# For Components 1 and 3 under the project Nationally Appropriate Mitigation Actions (NAMAs) for Low Carbon Island Development Strategy for the Republic of Mauritius

# (NAMA Project)

## GUIDELINES FOR IDENTIFYING AND PRIORITIZING MITIGATION ACTIONS

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# List of Acronyms

| | |
|---|---|
| CCA | Climate Change Act |
| CCM | Climate Change Mitigation |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gas |
| MCA | Multi-criteria Analysis |
| NAMA | Nationally Appropriate Mitigation Action |
| NMSAP | National Mitigation Strategy and Action Plan |
| NDC | Nationally Determined Contribution |
| PA | Paris Agreement |
| SEP | Stakeholder Engagement Plan |
| SWMD | Solid Waste Management Division |
| TAP | Technology Action Plan |
| TFS | Technology Fact Sheet |
| TNA | Technology Needs Assessment |
| TNC | Third National Communication |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |

# 1. Introduction

Component 1 of the Nationally Appropriate Mitigation Action (NAMA) project seeks to 'strengthen national capacity to identify, prioritize and develop mitigation actions to meet Nationally Determined Contribution (NDC) targets'. In order to achieve this, it has four outputs of which the second – i.e. Output 1.1 – is 'to strengthen institutional arrangements to coordinate development and implementation of NDC through development of process and procedures as well as clear institutional responsibilities'. Output 1.1 entails two activities:

- ✓ Activity 1.1.1 - Review the institutional arrangements for the development and implementation of mitigation actions and identify gaps; and
- ✓ Activity 1.1.2 – Develop process, procedure and guidelines for mitigation actions identifications, development and implementation for NDC.

This report relates to Activity 1.1.2 by providing a set of guidelines for identifying and prioritizing mitigation actions for NDC formulation. It complements the baseline analysis of mitigation actions,[1] and institutional arrangements for the formulation and implementation of mitigation actions.[2]

The identification and prioritization of mitigation actions is related to the decision of the Conference of Parties 1/CP21.[3] Paragraph 35, invited Parties "*to communicate, by 2020, to the secretariat mid-century, long-term low greenhouse gas emission development strategies in accordance with Article 4, paragraph 19, of the Agreement*". The low greenhouse gas (GHG) development strategies would be published on the United Nations Framework Convention on Climate Change (UNFCCC) website.[4] Article 4 of the Paris Agreement states that Parties[5] should aim to reach global peaking of GHGs as soon as possible, and to undertake rapid reductions thereafter based on the best available science in order to achieve balance between anthropogenic emissions and removals by sinks of GHGs – i.e. net zero carbon emissions – in the second half of this century. Reductions in GHGs are to be carried out on the basis of equity and based on national circumstances[6] so as to support sustainable development and eradication of poverty. The application of paragraph 35 and Article 4 to a small emitter like Mauritius has been carried out to provide an equity-based, effort sharing perspective on long-term GHG emission reductions aligned with the goal of net zero emissions by 2050.[7]

[1] P Deenapanray (2021) Baseline Analysis of Mitigation Actions – a sectoral perspective, Ministry of Environment, Solid Waste Management and Climate Change, Mauritius.

[2] P Deenapanray (2020) Institutional Arrangements for Climate Governance, Ministry of Environment, Solid Waste Management and Climate Change, Mauritius; P Deenapanray (2021) Draft Guidelines for the implementation of the climate change mitigation provisions of the Climate Change Act 2020 (Energy Industries), Ministry of Environment, Solid Waste Management and Climate Change, Mauritius.

[3] UNFCCC (2021) Report of the Conference of the Parties on its twenty-first session, held from 30 November to 13 December 2015.

[4] The long-term, low-carbon strategies that have been communicated to the UNFCCC are found at: https://unfccc.int/process/the-paris-agreement/long-term-strategies - accessed 19 October 2021.

[5] Article 4(6) states that '*The least developed countries and small island developing States may prepare and communicate strategies, plans and actions for low greenhouse gas emissions development reflecting their special circumstances*'.

[6] Parties should strive to formulate and communicate their long-term low GHG emission development strategies, mindful of Article 2 – i.e. pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels – using the principle of common but differentiated responsibilities and respective capabilities.

[7] PNK Deenapanray (2021) Increasing the ambition of mitigation action in small emitters: the case of Mauritius, Climate Policy 21(4):514-528.

The identification and prioritization of mitigation actions should therefore be carried out within the ambit of developing a national long-term low carbon development strategy. Such an approach will be aligned with the provisions of Section 14 of the Climate Change Act (CCA) 2020 related to National Mitigation Strategy and Action Plan (NMSAP).[8] According to Section 14(2), the NMSAP shall be formulated in accordance with (a) UNFCCC and related instruments; and (b) national development priorities. The latter implies understanding the time implications of climate change mitigation for the country's development priorities. The development priorities can be captured by the appropriate choice of criteria and indicators used in multi-criteria analyses for identifying and prioritizing mitigation actions.

The guidelines are set out in two parts:

1. Section 2: Process and procedures – This section describes the process that is proposed for identifying and prioritizing mitigation actions. Since the NDC is concerned with mitigation contributions, the linkage between mitigation contributions and mitigation actions is first discussed. It is explained how mitigation actions or the ensemble of policies and projects are equated to technological options for mitigation. The process is based on the Technology Needs Assessment (TNA) methodology, and its application as a bottom-up method to support the NDC process is explained. The procedures for making the process inclusive of necessary stakeholders and to have a gender-differentiated outcome are outlined.
2. Section 3: Identifying and prioritizing mitigation actions – This section details the steps of identifying and prioritizing mitigation actions. It also presents tools that can be used to carry out the two steps.

The process, procedures and tools are proposed from a learning-by-doing perspective to reinforce human and institutional capacity that have been acquired through successive UNFCCC-related and GEF-funded projects, including the TNA project and Third National Communication (TNC). The NAMA project delivered an online training on the use of multi-criteria analysis (MCA) for prioritizing mitigation technologies on 7 July 2021, and a training report was delivered. This guidance document applies the same process and procedures, and it references the tools that were used in the training and past projects.[9]

It is pointed out that the process of identifying and prioritizing falls under the ambit of Section 16(1)(b)(ii) of the CCA wherein public and private institutions 'take into account climate change in its strategies, action plans and other policies'.[10]

## 2. Process and procedures

This section discusses the TNA process for developing mitigation action plans (MAPs). The MAPs require the prior identification and prioritization of mitigation actions. The NDC includes a host of approaches or contributions for setting mitigation targets, and it is necessary to explain the relationships between mitigation actions and mitigation contributions so that the application of the TNA process can be better conceptualized. Implementation of the TNA process needs to integrate the principles of inclusiveness and gender-responsiveness. Procedures for applying these principles are discussed.

