilient development. Effective adaptation requires coordinated and consistent policy drawn on expertise from multiple sources. Thus, the establishment of a coherent, national level coordination mechanism is a key enablers to the NAIP's successful implementation. Such a coordination mechanism can help ensure efficient use of limited resources.

The development of the NAIP was overseen by the Ministerial Committee for Development and Infrastructure Projects. The Supreme Council for Environment (SCE) is now working to agree the institutional arrangements and coordination mechanisms with the Ministerial Committee for Development and Infrastructure Projects.

The key national institutions relevant to advancing the NAIP are highlighted in the following sections. Institutional arrangements, including a system for tracking project progress against the adaptation indicators to ensure consistency of monitoring and evaluation (M&E), will have to be established as concept notes are further elaborated into detailed project proposals as per the requirements of the funding agencies.

### 5.1 National Institutions Relevant to Implementation

#### Supreme Council of Environment

The Supreme Council for Environment (SCE) in Bahrain is a government entity in charge of the development of Bahrain's strategy for the environment and sustainable development and following up on the implementation of this strategy with relevant ministries, agencies, and institutions. The SCE's mandate also includes protecting Bahrain's natural habitat and human environment, ensuring the sustainability of its components, and preserving and developing its resources for future generations.

SCE is the primary body mandated to manage climate change issues with a dedicated Climate Change and Sustainable Development Directorate that works on both climate mitigation and adaptation matters. With respect to the implementation of the NAIP, SCE will provide technical guidance on the development and implementation of relevant climate adaptation policies and support the mobilization of project preparatory and readiness funding from the multi-lateral climate funds and other bilateral climate finance sources.

#### Ministry of Works

The Ministry of Works is responsible for all infrastructure in the Kingdom of Bahrain, including the public road network, drainage systems, and public buildings. Its work - which encompasses strategic planning, design, development, construction, project management and maintenance - is carried out in accordance with the Bahrain Economic Vision 2030 and National Development Strategies.

The ministry is well positioned to be the executing entity for the NAIP project on “Scaling wastewater reuse for climate resilience”. The Sanitary Engineering Planning & Projects Directorate (SEPPD) within the Ministry of Works plans, designs and constructs the sanitary water network across the Kingdom and is responsible for the rehabilitation and upgrade of old collection networks and sewerage treatment systems. Accordingly, the SEPPD may play a key role in the implementation of the NAIP project on wastewater reuse.

### **Ministry of Oil and Environment**

The Ministry of Oil and Environment is in charge of regulation, oversight, and development of the oil and gas and related industries in Bahrain as well as environmental issues. Also, the Ministry of Oil and Environment is the executing entity for the Green Climate Fund (GCF) project in Bahrain on “Enhancing climate resilience of the water sector in Bahrain”. Since the launch of its project with the GCF, many initiatives and programs aimed at strengthening ways to conserve water have been implemented. An integrated Water Resources Management Unit (WRM) was first established under the umbrella of the Ministry of Oil and Environment and under the supervision of the Water Resources Council to enhance the sustainability of water resources management. Currently, the WRM is part of the Supreme Council of Environment.

The Ministry of Oil and Environment is implementing the Managed Aquifer Recharge (MAR) pilot for the Dammam aquifer system and is expected to play a key role in the scale up of the MAR activities planned under the third component of the NAIP project on wastewater reuse. The ministry aims to cooperate with the Ministry of Works and contribute to building and strengthening the capabilities of institutions and technicians concerned with treated wastewater in the Kingdom of Bahrain.

### **Ministry of Municipalities Affairs and Agriculture**

The Ministry of Municipalities Affairs and Agriculture is the ministry that provides municipal services to citizens and residents in Bahrain. The Ministry contributes to the overall development of the Kingdom of Bahrain and is a key partner in the development plans and initiatives of the Economic Development Board.

In the sectors of agriculture and fisheries affairs, the ministry is concerned with achieving several goals, foremost of which is the development of agricultural, water, animal and fish wealth in a way that achieves sustainable development and proposing and implementing policies necessary to achieve food security and overseeing strategic food stocks.

