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Assessment of climate change mitigation readiness in the Kingdom of Bahrain

Maha Alsabbagh and Waheeb Essa Alnaser
Department of Natural Resources and Environment, Arabian Gulf University, Manama, Bahrain

Received 26 August 2021
Revised 25 January 2022
1 June 2022
28 August 2022
3 November 2022
Accepted 28 November 2022

Abstract

Purpose – This study aims to assess readiness for climate change mitigation in the Kingdom of Bahrain.

Design/methodology/approach – Two stages were followed aiming at understanding the situation related to climate change mitigation in Bahrain and assessing the mitigation readiness. Baseline and mitigation scenarios for the period 2019–2040 were developed using the Low Emissions Analysis Platform software based on historical emissions and energy data for the period 1990–2018. Using the analytic hierarchy process, the mitigation readiness was assessed by 13 experts, and priority areas for mitigation action were identified.

Findings – CO_2e emissions are projected to grow continuously. However, no explicit climate change strategy is in place yet. Mitigation is tackled implicitly through energy efficiency and renewable energy initiatives. These initiatives can make 23% reduction in CO_2e emissions by 2040. Adopting additional measures is needed to achieve the recently set emission reduction target of 30% by 2035. The findings revealed potential areas for improving mitigation efforts in Bahrain. Priority areas for mitigation actions, as identified by experts, were mainly related to policy and governance. Focus needs to be paid to the social aspect of climate change mitigation.

Originality/value – Literature on mitigation readiness in developing countries is sparse. Knowledge of the requirements for climate change mitigation and assessment of the country's performance can prioritize areas for improving mitigation action. Several lessons can be learnt from the case of Bahrain. In addition, the adopted methodology can be applied to other developing or Arab countries at local or institutional levels. However, its application to specific sectors may require adjustments.

Keywords AHP, Climate change mitigation, LEAP, Survey

Paper type Research paper

1. Introduction

Countries that ratified the Paris Agreement were required to submit or update their Nationally Determined Contributions (NDCs) by 2020, outlining the actions they are implementing to reduce CO_2 equivalent (CO_2e) emissions according to a five-year cycle of increasingly climate change mitigation action. Most of these NDCs include mitigation targets and proposed actions for their achievement. However, the submissions of a few countries lack explicit CO_2e emission targets and only specify mitigation measures or non-

International Journal of Climate Change Strategies and Management
Vol. 15 No. 3, 2023
pp. 391-411
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-08-2021-0096

CO_2e emission targets (Climate Watch, 2021). These countries are mostly developing countries with limited financial and technical capacities required to support the adoption of comprehensive climate change mitigation measures.

CO_2e emissions have been reduced in several industrialized countries, many of which have set zero-emission targets for different sectors. However, CO_2e emissions are not expected to peak before 2030 in several developing countries (United Nations Environment Program, 2022), possibly because of the strong coupling between development and fossil fuel consumption. Although many developing countries submitted their national communications, including sections on mitigation, to the United Nations Framework Convention on Climate Change (UNFCCC) in the 1990s or 2000s, implementation of the mitigation concept itself along with necessary actions is a very recent initiative. With the impacts of climate change increasing at a fast pace, many countries worldwide, especially developing countries, have prioritized strategies for adapting to climate change, perhaps because the impacts are more tangible and are occurring rapidly. Mitigation strategies may have received less attention during the past years, given that their impacts take time to manifest. In addition, many developing countries contribute relatively low absolute emissions, and their impacts on climate change are minimal. Therefore, an explicit climate change strategy or CO_2e emissions reduction target remained absent in these countries, including Bahrain, until recently when targeting carbon neutrality by 2060 was announced during the United Nations Climate Change Conference (COP 26).

This study was aimed at examining the readiness for climate change mitigation in Bahrain, one of the six Gulf Cooperation Council (GCC) countries. Bahrain is a high-income, oil-producing and a developing country. Whereas the global share of Bahrain's CO_2e emissions is negligible (around 0.1%) (Supreme Council for Environment, 2021), its per capita CO_2e emissions are amongst the highest in the world (19.9 metric tonnes of CO_2 per capita compared with the global average of 4.4 metric tonnes) (International Energy Agency, 2022), and its economy is highly energy intensive [1] (9.2 gigajoule/thousand 2015 USD in 2019 compared with a global average of 4.8 gigajoule/thousand 2015 USD) (International Energy Agency, 2022).

Climate change mitigation can stabilize the concentration of CO_2e at a level that prevents human interference with climate system and reduces negative effects of global warming (United Nations, 1992; Intergovernmental Panel on Climate Change, 2022). In addition, climate change mitigation can protect human lives and well-being, secure food production and ensure economic growth in a sustainable manner (Lamb and Steinberger, 2017; United Nations, 1992). Knowledge of the requirements for climate change mitigation can provide guiding inputs that can facilitate various countries' endeavors to reduce their CO_2e emissions, thus enabling them to stay on track and meet their international commitments relating to climate change. It can also contribute to the achievement of several Sustainable Development Goals (SDGs). In specific, it contributes to providing clean energy (SDG 7), fostering innovation (SDG 9), making cities sustainable (SDG 11), ensuring sustainable consumption and production (SDG 12) and taking climate action (SDG 13). This study addresses a knowledge gap concerning readiness for climate change mitigation in developing countries within the literature and provides inputs on the use of the readiness assessment framework to inform climate-related policies.

This study comprises six sections. Section 2 discusses the relevant literature. Section 3 of this study elaborates on the methodology used, followed by a presentation and discussion of the results of the analysis in Sections 4 and 5. Section 6 offers conclusions based on the results.