[8] Republic of Mauritius (2020) The Climate Change Act 2020, Government Gazette of Mauritius No. 145 of 28 November 2020.
[9] These Excel-based tools are available upon request from the Department of Climate Change.
[10] Republic of Mauritius (2020) The Climate Change Act 2020.

## 2.1. Mitigation contributions and actions

Figure 1 is a schematic of the multiple forms that a mitigation contribution can take, including outcomes and actions at the highest level. For the purpose of this guiding document, outcomes are essentially GHG emission reduction targets that can be set using different approaches. For instance, in the case of Mauritius, an outcome is defined in the form of 'baseline scenario target' – i.e. the mitigation target is the difference between an emission reduction scenario and a baseline-as-usual scenario. Even when targets are defined in the form of an outcome, for all practical purposes, the outcome has to be further defined in the form of actions, which in Figure 1 would correspond to policies and projects. In this guiding document, mitigation actions or the ensemble of policies and projects are equated to technological options for mitigation. Here, a technology is defined in a very broad sense as composed of hardware, software (processes associated with the production and use of the hardware) and organizational (or orgware) components that are interrelated.[11] The tangible aspects, such as equipment and products constitute the hardware element; the policy instruments that support technology uptake, know-how, experiences and practices form the software element; and the organizational framework required to operationalize these two elements is referred to as orgware. This broad definition of technology (applied here to climate mitigation) accommodates the policies and projects, which when implemented will culminate in GHG emission reductions.

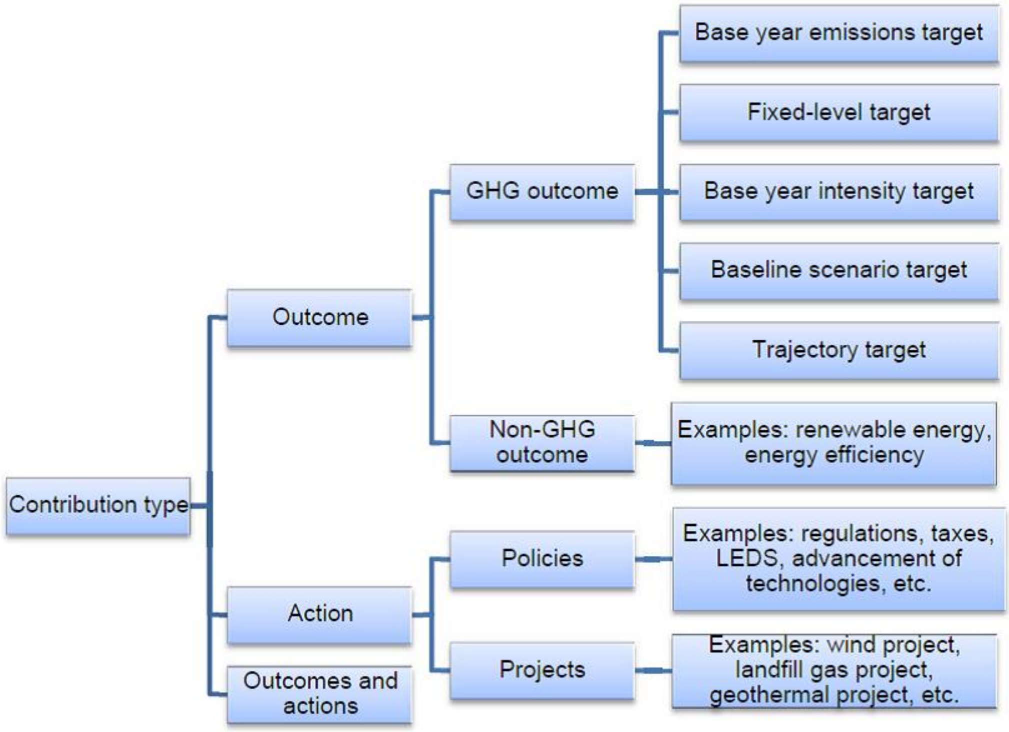


**Figure 1.** Approaches for defining mitigation contributions.
(Source: WRI & UNDP (2015) Designing and Preparing Intended Nationally Determined Contributions (INDCs))

[11] Brooks H (1995) Marshalling technology for development, National Academies Press, Washington DC, pp 83-96; Haselip J, Narkevičiūtė R, Rogat J, Trærup S (2019) TNA step by step: a guidebook for countries conducting a technology needs assessment and action plan. UNEP DTU Partnership, Copenhagen.

The conceptualization of mitigation actions (policies and projects) as mitigation technologies also serves to reconcile top-down and bottom-up approaches for operationalizing emissions reductions.[12,13]

- Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation such as carbon or other environmental taxes.
- Bottom-up models are most useful for studying options that have specific sectoral and technological implications.

So, the top-down approach may serve to define outcomes, and the bottom-up approach is a means to make the overall outcome actionable. Hence, even where the NDC may propose economy-wide sectoral targets, the guidelines will allow mitigation actions to be identified and prioritized to achieve such targets.

## 2.2. Technology Needs Assessment process

The TNA process illustrated in Figure 2 offers a robust methodological approach for climate action planning through the prioritization of environmentally sound technologies for climate technology transfer and diffusion. The TNA process and methodology has been applied in eighty nine (89) countries to date.[14] The process is equally applicable to climate adaptation and mitigation, and it proceeds through three stages:[15]

1. To **identify and prioritize** through country-driven participatory processes, **technologies** that can contribute to national **mitigation and adaptation** goals, while meeting their national sustainable development goals and priorities (TNA);
2. To **identify the barriers** that hinder the acquisition, deployment, and diffusion of the prioritized technologies for mitigation and adaptation; and
3. To develop Technology Action Plans (TAP) that **specify activities and enabling frameworks to overcome the barriers** and facilitate the transfer, adoption, and diffusion of selected technologies in order to achieve country-defined outcomes (mitigation or adaptation).