The ministry is well-positioned to be the executing entity for the NAIP projects on enhancing the climate resilience of the crop production, livestock, and fisheries sector as well as the afforestation and nursey development project. The Agricultural Affairs and Marine Resources Directorate of the Ministry of Municipalities Affairs and Agriculture is expected to play a key role in the implementation of these NAIP projects.

### **Ministry of Finance and National Economy**

The Ministry of Finance and National Economy (MOFNE) is responsible for formulating and implementing the financial policies of the Kingdom of Bahrain within the overall vision of the Bahrain Government. The Ministry prepares the state general budget in coordination with other ministries and public entities in a way that reflects the financial and economic objectives of the

Kingdom, particularly regarding improving living standards and increasing levels of economic growth.

MOFNE manages the public debt and maintains its levels within internationally approved limits. Financial stability is sought through the best allocation of available financial resources. The implementation of the NAIP projects will depend on the availability of public funding from MOFNE through appropriate allocation of the national budget to the respective line ministries.

## 5.3 Monitoring and Evaluation

A set of clearly defined and quantifiable indicators have been selected to monitor and evaluate the climate adaptation actions proposed in the NAIP. The monitoring and evaluation indicators have been selected based on three criteria:

- 1. Conceptual and technical soundness:** This criterium refers to whether the indicator is relevant and accurate to measure an action's impact. Among others, it considers to what extent an observed change in the indicator can be attributed to the action, the underlying assumptions behind the indicator, in how far it relies on clearly defined concepts, the degree to which it simplifies the aspect it is intended to measure, and whether there are relevant elements that the indicator does not capture.
- 2. Data availability:** This criterium considers the effort required to collect data to track an indicator, with the explicit aim of limiting the burden of additional time and resource intensive data collection. It also considered to what extent relevant data is already being collected.
- 3. Data quality:** This criterium refers to the reliability of the collected data to track an indicator. It considers, among other things, the preciseness of its underlying definitions, measuring value errors, local and temporal variability in measurement values, and consistency of measurements over time.