2. Literature review

Climate change mitigation is defined as "a human intervention to reduce emissions or enhance the sinks of greenhouse gases" (Intergovernmental Panel on Climate Change, 2022). As for readiness, it appears that there is no agreement on its definition yet. In the context of climate change, adaptation readiness "examine(s) the extent to which policy processes and governance structures which determine when, how, and if adaptation occurs, are in place" (Ford and King, 2015). The Green Climate Fund defines readiness as "provid(ing) resources for strengthening institutional capacities, governance mechanisms, and planning and programming frameworks to identify a transformational long-term climate action agenda for developing countries" (Green Climate Fund, 2020). Accordingly, assessment of readiness examines two main areas, namely, governance and policy and capacity building.

Literature on countries' readiness for climate change mitigation has seldom been evident. Focus is usually paid to examining mitigation readiness in specific industrial sectors or on the individuals' level (micro level) (Figure 1), with the use of quantitative methods prevailing. For instance, a techno-economic assessment was carried out in (Ding *et al.*, 2020) to explore the readiness of iron and steel sector in China for carbon capture and storage. As for the individual level, a recent trend toward examining the individuals' readiness for climate change mitigation from a psychological perspective can be noticed. In Australia, O'Brien *et al.* (2018) applied low carbon readiness index to explore individuals' readiness for transition to low-carbon lifestyle. Four case studies were presented with data being collected using surveys. As an aspect of environmental identity, individuals' willingness to shift to a low-carbon lifestyle was also explored in Australia in Kashima *et al.* (2021). Telephone surveys were used to collect the data in three years, from 2015 to 2017. The impact of social norms on climate change mitigation readiness in the transportation sector was investigated in Namagembe (2021). Analysis of data collected from shipping and bus transport firms showed that social norms influenced readiness for climate change mitigation. Multicriteria analysis was also used in climate change mitigation readiness studies. Neofytou *et al.* (2020) developed a multicriteria assessment index to explore readiness for sustainable energy transition in fourteen countries. Thirty-six experts were consulted to validate the index. Both quantitative and qualitative criteria were used to build the index along with two multicriteria analysis methods, namely, preference ranking organization method for enriching evaluation and analytic hierarchy process (AHP).

On the municipalities level (meso level) (Figure 1), literature cites criteria for climate change mitigation readiness implicitly. These were referred to as requirements for climate change mitigation or components of mitigation plans. For instance, Salvia *et al.* (2021) identified several key components of mitigation plans in their analysis of local-level plans in 327 cities in the European Union (EU). The components list included existence of previous

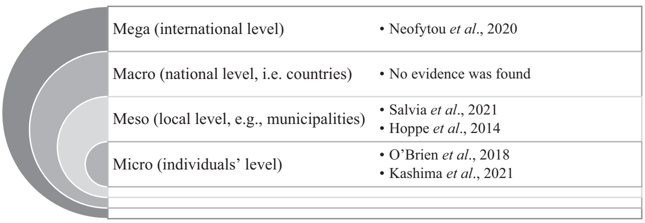


Figure 1. Categorization of literature related to the investigation of climate change mitigation readiness

mitigation plans, baseline emissions inventory, emissions reduction targets and sectors for implementing mitigation measures, along with explicit targets for energy efficiency and renewable energy (Salvia *et al.*, 2021). Components of mitigation policies were also analyzed in Hoppe *et al.* (2014). A typical climate change mitigation policy in the Netherlands, for example, includes CO_2e emissions reduction target, calculation and monitoring of produced emissions, allocation of budget, raising public awareness and education, active collaboration with stakeholders and membership in a climate alliance (Hoppe *et al.*, 2014).

On the international level (mega level) (Figure 1), literature review suggested that there were several criteria for assessing sustainable energy transition readiness. A key study grouped them into social, political/regulatory, economic and technological pillars (Neofytou *et al.*, 2020). The social pillar focused on human capital and public awareness and acceptance, whereas the political pillar included political will and regulatory indicators. Sustainability of the financial sector and ease of doing business were among the economic criteria, whereas dependence on fossil fuels and infrastructure were among the technological criteria.

Criteria and indicators used in assessing mitigation readiness can be linked with the SDGs. As climate change mitigation is strongly linked with the use of low or zero-carbon energy sources, progress toward the achievement of SDG 7 (access to affordable and clean energy) is usually found among the mitigation readiness assessment criteria. For instance, it is considered among assessment components of EU cities mitigation plans (Salvia *et al.*, 2021). In addition, progress toward providing affordable and clean energy (SDG 7) and promoting innovation (SDG 9) are among criteria used for assessing transition toward sustainable energy in (Neofytou *et al.*, 2020).

It is noteworthy that assessing climate change readiness is different from the assessment of climate change performance. Assessing the performance can be observed in several examples such as the Climate Change Performance Index (CCPI) (Burck *et al.*, 2021), the Mitigation Action Assessment Protocol (World Bank Group, 2016) and the Climate Change Mitigation Policy Progression Indicator (Kameyama *et al.*, 2015). These approaches assume that the required infrastructure, capacities and plans are all in place while progress toward achieving mitigation targets is assessed. Nonetheless, none of the GCC countries was included in these assessments, except for Saudi Arabia that was ranked 63 out of 64 countries in the CCPI.

In general, literature on climate change mitigation in the GCC countries focuses mainly on measures to reduce CO_2e from different sectors. Majority of the studies tackle energy efficiency (Alarenan *et al.*, 2019) and renewable energy (Alnaser *et al.*, 2022; Alharbi and Csala, 2021; Malik *et al.*, 2019; Praveen *et al.*, 2020). As in international literature, literature on the GCC countries addresses readiness for climate change implicitly through assessing the adoption of renewable energy technologies. For instance, in Mondal *et al.* (2016), factors that determine readiness for renewable energies in the GCC countries were grouped into three pillars: infrastructure, institutions and human capital. Both quantitative and qualitative indicators were used to build the renewable energies readiness index, and multicriteria analysis was applied for aggregation of the results. The review of literature revealed that energy-related policies and legislations may not be mature enough to ensure CO_2e emissions reductions in some of the GCC countries (Khondaker *et al.*, 2015). Accordingly, gaps in climate policy in the GCC countries were identified. Findings from semistructured interviews with stakeholders in the United Arab Emirates (UAE) and Oman revealed gaps in terms of climate-related financial and human capital capacities (Al-Sarihi and Mason, 2020). Other challenges were also evident in relation to organizational arrangements, governance approach, availability of climate action plan and quality, availability and accessibility of climate-related data (Al-Sarihi and Mason, 2020).