[12] UNFCCC (2005) The UNFCCC manual for the preparation of information on measures to mitigate climate change.
[13] UNFCCC (2006) Training Handbook on the Mitigation Assessment for Non-Annex I Parties.
[14] PNK Deenapanray and S Trærup (2021) Technology needs assessment for climate change adaptation: Experiences of Mauritius and Seychelles, Regional Environmental Change (revised version under review).
[15] Boldt et al. 2012; Haselip et al. 2019.

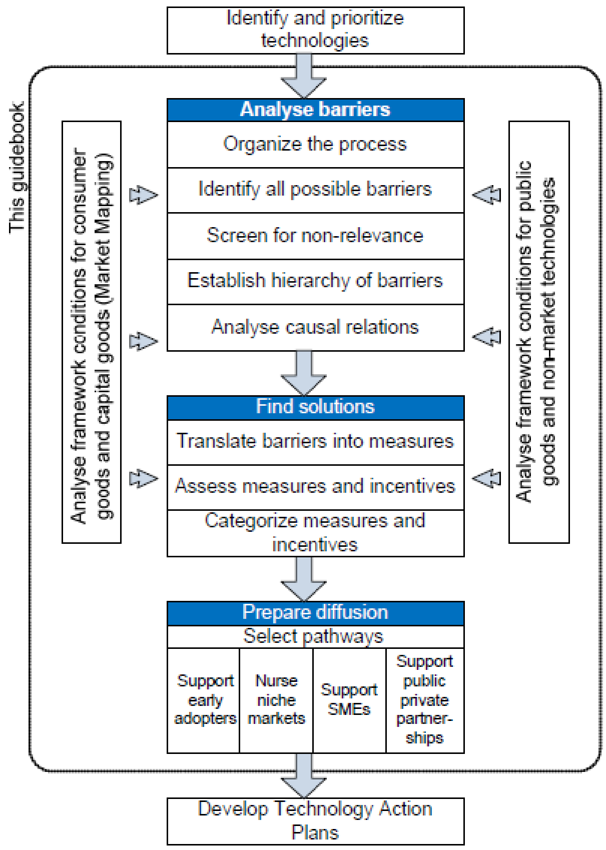


**Figure 2.** The TNA process: from technology prioritization to action plans. (Source: Boldt J, Nygaard I, Hansen UE, Trærup S (2012) Overcoming Barriers to the Transfer and Diffusion of Climate Technologies. UNEP Risø Centre, Roskilde)

Of particular interest in this guiding document is stage 1 of the process, which is detailed in Section 3. Stage 2 of the process relates to discussions in Section 2.1 since the measures (enabling environment) and incentives (financial/economic) take the form of policy instruments – i.e. the policy aspect of action in Figure 1 - that support technology deployment.

## 2.3. Stakeholder inclusiveness

The inclusion of relevant stakeholders at different steps in the TNA process is critical. Any person or institution having an interest in or is affected by the mitigation action identification and prioritization process or results thereof should be considered a relevant stakeholder. The NAMA project has developed a Stakeholder Engagement Plan (SEP)[16] that can be used to develop a stakeholder-driven process for the identification and prioritization of mitigation actions. It is noteworthy that the SEP provides guidance from the broader perspective of engaging stakeholders for the formulation, monitoring and evaluation and review of long-term mitigation strategies, of which the identification and prioritization of mitigation actions will be a subset. In addition to the SEP, the global TNA project has also developed a guidance document on how best to identify and engage the relevant stakeholders.[17]

[16] UDP (2021) Stakeholder Engagement Plan.
[17] UDP (2015) Identification and Engagement of Stakeholders in the TNA Process: A Guide for National TNA Teams.

It is important to plan stakeholder meetings to maximize their usefulness and maintain engagement of participants. An important consideration is to avoid stakeholder fatigue that can be prominent in a small island state whereby the same individuals are called upon to participate in a multitude of parallel climate initiatives and activities. In order to minimize stakeholder fatigue, a balanced approach combining plenary and bilateral meetings using face-to-face, orthodox and virtual media is encouraged.[18] A most important consideration is to integrate technology identification and prioritization in ongoing sectoral processes such as integrated policy planning that will avoid seeing climate change as an 'add-on' to existing work. This is the ambition of the CCA 2020. Hence, all stakeholder coordination will fall within a context wherein climate change is mainstreamed.

Stakeholder meetings can be coordinated by the Department of Climate Change, Ministry of Environment, Solid Waste Management and Climate Change as per the provisions of Section 19 of the CCA.[19] Facilitation of meetings can be carried out by either the coordinator – i.e. Department of Climate Change, or the ministry that has the mandate to formulate sectoral policies and strategies or an independent facilitator. For increased ownership and appropriation of the results of the process, it is recommended that facilitation would be carried out by the respective ministries having the mandate to formulate sectoral policies and strategies. An audit trail of what is discussed and the reasons for the basis of any decisions should always be written up after each event and circulated for feedback.

## 2.4. Gender mainstreaming

The stakeholder consultation process should also be gender-sensitive in both process and content. This means that the perspectives of both women and men need to be sought during consultation to ensure that both have an opportunity to voice their opinions. In this way, it can be ensured that men and women benefit equally from mitigation actions and that gender disparities in actions and outcomes are reduced or eliminated. In the TNA process, there are several instances where gender issues can be taken into account as follows:

- Prioritization of mitigation actions: As discussed below, prioritization of mitigation actions that have been identified is carried out using multi-criteria analysis (MCA). Gender-relevant indicators can be used to prioritize mitigation actions. Gender-differentiated indicators that can be applied are listed in section 3.2.2; and
- Mitigation action planning or TAP: The gender dimension can be taken into account while conducting barrier analyses (Stage 2 of the TNA process) for mitigation actions. This is also the stage at which gender analysis takes place to deliver a gender-responsive mitigation action plan.

The guidebook that has been developed for conducting gender-responsive TNA is a useful reference.[20]

[18] PNK Deenapanray and S Trærup (2022) Technology needs assessment for climate change adaptation: Experiences of Mauritius and Seychelles, Regional Environmental Change 22(2); https://doi.org/10.1007/s10113-021-01859-y.

[19] Republic of Mauritius (2020) The Climate Change Act 2020, Government Gazette of Mauritius No. 145 of 28 November 2020.

[20] J de Groot (2018) Guidance for a gender-responsive Technology Needs Assessment, UNEP DTU Partnership, Copenhagen.