Figure 10: Criteria for Monitoring & Evaluation Indicators

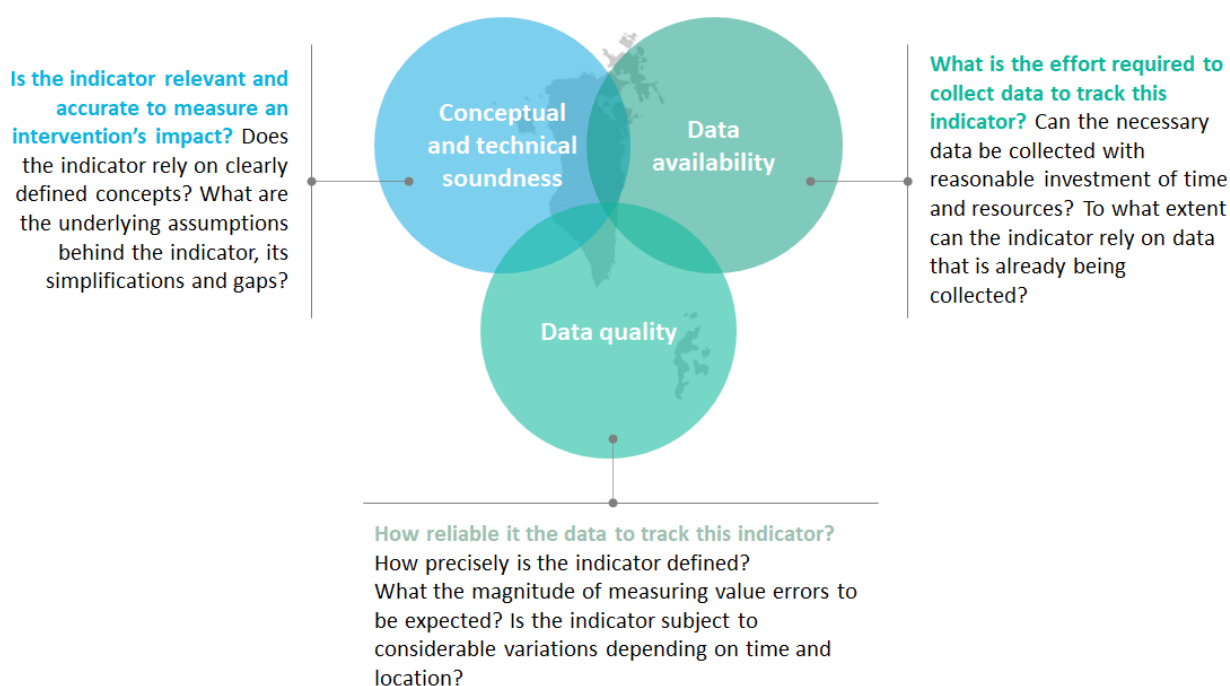


Table 41 below summarizes key adaptation indicators selected for each of the NAIP projects and their respective components. Further indicators may be elaborated during the later stage of preparing detailed project proposals.

**Table 41: NAIP - Monitoring & Evaluation of Adaptation Indicators**

No	NAIP Project	Project Component	Key Adaptation Indicator(s)
1	Scaling Wastewater Reuse for Climate Resilience	# 1. Expansion of TSE transmission and distribution network	Area (ha) of land made more resilient to reduced supply of desalinated water and groundwater resources.
		# 2. Upgradation of feedwater treatment systems for industrial uses	Number and value of physical assets made more resilient to reduced supply of desalinated water.
		# 3. Artificial groundwater storage and recovery	Percentage increase in Groundwater levels and quality. Groundwater Salinity levels recovery (stopping sea water intrusion). Percentage increase in nonconventional water utilization.
2	Accelerating Climate Resilience in Agriculture and Crop Production	# 1. Promotion of Climate-Smart Agricultural Systems	Area (ha) of agricultural land protected and strengthened in response to climate variability and change. Number and value of physical assets made more resilient to climate variability and change.
		# 2. Promoting cultivation of native and climate compatible crops	Value (BHD) of agricultural production using native and climate compatible crops
3	Climate Resilient Livestock & Poultry Development	# 1. Institutional strengthening for enhancing surveillance, diagnostic and control of animal diseases.	Degree of integration/ mainstreaming of climate change in biosecurity regulations.

		# 2. Development of climate-resilient and low-carbon livestock and poultry value chain.	Number and value of physical assets in the livestock and poultry value chain made more resilient to climate variability and change.
4	Climate Resilient Fisheries and Aquaculture Development	# 1. Enhancing resilience of fish habitats.	Area (sq.km) of fish habitats protected and strengthened in response to climate variability and change
		# 2. Development of climate-resilient fisheries value chain	Number and value of physical assets in the fisheries value chain made more resilient to climate variability and change.
5	Restoration of Mangrove Ecosystems for Climate Resilience	# 1. Strengthening policy and institutions for mangrove management.	Degree of integration/ mainstreaming of climate change in coastal zone regulations.
		# 2. Restoring and promoting sustainable mangrove ecosystems.	Area (ha) of mangrove area habitats restored and strengthened in response to climate variability and change.
		# 3. Developing a blue carbon market	Institutional and regulatory systems that improve incentives for climate resilience and their effective implementation.
6	Afforestation & Nursery Development	# 1. Expansion of green cover in urban areas	Number of trees planted in the urban areas to reduce urban heat island effects.  Coverage (sq. km) of dense urban green zones developed in response to climate variability and change.
		# 2. Development of climate-smart nurseries	Value (BHD) of ecosystem services generated or protected in response to climate change.



**Supreme Council for Environment**  
**Tel.** + 973 17 386 999  
**E-mail.** info@sce.gov.bh  
**P.O.Box.** 18233 Manama, Kingdom of Bahrain

sce\_bh    sce.gov.bh