The present study contributes to existing literature on climate change mitigation in the GCC countries. Assessment of climate change mitigation readiness is limited in the GCC countries, thus this study comes to fill the identified knowledge gap in the literature.

3. Methodology

A methodological framework was developed and implemented (Figure 2). Quantitative data were used to develop an understanding of Bahrain's historical CO_2e emissions trend and future trajectories and assess readiness for climate change mitigation. National reports, studies and peer-reviewed literature were consulted, and surveys to national experts in climate change mitigation were conducted.

3.1 Phase 1: understanding the situation

A literature review was carried out to identify research and studies related to climate change mitigation in Bahrain. Search was conducted in several databases including Scopus, Web of Science and E-Marefa (for peer-reviewed journals published in Arabic). Studies and reports were collected from national and international repositories. To understand existing relationships among socioeconomic factors, energy use and CO_2e emissions, data sourced from the International Energy Agency (IEA) and the World Bank were analyzed using the IBM SPSS statistical package (version 27).

Quantitative data collected from national and international energy and climate change databases were used to explore historical, current and future CO_2e emissions trajectories. The Low Emissions Analysis Platform (LEAP), developed by the *Stockholm Environment Institute,* was used to build past trends and future scenarios. Energy and emissions modeling was performed based on the list of assumptions presented in Table 1. The selection of the assumptions was based on available time-series data along with literature related to climate change mitigation in Bahrain.

CO_2e emissions were calculated for all energy-consuming sectors following tier 1 approach which requires data on fuel combustion by fuel type and emission factors (Intergovernmental Panel on Climate Change, 2006):

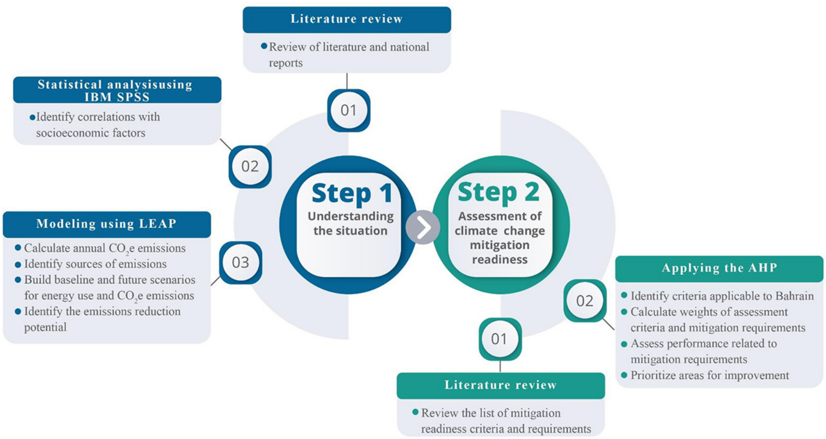


Figure 2.
Methodological steps followed in this study

Scenario	Variable	Main assumption
Historical trend and current state	Years	1990–2018
	Energy production	IEA
	Energy use	IEA
	Efficiency of electricity generation	23.29% in 1990; 29.29% in 2018
	Efficiency of oil refineries	100%
	Electricity transmission and distribution losses	5.6% in 1990; 1.9% in 2018
	Electricity generation capacity (MW)	3,920.9 in 2018
Baseline scenario	Scenario period: first year	2019
	End year	2040
	Growth rate of local demand for electricity (accumulated)	≈ 0.9% per annum (39.7%)
	Growth rate of local demand for natural gas (accumulated)	≈1% per annum (20.4%)
	Growth rate of local demand for petroleum products (accumulated)	≈1% per annum (21.6%)
	All other variables remain almost constant	
Mitigation scenario	NEEAP	The initiatives and savings are assumed to continue after 2025 (the end year of NEEAP)
	NREAP	The initiatives and savings are assumed to continue after 2035 (the end year of NREAP)
	Additional measures	• Projects in the oil and gas sector (NOGA, 2018) • Measures that reduce emissions from the residential and transportation sectors by 30% and 1.9%, respectively, in 2040, built additionally on Alsabbagh (2018, 2020) • Installation of solar panels on all residential buildings • Electricity and natural gas consumption of industrial sectors is reduced by 6% and 43%, respectively, in 2040 • Improved power generation efficiency from 29% to 33% • Landfill gas is used for electricity generation by a 15 MW power plant, starting from 2025 (Alsabbagh, 2019)

Notes: IEA means International Energy Agency, NEEAP means National Energy Efficiency Action Plan, NOGA means National Oil and Gas Authority, NREAP means National Renewable Energy Action Plan
Sources: Alsabbagh (2018); Alsabbagh (2019); Alsabbagh (2020); International Energy Agency (2022, 2021); National Oil and Gas Authority (2018)

Table 1.
Assumptions entailed in the construction of the different scenarios

$$Emissions_{CO2e,fuel} = Fuel\ Consumption_{fuel} * Emission\ Factor_{CO2e,\ fuel}$$

where Emissions $_{CO2e,\ fuel}$ are the emissions of a given CO_2e by fuel type (kg CO_2e), Fuel Consumption $_{fuel}$ is the amount of fuel combusted (TJ) and Emission Factor $_{CO2e,\ fuel}$ is default emission factor of a given CO_2e by fuel type (kg gas/TJ). For CO_2, oxidation factor is assumed to be 1:

$$Emissions_{GHG} = \sum_{fuels} Emissions_{GHG,\ fuel}$$

It is noteworthy that an initial attempt to model historical trends of energy production, transfer and consumption using national data proved unsuccessful. Whereas an energy balance is required for modeling, the national energy data did not sum to zero and were incomplete for the desired time series. Therefore, data were retrieved from the IEA energy balances for the period 1990–2018 for different energy types and end users.