## 3.0 Identifying and prioritizing mitigation actions

This section provides an overview of the methods that can be applied to first identify mitigation actions, and to then prioritize them.

### 3.1. Identifying mitigation actions

Mitigation actions supported by technological options are varied, and they can be grouped based on their relevance and applicability in the local context. The category in which a mitigation action or technology falls into determines its mode of identification. **Table 1** gives a summary of three broad groups of mitigation actions or technologies, as well as the means of identifying them.

**Table 1.** Categorization of mitigation actions and their sources of identification.

| Category of mitigation action | Source of information for technology identification | Institutional stakeholders |
|---|---|---|
| Scaling up an existing mitigation action (e.g. adoption of a mitigation technology) | Existing sectoral policies, strategies and action plans | Decision makers in public and para-governmental institutions |
| Scaling up a mitigation action that is at pilot stage or proof-of-concept (e.g. demonstration or diffusion stage of technology lifecycle)<br><br>OR<br><br>Mitigation technologies that are under development in the country | There can be several sources of information on this category of mitigation actions:<br>→ Institutional knowledge captured in internal reports on pilots and proof-of-concept, or technology development<br>→ Publications on the results of proof-of-concept and/or technology development in the public domain | Academic and research organisations; public and para-governmental institutions; private sector organisations; civil society organisations; non-governmental organisations; independent researchers |
| Mitigation technology not currently available in the country | Information about this category of technology will emanate from expert knowledge and from thorough literature reviews | Academic and research organisations; public and para-governmental institutions; private sector organisations |

Source: Author

At the stage of technology identification, all categories of technologies referred to in **Table 1** should be covered although the time scale of mitigation actions will differ from technology to technology. This is an important consideration since the formulation of low-carbon development strategies should cover at least the 2050 time horizon so that consecutive NDCs can be connected coherently to contribute towards achieving net-zero emissions by 2050.[21]

**Table 1** also identifies a list of potential institutional stakeholders that may host knowledge on mitigation actions. The importance of putting in place a robust multi-stakeholder process so that the best knowledge of mitigation actions can be collected at the start of the process cannot be overstated.

In order to avoid stakeholder fatigue at this early stage of the process, the identification of mitigation technologies can be carried out by distance (e.g. electronic mails and telephone) or

[21] The proposed time horizon is subject to change and needs to be aligned with the policy decision regarding the timeline for National Mitigation Strategy and Action Plan to be developed under Article 14 of the Climate Change Act 2020.

through short bilateral meetings (e.g. in person or virtual meetings). The process can be coordinated by the Department of Climate Change.

In addition to institutional knowledge, mitigation actions can be identified in the secondary literature. A non-exhaustive list of prominent sources of information is:

- Handbook for Conducting TNA for Climate Change:[22] Table A7-1 in Annex 7 of the Handbook provides an indicative list of mitigation technologies covering the following areas: (i) electricity production,[23] (ii) heating for industrial and domestic use; (iii) cooling-climate control; (iv) hot water in buildings; (v) lighting; (vi) demand-side management for electricity; (vii) cooking; (viii) industrial; (ix) transport; (x) carbon capture and storage; (xi) substitution of ozone depleting substances; (xii) agriculture; (xiii) forestry; (xiv) waste management; and (xv) management of ozone depleting substances in products and equipment at end-of-life;
- TNA Guidebooks:[24] The global TNA project hosts a number of resources that can be used to identify mitigation actions. A brief summary of the existing resources is:
  - *Climate technologies in an urban context*:[25] This guidebook provides information on technologies for climate change mitigation and adaptation that are relevant in an urban context, specifically in relation to buildings, transportation and waste management for mitigation, and in relation to droughts, floods and heatwaves for adaptation. It aims to provide TNA stakeholders and city-level decision-makers with information about various technological options and potential challenges and opportunities for their use in cities;
  - *Technologies for mitigation in the building sector*:[26] This guidebook covers a range of building technologies, design principles and practices which can significantly reduce emissions of greenhouse gases, while improving living and working conditions;
  - *Technologies for mitigation in the agriculture sector*:[27] This guidebook covers a range of technologies and practices in the agricultural sector related to crops and livestock that can control emission of greenhouse gases, and help improve productivity at the same time;
  - *Technologies for mitigation in the transport sector*:[28] This guidebook covers a range of transport technologies and practices that can significantly reduce emissions of greenhouse gases and support key development goals.
- TNA database:[29] The global TNA project hosts a database of TNA Reports and Technology Action Plans, as well as Technology Fact Sheets produced by some 72 countries to date.[30]

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[22] UNDP (2010) Handbook for Conducting Technology Needs Assessment for Climate Change, UNDP, NY.
[23] This area of emissions covers the following categories of technologies: renewable, fossil fuel-based energy supply, fuel cells and combinations thereof.
[24] Please see resources available at: https://tech-action.unepdtu.org/resources/ - accessed 28 October 2021.
[25] UDP (2021) Climate technologies in an urban context, UNEP DTU Partnership, Copenhagen.
[26] W.C-N. Cam (2012) Technologies for Climate Change Mitigation – Building Sector, UNEP Risø Centre, Roskilde.
[27] D.C. Uprety, S. Dhar, D. Hongmin, B.A. Kimball, A. Garg and J. Upadhay (2012) Technologies for Climate Change Mitigation – Agriculture Sector, UNEP Risø Centre, Roskilde.
[28] UNEP (2011) Technologies for Climate Change Mitigation – Transport Sector, UNEP Risø Centre, Roskilde.
[29] https://tech-action.unepdtu.org/tna-database/ - accessed 28 October 2021.
[30] The database contained 185 documents relayed to climate change mitigation across several sector as of 28 October 2021.

## 3.2. Prioritizing mitigation actions

The prioritization of mitigation actions is a means of obtaining an ordinal ranking of pre-identified mitigation actions based on the country's development priorities. For all practical purposes, the list of mitigation actions to be prioritized would typically not exceed ten to twelve technologies. However, the list of mitigation actions that have been identified in the previous step may well exceed this guiding range. In this case, a pre-screening step needs to be carried out in order to obtain a short-list of mitigation actions from a starting long-list.

### 3.2.1. Pre-screening of long-listed mitigation technologies

This intermediary step is required in case the list of pre-identified mitigation actions would exceed the guiding range of ten to twelve technologies.[31] Pre-screening consists of assessing the long-list of mitigation actions against a small number of criteria in order to rate them from low applicability/technically feasible to high applicability based on expert knowledge. The criteria that can be used are: (1) Criterion 1: applicability of technology to a sub-tropical country;[32] (2) Criterion 2: support to national policy (i.e. technology is current practice; technology is supported by ongoing initiatives or initiatives in the pipeline or has high potential to support policy); (3) Criterion 3: relevance of technology scale of economies in the context of a small island State; and (4) Criterion 4: level of technology maturity (time horizon for technology implementation).

The mitigation technologies can be rated using the scheme shown in

[31] An example of using the pre-screening step is the detailed analysis of baseline technologies that was carried out during the TNA project in 2011 for the identification of a short-list of mitigation technologies in the energy industries. The starting point was the mitigation technologies listed in Annex 7 of the TNA Handbook that is mentioned in section 3.1. Sixty (60) technologies were screened and the results can be found in Annex 7(a) of the Mauritius TNA Report [Republic of Mauritius (2012) Technology Needs Assessment for an Enhanced Climate Change Adaptation and Mitigation – TNA Report I, Ministry of Environment and Sustainable Development].

[32] It is pointed out that several mitigation technologies are not applicable in Mauritius because of a combination of context (e.g. climatic conditions implying no need for heating; topography that limits hydro-electricity; feed-in-tariffs to promote micro-generation of renewable energy technologies in place); technology already adopted (e.g. CFL and solar water heating for household and industrial applications); low socio-cultural acceptability (e.g. solar cook stoves); and/or the stage of development of Mauritius (e.g. use of modern fuels like LPG for cooking automatically excludes biomass/coal/kerosene cook stoves).

**Table** 2. The rating scheme uses a combination of binary (yes, no) and colour (low, moderate, high) codes. A mitigation technology is short-listed if it follows the ratings shown in **Table 3**. This means that the short-listed technology should (i) be applicable in the local context, (ii) provide a high level of support to implementing national policy, and (iii) high relevance in terms of relatively small scale of economies. As for the Criterion 4, the rating can be either high or moderate or low depending on the timeline for implementation from short- to medium- to long-term.

**Table 2.** Criteria scoring scheme.

| Criterion | Scoring scheme | | |
|---|---|---|---|
| Criterion 1 | Yes | No | |
| Criterion 2 | High | Moderate | Low |
| Criterion 3 | High | Moderate | Low |
| Criterion 4 | High | Moderate | Low |

Source: Author

**Table 3.** Application of scoring scheme to a short-listed mitigation action.

| Criterion 1 | Criterion 2 | Criterion 3 | Criterion 4 |
|---|---|---|---|
| Yes | High | High | High |
| | | | Moderate |
| | | | Low |

Source: Author

### 3.2.2 Prioritization of short-listed mitigation technologies

MCA is used to prioritize the short-listed mitigation actions. Some of the main attributes of MCA are summarized in **Table 4**.

**Table 4.** Attributes of multi-criteria analysis.

| | |
|---|---|
| Key output | A single most preferred option, ranked options (ordinal), short list of options for further appraisal, or characterization of acceptable or unacceptable possibilities. |
| Key input | Criteria of evaluation as well as relevant metrics for those criteria (monetary and non-monetary dimensions of development) |
| Ease of use | Depends on the particular MCA tool employed. All rely on the exercise of some expert judgement. For ordinal ranking of a number of technology options, the simple linear additive method suffices. |
| Training required | Choice and application of appropriate MCA technique require some expertise, but can be acquired fairly easily. Low level of technical training required for the application of the linear additive model. |

Source: Author

MCA is applied using the eight decision steps shown in **Figure 3**, which is an extension of the pre-screening method used in section 3.2.1. Steps 3 to 8 constitute the backbone of the prioritization process. The application of each step is discussed separately below.

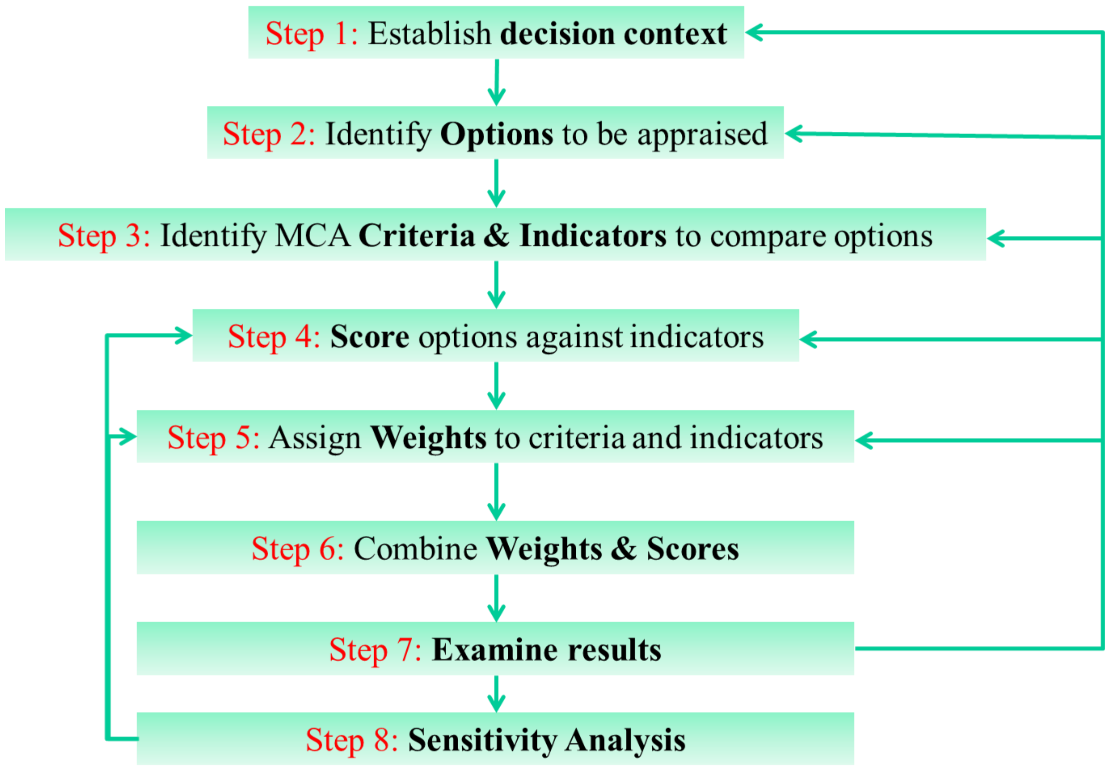


**Figure 3.** Steps of multi-criteria analysis.
(Source: Author)

Step 1: Establish decision context – The MCA is applied in the context of prioritizing a bundle of mitigation actions that can then be used for developing a Mitigation Strategy and Action Plan for either formulating the NDC or to implement the NDC.