3.2 Phase 2: assessment of climate change mitigation readiness

To assess readiness for climate change mitigation in Bahrain, a list of criteria and climate change mitigation requirements (or criterion), obtained from literature, constituted the basis for the assessment.

Two self-administrated questionnaires were prepared. The questionnaires were distributed in December 2021 and January 2022 to purposively sampled academic and professional experts from Bahrain. The experts were selected based on participation in the preparation of the national communication reports on climate change submitted to the UNFCCC or publishing in the field of climate change mitigation in Bahrain. The potential participants were contacted via email and phone, and the total number of valid responses was 13.

The first questionnaire was designed to identify criteria and mitigation requirements applicable to Bahrain and to elicit the criteria weights based on its importance, using a multicriteria analysis approach, that is, the AHP method (Saaty, 1990). Pairwise comparisons of the criteria were conducted by the participants. A scale from 1 to 9 was used in the pair-wise comparisons, where 1 meant equal importance and 9 referred to extreme importance. To calculate the weights, matrices were constructed. The number of judgements required to build the criteria weight matrices was determined as follows (Saaty, 1987):

$$Number\ of\ judgments\ required = \frac{n(n-1)}{2}$$

where n is the number of criteria. The matrices were then constructed to show the relative importance of the criteria. Eigenvector associated with the maximum eigenvalue of each matrix was used to calculate the weights.

The second questionnaire was prepared to assess Bahrain's performance against the mitigation requirements (or criterion). A 1–5 Likert scale was used with 1 referring to very weak performance and 5 referring to very strong performance.

To prioritize areas for improving climate action, the median of participants' scores was converted to a 0–1 scale. A score of 1 was assigned to weak and very weak performance, a score of 0.5 was assigned to moderate performance and 0 was assigned to strong and very strong performance. Aggregation of criteria weights and performance scores was carried out following the linear additive multicriteria model, which is a straightforward and transparent approach used in decision-making and assessment studies (Alsabbagh, 2019; Mondal *et al.*, 2016). Priority areas for mitigation action were identified by multiplying criteria weights by performance scores, as follows (Department for Communities and Local Government, 2009):

$$S_i = w_1 s_{i1} + w_2 s_{i2} + \ldots + w_n s_{in} = \sum_{j=1}^{n} w_1 s_{ij}$$

where:

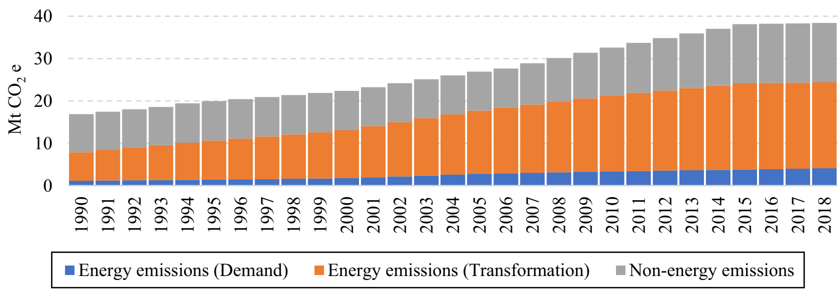
i = denotes the performance;
j = criterion;
n = criteria;
s = score; and
w = weight of the criterion.

It is noteworthy in this context that criteria weights were calculated by multiplying the weights of the criteria by the weights of the mitigation requirements (or criterion), collected using pairwise comparisons in the first questionnaire. Having a list of criteria grouped within a set of criteria is essential when applying the AHP method. This is because the recommended number of criteria is seven, to ensure that pairwise comparisons are carried out properly by participants (Saaty, 2006).

4. Results

4.1 Understanding CO_2e emissions situation in Bahrain

The CO_2e emissions in Bahrain increased by 128% during the period 1990–2018 (Figure 3). Evidently, electricity generation (both grid electricity and industrially produced electricity) contributed significant shares of CO_2e emissions. In addition, CO_2e attributed to energy end users (especially transportation), along with industrial processes and product use [2] has shown a notable increase in recent years (Supreme Council for Environment, 2020; General



Notes: The calculation was based on data sourced from the International Energy Agency. Energy demand includes all energy end users (i.e. the transportation, residential, industrial, agricultural and commercial sectors). Energy transformation includes electricity generation and oil refining, whereas nonenergy includes emissions from waste and industrial processes and product use

Figure 3.
CO_2e emissions in Bahrain during the period 1990–2018 (million metric tonnes CO_2 equivalent)

Commission for the Protection of Marine Resources, Environment and Wildlife, 2005, 2012) (Figure A1). The increase in Bahrain's CO_2e emissions is attributable to electricity use and local natural gas consumption associated with population growth [3]. A strong positive correlation between CO_2e emissions and these factors is evident, in addition to the gross domestic product growth (Naser, 2017).

The profile of energy production and consumption in 2018 differs from that in 1990, as the coupling between economic growth and energy consumption has grown stronger. In 1990, a major proportion of oil and natural gas was refined and exported (Figure A2). However, there was a notable decrease in exports in 2018 on account of electricity generation and sectoral uses (industrial, transportation and residential) (Figure A3). This change resulted not only in increasing national CO_2e emissions but also in depleting the nonrenewable energy sources (i.e. oil and natural gas).

The mitigation of CO_2e emissions was addressed implicitly in Bahrain, through the adoption of the National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy Action Plan (NREAP), until COP 26 when achieving carbon neutrality by 2060 was announced, with an interim target of 30% reduction in emissions by 2035. The NEEAP and NREAP were prepared by the Sustainable Energy Authority in Bahrain, in collaboration with the United Nations Development Program and were approved by the Cabinet of Ministers of Bahrain. The NEEAP encompasses 22 initiatives for different energy-consuming sectors and is aimed at improving energy efficiency by 6% by 2025 (Sustainable Energy Unit, 2017a). The NREAP provides initiatives to increase renewable energy penetration, with targets of 5% by 2025 and 10% by 2035 (Sustainable Energy Unit, 2017b).