Step 2: Identify options to be appraised – The mitigation actions or technologies to be appraised are those identified in section 3.1 or the short-list formulated in section 3.2.1.

Step 3: Identify Criteria and Indicators to compare options – This is a crucial step since the outcome of the prioritization process will hinge on the choice of the criteria and indicators that are used to carry out MCA. The choice of criteria and indicators should be carried out using a stakeholder engagement process involving a combination of high level policy makers and senior technicians / technical officers. The number and type of criteria and indicators used in MCA is a matter of trade-off between the time inputs from stakeholders (and hence stakeholder fatigue), the technical capacity of stakeholders to calculate objective indicators, availability of data to quantify objective indicators, and the diminishing marginal impact of indicators.[33]

- Criteria: These should cover the sustainable development priorities of the country, and should lend themselves to be measured either subjectively (e.g. rated on a subjective scale) or objectively (e.g. using quantifiable indicators). The number of criteria should be kept to a manageable set (seven in the example given below) since each one will be measured using between one and three indicators.
- Indicators: MCA is prone to bias, and all effort should be spent to minimize if not eliminate sources of bias. One form of bias arises from the subjective evaluation of

[33] This is because of the effect of dilution of the impact of any indicator towards the final result because of the decreasing values of weights when criteria and indicators increase in numbers.

indicators. This source of bias can be minimized by having a balanced blend of subjective and objective indicators. The latter are calculated using analytical or mathematical approaches and are subject to an objective evaluation. Although there are no rules to determine the appropriate mix of subjective and objective indicators, a good balance could be to achieve parity between the two types of indicators.

The MCA4Climate[34] framework is proposed as a starting point for selecting criteria and indicators.[35] It provides a robust framework for developing climate change mitigation (and adaptation) plans and strategies. In particular, it aims to support developing countries identify policies and measures that are low cost, environmentally effective and consistent with national development goals. The MCA4Climate framework does this by providing a structured approach to assessing and prioritizing climate options, while taking into consideration associated social, economic, environmental and institutional costs and benefits.[36] The criteria and indicators in the MCA4Climate framework are shown in **Table 5**, as well as an indication of which indicators can be gender-differentiated.

**Table 5.** Criteria and indicators from the MCA4Climate framework.

| Criteria | Indicators |
|---|---|
| Financing needs | - Direct costs<br>- Indirect costs |
| Implementation barriers | - Ease of implementation<br>- Compliance with required timing of policy intervention |
| Climate-related | - GHG reduction (& black carbon emissions) |
| Economic | - Trigger private investments<br>- Improve economic performance<br>- Job creation[37] (gender differentiated)<br>- Contribute to fiscal sustainability |
| Environmental | - Protect environmental resources (quality & stock)<br>- Protect biodiversity<br>- Support ecosystem services |
| Social | - Poverty reduction (gender differentiated)<br>- Reduce inequity (gender differentiated)<br>- Improve health (gender differentiated)<br>- Preserve cultural heritage |
| Political & institutional | - Contribute to political stability<br>- Improve governance |

Source: MCA4Climate framework

An example of the application of the MCA4Climate framework for prioritizing mitigation technologies in the TNA project is given in Annex 1.[38]

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[34] UNEP (2011) A Practical Framework for Planning Pro-development Climate Policy, UNEP DTIE, Paris.
[35] The MCA4Climate framework has been applied in technology prioritization in Mauritius under the following projects: Technology Needs Assessment Project, Third National Communication Project and NAMA Project.
[36] https://www.unep.org/resources/report/practical-framework-planning-pro-development-climate-policy - accessed 8 November 2021.
[37] Depending on the country priorities, job creation can be further divided into gender-differentiated formal and informal jobs. Another distinction that can be brought is the quality of jobs in terms of whether the jobs created support a green economy or not. Methodologies to estimate green job creation are given in: Jarvis, Varma and Ram (2011) Assessing green jobs potential in developing countries: A practitioner's guide, International Labour Organization, Geneva; https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_153458.pdf - accessed 20 April 2022.

Step 4: Scoring options against indicators – This step seeks to assess the performance of each mitigation action against the chosen indicators. The objective indicators are calculated based on methodologies chosen by the stakeholders (high policy makers and senior technical staff) in each sector. For instance, avoided GHG emissions will be computed using standardized baseline and approved methodologies of the UNFCCC.[39]

Another way to minimize bias is to have a sufficiently large number of stakeholders who together will have adequate knowledge of the short-listed mitigation technologies. Experience with the TNA, TNC and NAMA projects has shown that a cohort between 6 – 10 persons is appropriate. Nevertheless, it is highly possible that several participants in the MCA do not have knowledge on all aspects of technologies covered by indicators. To bridge this knowledge gap, a technology fact sheet (TFS) is developed for each technology. Annex 2 provides an example of a TFS for utility-scale solar photovoltaic (PV) with battery storage. As mentioned above, the global TNA database contains a large number of TFS for reference and that can be customized for the local context.

Performance matrix

**Table 6** gives an example of the application of the MCA4Climate (Annex 1) for seven mitigation actions. It shows the performance of each technology against the criteria and indicators, and hence called performance matrix. Out of the nine indicators four are objective indicators and five are subjective indicators. The objective indicators are calculated using quantitative data,[40] while the subjective indicators are scored using expert judgements with the help of the TFS.

While it is desirable to have consensual decision making, it is not a necessity. For example, stakeholders may have different views on assumptions used to calculate objective indicators, or they may have different appreciations of subjective indicators. When these situations arise, the different values of indicators should be noted down for carrying out sensitivity analyses.