In the baseline scenario, projections for energy consumption show an increase in primary energy demand by an annual average of 1.3% during the period 2019–2040, if no new mitigation measures are introduced (Figure A4). Adopting NEEAP and NREAP, along with additional mitigation measures, can achieve a 23% reduction in CO_2e emissions in 2040 compared with the baseline scenario. The cumulative emissions reduction is equal to 134.8 MMT CO_2e during the period 2019–2040 (Figure A5). However, the percentage of emissions reduction is lower than the recently set interim target of 30%, set for the year 2035.

The mitigation potential within various energy-consuming sectors, including water desalination (Alsabbagh *et al.*, 2021), buildings (Alsabbagh, 2018), waste (Alsabbagh, 2019) and transportation (Alsabbagh, 2020), as well as the energy sector as a whole and renewable energy, was investigated by scholars in Bahrain. However, only a limited number of peer-reviewed studies is evident (Table A1). In addition, there is a lack of specialized academic degrees focusing on climate change in general and mitigation in particular, offered at universities in Bahrain. Bahrain's main efforts to address climate change mitigation can be summarized as follows:

- Announcement of targeting carbon emission neutrality by 2060 in October 2021.
- Establishment of a new directorate within the Supreme Council for Environment devoted to the management of climate change and sustainable development in 2021.
- Assignment of a special envoy for climate affairs in 2020.
- Adoption of the NEEAP and NREAP in 2017.
- Establishment of a Joint National Committee on Climate Change in 2007.
- Preparation of three national communication reports submitted to the UNFCCC, in addition to Bahrain's NDC.

4.2 Assessment of climate change mitigation readiness

Surveys to experts revealed the list of criteria and requirements for assessing the mitigation readiness in Bahrain, in addition to their weights. The list consisted of four main criteria, namely, governance/policy, technical, financial and social, in addition to 15 mitigation requirements (or criterion) within these four main criteria. Assigning the weights of the criteria, carried out following the AHP methodology, revealed that the highest weight was assigned to governance/policy (44% of total weight), followed by technical (25%) and financial (24%) criteria. The social criteria were ranked last by participants with only 7% of the total criteria weight. The weights of the mitigation requirements varied as well as depicted in Table 2. The overall performance of Bahrain in relation to mitigation readiness, as expressed by the participating experts, is moderate in 60% of the mitigation requirements. However, it was identified as strong in only 6.6% of the requirements, whereas it was weak in the remaining (33.3%) (Table 2).

Aggregation of criteria weights and performance scores revealed the priorities list for climate change mitigation in Bahrain. Results showed that the top priorities were mainly related to governance and policy. Having a climate change strategy in place along with sectoral emissions reduction targets, capacity building and strengthening partnerships with national and international stakeholders were at the top of the priority list for improving mitigation actions in Bahrain. On the other hand, stakeholders' awareness, education and participation in the policymaking process received low scores, implying lower importance from the participants' perspective. The priority for meeting the technical and financial mitigation requirements varied. For instance, identifying sources and quantities of CO_2e emissions, budget allocation and conducting ex ante and ex post assessments received high scores, whereas identifying funding opportunities and creating a database for mitigation measures received low scores.

It is noteworthy that priorities are set based on the weights of criteria and mitigation requirements (or criterion) along with performance scores. This means that mitigation requirements with low weights or good performance received relatively low priority scores.

5. Discussion

5.1 Energy policy and mitigation readiness

Up to COP 26, climate change mitigation was addressed implicitly in Bahrain through adopting energy efficiency and renewable energy national plans (Alsabbagh and Alnaser, 2022). The GCC countries aimed to achieve CO_2e emission reductions voluntarily, based on historical responsibility for climate change and its small share of total emissions (Al-Sarihi, 2018). Addressing energy efficiency and renewable energy appears to be a reasonable starting point for an oil-producing country. However, the contribution of the current energy efficiency and renewable energy policy in Bahrain in reducing CO_2e emissions may be insignificant. This finding resonates with that reported for Saudi Arabia (Khondaker *et al.*, 2015) and Oman (Al-Sarihi and Mason, 2020), where the achievement of emission reduction targets may be challenging.

In Bahrain, the effectiveness of renewable energy and energy efficiency action plans in climate change mitigation may be limited because of several issues related to the design of the action plans. The renewable energy penetration goal targets grid electricity only, whereas 37% of the installed capacity is owned and operated by large industries (Sustainable Energy Unit, 2017b). Despite being a source for energy and industrial processes-related CO_2e emissions, the energy efficiency action plan included only one initiative (the industry program) that targets the industrial sector. Findings from this study

Table 2. Criteria weights, performance scores and priorities for climate change mitigation in Bahrain

Main criteria	Weight	Mitigation requirement (or criterion)	Weight	Final criteria weight[1]	Performance[2] (respective score)	Priorities (unnormalized)	Priorities (normalized, %)[3]
Governance/Policy	0.440	Leadership commitment	0.380	0.167	Strong (0)	0	0
		Existing assessments and research	0.180	0.079	Moderate (0.5)	0.039	7.202
		Climate change strategy and sectoral emission reduction targets	0.150	0.066	Weak (1)	0.066	12.188
		Capacity building	0.150	0.066	Weak (1)	0.066	12.188
		Partnerships with national and international stakeholders	0.140	0.061	Weak (1)	0.061	11.265
Technical	0.250	Sources and quantities of CO_2e emissions	0.360	0.090	Moderate (0.5)	0.045	8.31
		Energy and emissions models and projections	0.240	0.060	Moderate (0.5)	0.030	5.54
		Available mitigation options	0.210	0.052	Moderate (0.5)	0.026	4.801
		Database of implemented initiatives, effectiveness, costs, historical emissions, and sources	0.190	0.047	Moderate (0.5)	0.023	4.339
Financial	0.240	Budget allocation	0.340	0.081	Moderate (0.5)	0.040	7.386
		Ex ante analysis	0.280	0.067	Moderate (0.5)	0.033	6.094
		Funding opportunities	0.210	0.050	Moderate (0.5)	0.025	4.616
		Ex post analysis	0.170	0.040	Weak (1)	0.040	7.386
Social	0.070	Stakeholders' participation in policymaking	0.620	0.043	Moderate (0.5)	0.021	3.878
		Stakeholders' awareness and education	0.380	0.026	Weak (1)	0.026	4.801