**Table 6.** Performance matrix.

| | CRITERIA AND INDICATORS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Public Financing | Implementation Barriers | Climate | Economic | | | Social | | Political & Institutional |
| TECHNOLOGY | Incremental cost (Rs/tCO2) | Ease of implementation (0-100) | GHG reduction (tCO2) | catalysing private invest (0-100) | Reduction in energy bill (MRs) | replicability (0-100) | positive impact on health (0-100) | job creation (number) | Enhance political stability (0-100) |
| **Solar PV (>1MW)** | 5,552.8 | m | 769,536.5 | h | 5,521.2 | m60 | l | 1430 | m70 |
| **Wind (utility scale)** | 1,514.4 | h | 1,869,815.3 | m | 13,415.4 | l | l | 366 | m70 |
| **Small-scale hydro (>50kW)** | 1,514.4 | h40 | 70,454.3 | l30 | 505.5 | m70 | l | 26 | m60 |
| **EE HVAC (industrial)** | 17,298.0 | m60 | 40,454.9 | m70 | 290.3 | h80 | m | 73 | m |
| **EE Bldg Des (exterior insulation)** | 833.0 | vh10 | 17,441.1 | l30 | 125.1 | h80 | m70 | 32 | m |
| **HE Compressors (industrial)** | 125.5 | h | 13,485.0 | m70 | 96.8 | m70 | m60 | 24 | m |
| **EE Boilers/Heat recovery** | 2,246.3 | h30 | 143,090.5 | h80 | 56.3 | h80 | m65 | 287 | m |

Source: Author

[38] Republic of Mauritius (2012) Technology Needs Assessment for an Enhanced Climate Change Adaptation and Mitigation – TNA Report I, Ministry of Environment and Sustainable Development.
[39] https://cdm.unfccc.int/methodologies/index.html ; https://cdm.unfccc.int/methodologies/standard_base/index.html - accessed 9 November 2021.
[40] The Excel tool for carrying the MCA shown in Table 6 integrates the calculation of the objective indicators and it is available from the Department of Climate Change upon request.

The subjective indicators were evaluated on a scale of 0 to 100 using the coding given in **Table** 7. It is pointed out that the scale used for 'Ease of implementation' is the reverse of the scale used for the other four subjective indicators.[41] This is illustrated using colour-coding in Table 6 and Table 7.[42]

**Table 7.** Scales used for evaluating subjective indicators.

| VL | VL5 | VL10 | VL15 | VL20 | L | L30 | L35 | L40 | L45 | M | M55 | M60 | M65 | M70 | H | H80 | H85 | H90 | H95 | VH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 50 | 45 | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 |

Source: Author

<u>Scale normalization</u>

Two important observations can be made from **Table 6**:

1. The range of values of objective indicators are different from each other, and
2. The scales of objective and subjective indicators are not commensurate.

Therefore, it is not possible at this stage to have a total score or overall performance of one technology simply by adding its scores across the different indicators as given in the performance matrix. Before summation of scores across indicators can be effected, it is necessary to normalize the values of objective indicators on a relative scale of 0 to 100 – i.e. similar to the scale range used for the subjective indicators. This is done using the MIN-MAX scale normalization. However, it is pointed out that, just as the scales of subjective indicators can be reversed, the same attribute applies to the objective scores.

***Financing cost***: For this indicator, the highest (MAX) value in the performance matrix is assigned a score of 0, whereas the lowest (MIN) value in the performance matrix is assigned a value of 100. The rationale is that a higher financing cost will hinder the adoption and diffusion of a technology. All values between the MIN and MAX scores are then normalized on the new scale between 0 and 100. Therefore, the scores across all technologies are normalized using Eq(1). Equation (1) is used whenever the preferred performance value for an indicator is on the low side.

$$S_i = 100\left(1 - \frac{[X_i - X_{MIN}]}{[X_{MAX} - X_{MIN}]}\right) \qquad \text{Eq(1)}$$

Where: $S_i$ is the normalized score;
$X_i$ is the performance score of mitigation option $i$;
$X_{MIN}$ is the minimum score among all mitigation options; and
$X_{MAX}$ is the maximum score among all mitigation options.

***Other objective indicators (GHG reduction, Energy bill and Job creation)***: For these indicators, a higher performance score is desirable. Hence, normalization of scores is performed using Eq(2) – i.e. the reverse of Eq(1). Equation (2) is used whenever the preferred performance value for an indicator is on the high side.

[41] An Excel-based tool was developed for the training delivered on 7 July 202 for prioritizing mitigation actions using MCA. The tool is customized to convert the subjective code given in Table 7 into the corresponding scores. The Excel tool used to generate Table 6 applies the same method.

[42] For instance, a very high (VH) level of 'Catalysing private investment' or 'Replicability' or 'Positive impact on health' or 'Enhance political stability' will correspond to a score of 100. In contrast, a very high level of 'Implementation barriers' will correspond to a score of zero.

$$S_i = 100\left(\frac{X_i - X_{MIN}}{X_{MAX} - X_{MIN}}\right) \qquad \text{Eq(2)}$$

Normalized performance scores

After transcribing the subjective codes using Table 7, and normalizing the objective indicators using Eq(1) and Eq(2), the performance scores given in **Table 6** can be translated into the scores given in
**Table** 8. It is observed that the normalized objective scores are now on a dimensionless 0 – 100 relative scale.

**Table 8.** Normalized performance scores.

| | CRITERIA AND INDICATORS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Public Financing | Implementation Barriers | Climate | Economic | | | Social | | Political & Institutional | |
| TECHNOLOGY | Direct cost | Ease of implementation | GHG reduction | catalysing private investme | Reduction in energy bill | replicability | Impact on health | Job creation | political stability | TOTAL |
| **Solar PV (>1MW)** | 68.4 | 50 | 40.7 | 75 | 40.9 | 60 | 25 | 100.0 | 70 | **530.03** |
| **Wind (utility scale)** | 91.9 | 25 | 100.0 | 50 | 100.0 | 25 | 25 | 24.3 | 70 | **511.24** |
| **Small-scale hydro (>50kW)** | 91.9 | 40 | 3.1 | 30 | 3.4 | 70 | 25 | 0.1 | 60 | **323.49** |
| **EE HVAC (industrial)** | 0.0 | 60 | 1.5 | 70 | 1.8 | 80 | 50 | 3.5 | 50 | **316.69** |
| **EE Bldg Des (exterior insulation)** | 95.9 | 10 | 0.2 | 30 | 0.5 | 80 | 70 | 0.6 | 50 | **337.18** |
| **HE Compressors (industrial)** | 100.0 | 25 | 0.0 | 70 | 0.3 | 70 | 60 | 0.0 | 50 | **375.30** |
| **EE Boilers/Heat recovery** | 87.6 | 30 | 7.0 | 80 | 0.0 | 80 | 65 | 18.7 | 50 | **418.34** |