Notes: [1]Final criteria weight equals the criteria weight multiplied by the criterion weight. [2]A 1–5 Likert scale was used to derive performance scores where 1 referred to very weak performance and 5 referred to very strong performance. The median of participants' responses is presented. Scores from 0 to 1 were assigned to performance, where 0 was set for strong and very strong performance, 0.5 was set for moderate performance and 1 was assigned for weak and very weak performance. This step was conducted to prioritize areas for improvement taking into consideration the criteria weights. [3]High scores represent priority areas for improving climate action in Bahrain based on the results of the analysis highlight the importance to tackle emissions from industries, which was also emphasized in literature (Alsabbagh and Alnaser, 2022).

The assessment of mitigation readiness in Bahrain revealed several challenges in relation to governance, availability of data and technical capacities. The existence of climate change strategy and action plan is critically important for ensuring the establishment of a monitoring, evaluation and reporting system and integration of mitigation options into the policies developed for different sectors, such as oil and gas, electricity, water, agriculture, industry and transportation. Thus, the absence of climate change strategy and action plan may hinder mitigation efforts. Despite the importance of integrating climate policy across different sectors, lack of clear policy integration was reported for some of the GCC countries (Al-Sarihi and Mason, 2020).

Climate-related data constitute the basis for climate change mitigation and planning, especially in terms of sources of emissions, energy balances and effectiveness of mitigation measures. Accordingly, availability and quality of climate-related data was ranked among the top five priority areas for Bahrain. This finding is consistent with that reported for the UAE and Oman where the data availability, quality and accessibility were identified among the main challenges for climate policy (Al-Sarihi and Mason, 2020).

As for the technical challenges, although capacity building was targeted during the preparation of the national communication reports in Bahrain, there is a need for more specialized capacity, especially in relation to emissions inventories and modeling. Therefore, Bahrain's performance in relation to technical mitigation requirements was identified as "moderate" by the survey participants. A similar finding was reported in literature where climate-related human capacity was perceived as a challenge for the UAE and Oman (Al-Sarihi and Mason, 2020). In fact, human capacity was identified as a challenge in energy-related areas as well for the GCC countries (Al-Sarihi and Mansouri, 2022).

The assessment of mitigation readiness in Bahrain was based on a set of criteria, where governance was ranked highest by the survey participants and social criteria ranked lowest. A similar finding was reported in an assessment of readiness for sustainable energy transition in selected developed and developing countries, where public awareness and acceptance was ranked lowest (Neofytou *et al.*, 2020). These findings illustrate how social criteria is perceived in readiness assessments, despite the importance of the role that can be played by public, and the significance of social innovation and behavioral change in climate change mitigation (Intergovernmental Panel on Climate Change, 2022).

To achieve significant CO_2e emissions reductions, priority areas identified in the assessment of mitigation readiness need to be addressed. Raising the awareness of different stakeholders and involving them in the process is imperative, in addition to preparing climate change strategy and integrating mitigation initiatives with existing relevant sectoral policies. All stakeholders' groups, including the private sector and the nongovernmental organizations (NGOs), need to become more involved. On the GCC countries level, developing explicit regional climate policy can boost climate change mitigation. Adopting such approach can assist in addressing challenges and strengthening collaboration, along with facilitating policy learning among the GCC countries (Alsabbagh and Alnaser, 2022).

5.2 Implications of the study

This study applies the single case study approach. Although generalization of findings is limited (Sarantakos, 2005; Yin, 2003), single case studies allow for deep understanding of the subject (Dyer and Wilkins, 1991), where lessons can be drawn and areas for possible transferability [4] can be identified (Dolowitz and Marsh, 2000; Wolf and Baehler, 2018).

Several policy lessons can be derived from the Bahrain case study as follows:

- The three pillars of sustainability (environment, economy and society) need to be considered when preparing climate change mitigation policies, with emphasis on the roles of the private sector and NGOs.
- Understanding the national context and climate change mitigation initiatives can explain performance scores set by the experts during the assessment of mitigation readiness.
- Social acceptance and adoption of energy efficiency and renewable energy technologies is imperative. Although it was ranked last by the survey participants in the case of Bahrain, it is crucial for climate change mitigation.
- Reducing CO_2e emissions from energy consumption alone is not enough for climate change mitigation. Addressing emissions from all sources and sectors is needed.
- Investing in national capacity building is imperative.
- Climate change mitigation research and funding of this research should be prioritized.
- Involving national experts in climate action planning and implementation can be rewarding where opportunities for improvement can be identified. However, it should be ensured to have a balanced representation of different stakeholders' groups.
- The methodology adopted in this study can be applied to different scales, that is, countries, cities, municipalities, sectors or institutions in developing countries. This is specifically the case for many Arab and GCC countries where climate change mitigation is in its early stages, compared to developed countries. However, few points need to be considered. The list of mitigation requirements may be extended or reduced based on the level of climate action. Addressing mitigation within specific sectors may necessitate a more detailed list of mitigation requirements. Moreover, the methodology may be extended to include Delphi method, if experts disagree on the performance scores.

5.3 Limitations and opportunities for future research

As with all research, this study had its limitations. These limitations are acknowledged and discussed here, along with recommendations for future research. The sample size of survey participants is one of the limitations, as only 13 participants were involved in assessing Bahrain's readiness for climate change mitigation. This is mainly because the concept and implementation of climate change mitigation is relatively new in the country, in addition to the relatively small size of the population in Bahrain (Information and E-Government Authority, 2022) [5]. Another limitation is the potential subjective assignment of criteria weights or performance scores when applying the AHP method. This can be overcome through implementing a fuzzy AHP approach (Liu *et al.*, 2020). Such approach may be needed when having a wide range of participants with divergent views.

Future research can focus on assessing sectoral readiness for climate change mitigation. Exploring the various assessment criteria for different sectors can provide guidance for sectoral mitigation actions. In addition, investigating the perspectives of different experts' groups can be beneficial. The adoption of multi-actor multi-criteria analysis (Macharis *et al.*, 2010) can prioritize areas for policy improvement from different perspectives (e.g. academic and professional).

6. Conclusions

This study aimed at assessing climate change mitigation readiness in Bahrain. To achieve the study's objective, the relevant literature was reviewed, energy and CO_2e emissions models were built using the LEAP software and readiness for mitigation was assessed using surveys and the AHP method. The study's findings revealed that existing energy-related initiatives addressed mitigation implicitly and can only lead to a 23% reduction in emissions. Achieving a higher percentage of emissions reduction requires a radical transformation of all sectors along with broad stakeholder participation. A particular focus on the industrial sector is required, as it accounts for a substantial proportion of CO_2e emissions derived from energy and industrial processes. The assessment of mitigation readiness in the case study of Bahrain identified several mitigation requirements that need to be addressed, with special focus on governance and policy. The case study provides several lessons that can be transferred to other developing or Arab countries.

Notes

1. Energy intensity is calculated by dividing the total energy supply by the gross domestic product (purchasing power parity).
2. According to the IPCC inventory guidelines, sources of emissions are energy, industrial processes and product use, agriculture, forestry and other land use and waste (Intergovernmental Panel on Climate Change, 2006).
3. This conclusion is based on the results of regression modeling performed using SPSS, R^2 adjusted for the model 99.9%, with importance of 4.2%, 85.6% and 10.2%, respectively, and a significance level of 0.00.
4. Transferability can be related to policy goals, content, instruments, programs, institutions, ideologies, ideas and attitudes or negative lessons (Dolowitz and Marsh, 2000). Three degrees for policy transfer are identified, namely, copying, emulation, combinations and inspiration (Dolowitz and Marsh, 2000).
5. The population of Bahrain is 1.5 million. However, only 1.4% are holders of a postgraduate degrees (PhD holders are 0.1%) and the share of those specialized in environment is expected to be less (Information and E-Government Authority, 2022).

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Further reading

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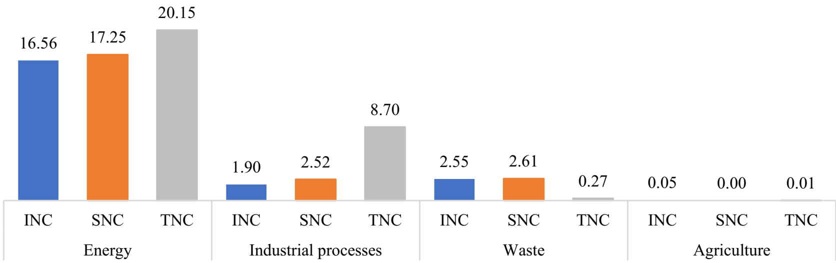
Corresponding author

Maha Alsabbagh can be contacted at: mahamw@agu.edu.bh

Appendix



Notes: INC denotes Bahrain's Initial National Communication (base year 1994), SNC denotes the Second National Communication (2000) and TNC denotes the Third National Communication (2006) submitted to the United Nations Framework Convention on Climate Change. Bahrain's TNC included time series for CO_2e emissions for the years 2006–2015

Figure A1.
CO_2e emissions by source (thousand Gg CO_2e) (Supreme Council for Environment, 2020; General Commission for the Protection of Marine Resources, Environment and Wildlife, 2005, 2012)

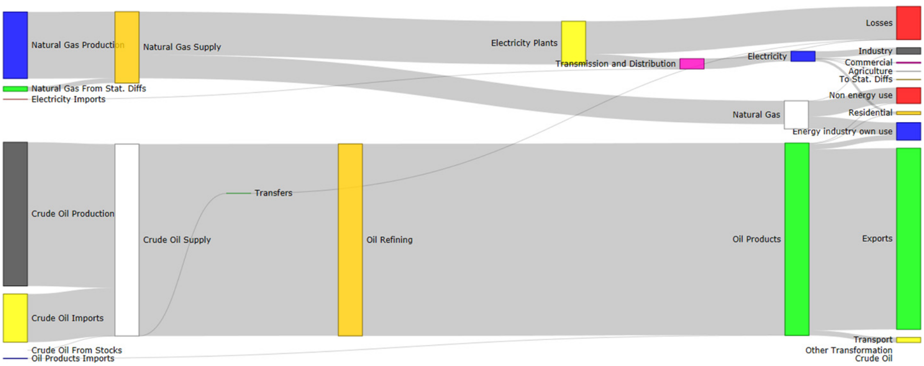


Figure A2.
Sankey diagram depicting Bahrain's energy use in 1990

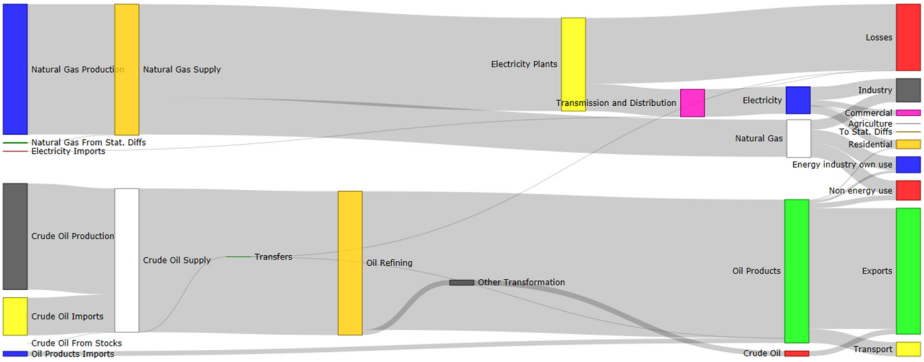
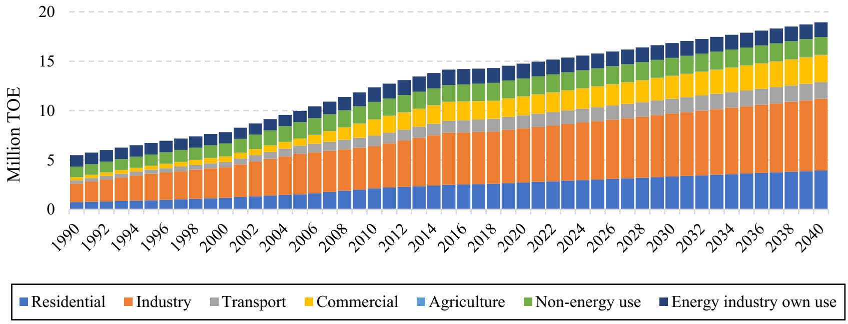


Figure A3. Sankey diagram depicting Bahrain's energy use in 2018



Note: TOE means tonnes of oil equivalent

Figure A4. Primary energy demand under the baseline scenario

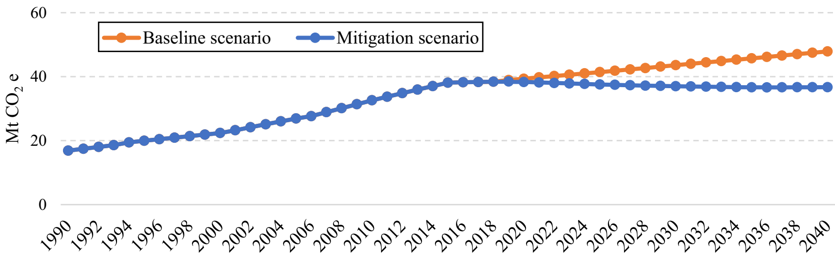


Figure A5. CO_2e emissions under the baseline and mitigation scenario (million metric tonnes CO_2 equivalent)

Table A1.
Peer-reviewed articles on climate change mitigation in Bahrain

	Authors	Title	Year	Journal/Book/Conference	Type	Focus
1	Alsabbagh and Alnaser	Transitioning to carbon neutrality in Bahrain: a policy brief	2022	*Arab Gulf Journal of Scientific Research*	Policy brief	General
2	Alsabbagh *et al.*	Electricity consumption in the municipal water sector in an oil-exporting, water-stressed country: the case of Bahrain	2021	*Desalination and Water Treatment*	Article	Water
3	Alsabbagh	Methodological framework for adopting sustainable transport measures	2020	*International Journal of Global Warming*	Article	Transportation
4	Qamber and Al-Hamad	Photovoltaic design for smart cities and demand forecasting using a truncated conjugate gradient algorithm	2020	*Advances in Intelligent Systems and Computing*	Book chapter	Renewable energy
5	Tazay	A comparison of techno-economic analysis of a hybrid renewable energy supply options for grid-connected buildings: case study	2020	2020 2nd International Sustainability and Resilience Conference: Technology and Innovation in Building Designs	Conference paper	Renewable energy
6	Alsabbagh	Mitigation of CO_2e emissions from the municipal solid waste sector in the Kingdom of Bahrain	2019	*Climate*	Article	Waste
7	Alsabbagh	Household electricity consumption and climate change in the Kingdom of Bahrain: current state and future scenarios	2018	*Ajman Journal of Studies and Research*	Article	Residential
8	Al-Zubari *et al.*	Impacts of climate change on the municipal water management system in the Kingdom of Bahrain: vulnerability assessment and adaptation options	2018	*Climate Risk Management*	Article	Water
9	Alsabbagh	Effectiveness of setting vehicle fuel economy standards in reducing transport CO_2 emissions in the Kingdom of Bahrain	2017	*Ajman Journal of Studies and Research*	Article	Transportation
10	Alsabbagh	Social learning and the mitigation of transport CO_2 emissions	2017	*Climate*	Article	Transportation
11	Alsabbagh *et al.*	Mitigation of CO_2 emissions from the road passenger transport sector in Bahrain	2017	*Mitigation and Adaptation Strategies for Global Change*	Article	Transportation
12	Alsabbagh *et al.*	Integrated approach to the assessment of CO2e-mitigation measures for the road passenger transport sector in Bahrain	2017	*Renewable and Sustainable Energy Reviews*	Review	Transportation

(*continued*)

	Authors	Title	YearJournal/Book/Conference	Type	Focus
13	Naser	Analyzing long-run relationship between energy consumption and economic growth in the Kingdom of Bahrain	2017E3S Web of Conferences	Conference paper	Energy use
14	Radhi	Can envelope codes reduce electricity and CO2 emissions in different types of buildings in the hot climate of Bahrain?	2009*Energy*	Article	Buildings
15	Al-Nasir *et al.*	Wind characteristics and wind power analysis in the Kingdom of Bahrain for building integrated wind turbine application and CO_2 emission reduction	2007*Arab Journal of Basic and Applied Sciences*	Article	Renewable energy
16	Al-Nasir	The solar gain in automobiles in Bahrain and its negative impact	2007*Arab Journal of Basic and Applied Sciences*	Article	Transportation

Notes: The search terms were climate change, mitigation, Bahrain and CO_2 reduction in both Arabic and English

Table A1.