Source: Author

Step 5: Assign weights to criteria and indicators - Since both the objective and subjective scores are now on the same relative scale, they can be added into a total score. However, the total score cannot be used to rank the mitigation options. This is because some criteria (and their indicators) can be considered of higher importance in decision making, such as to reflect the sustainable development needs of the country. Hence, the highest weight will be assigned to the criterion most important for the country's development context, and vice versa. Since the objective of the exercise is to resolve differences between technologies, a relatively lower weight can be assigned to the criteria whose indicator(s) is (are) least resolved – i.e. the lowest difference between the maximum and minimum values. A good example is 'Political stability' (Political and Institutional criterion) for which the scores across mitigation options are contained in a narrow window of only 20 points. The weights should be assigned following discussions between stakeholders participating in the MCA exercise. In order to take into account any differences in views between stakeholders in assigning weights, different sets of weights can be identified that cover the views of all stakeholders. The use of different sets of weights for carrying out sensitivity analyses is discussed in Step 8 below.

For any combination of weights, the sum of weights is equal to 1.

Step 6: Combining scores and weights – The linear additive model shown in Eq(3) is used to combine the scores and weights.

$$S_{Ti} = \sum_{j=1}^{n} S_{ij} w_j \qquad \text{Eq(3)}$$

Where: $S_{Ti}$ is the total performance score for mitigation option $i$;
$S_{ij}$ is the performance score of mitigation option $i$ for indicator $j$; and
$w_j$ is the weight assigned to indicator $j$.

For the example given in **Table 6**, the ranking of mitigation technologies following the summation of combined scores and weights is given in
**Table** 9. In this example, the weights correspond to the first set of weights given in Annex 1. In the ordinal ranking, the mitigation technology receiving the highest combined score is the most preferred option, or the option that would be implemented with highest priority to achieve mitigation objectives. The priority of mitigation actions in achieving mitigation objectives will decrease with decreasing combined scores.

**Table 9.** Ranking of mitigation options after combining scores and weights.

| | CRITERIA AND INDICATORS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Public Financing | Implementation Barriers | Climate | Economic | | | Social | | Political & Institutional | | |
| TECHNOLOGY | Direct cost | Ease of implementation | GHG reduction | catalysing private investme | Energy bill | replicability | Impact on health | Job creation | political stability | TOTAL | RANK |
| Solar PV (>1MW) | 10.3 | 7.5 | 8.1 | 11.3 | 4.1 | 3.0 | 1.3 | 10.0 | 3.5 | **59.00** | **2** |
| Wind (utility scale) | 13.8 | 3.8 | 20.0 | 7.5 | 10.0 | 1.3 | 1.3 | 2.4 | 3.5 | **63.47** | **1** |
| Small-scale hydro (>50kW) | 13.8 | 6.0 | 0.6 | 4.5 | 0.3 | 3.5 | 1.3 | 0.0 | 3.0 | **33.00** | **5** |
| EE HVAC (industrial) | 0.0 | 9.0 | 0.3 | 10.5 | 0.2 | 4.0 | 2.5 | 0.3 | 2.5 | **29.31** | **7** |
| EE Bldg Des (exterior insulation) | 14.4 | 1.5 | 0.0 | 4.5 | 0.1 | 4.0 | 3.5 | 0.1 | 2.5 | **30.53** | **6** |
| HE Compressors (industrial) | 15.0 | 3.8 | 0.0 | 10.5 | 0.0 | 3.5 | 3.0 | 0.0 | 2.5 | **38.28** | **4** |
| EE Boilers/Heat recovery | 13.1 | 4.5 | 1.4 | 12.0 | 0.0 | 4.0 | 3.3 | 1.9 | 2.5 | **42.66** | **3** |
| | | | | | | | | | | | |
| **WEIGHTS** | 0.15 | 0.15 | 0.2 | 0.15 | 0.1 | 0.05 | 0.05 | 0.1 | 0.05 | 1 | |

Source: Author

<u>Step 7: Examine results</u>: This step consists of detailed analysis and discussion of the MCA results by all stakeholders. The purpose is to see if the results could be expected given the national decision context. It is also an opportunity to reflect on the process and to discuss ways in which it could be improved. As shown in **Figure 3**, this step provides an opportunity to review earlier steps (namely steps 1 to 5) in order to make corrective changes in the process.

<u>Step 8: Sensitivity analysis</u> – Sensitivity analysis is carried out to establish the robustness of the prioritization results due to small changes scores and weights. Further, as mentioned above, stakeholders may not give the same performance scores for a given mitigation option and indicator or they can give differing considerations for weights. The robustness of the results would imply that small changes in performance scores and/or weights should not significantly change the ordinal ranking. An example of sensitivity analysis on weights is given in

**Table** 10. In this case, the last combinations of weights (rightmost column) given in Annex 1 is used. It can be seen that the order of ranking is unchanged, showing that the result is robust for the changes in weights. A similar analysis can be carried out for small changes in scores.

**Table 10.** Technology prioritization using a different set of weights.

| | CRITERIA AND INDICATORS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Public Financing | Implementation Barriers | Climate | Economic | | | Social | | Political & Institutional | | |
| TECHNOLOGY | Direct cost | Ease of implementation | GHG reduction | catalysing private investment | Energy bill | replicability | Impact on health | Job creation | political stability | TOTAL | RANK |
| Solar PV (>1MW) | 10.3 | 5.0 | 8.1 | 3.8 | 4.1 | 3.0 | 1.3 | 15.0 | 10.5 | 61.00 | 2 |
| Wind (utility scale) | 13.8 | 2.5 | 20.0 | 2.5 | 10.0 | 1.3 | 1.3 | 3.6 | 10.5 | 65.44 | 1 |
| Small-scale hydro (>50kW) | 13.8 | 4.0 | 0.6 | 1.5 | 0.3 | 3.5 | 1.3 | 0.0 | 9.0 | 34.01 | 5 |
| EE HVAC (industrial) | 0.0 | 6.0 | 0.3 | 3.5 | 0.2 | 4.0 | 2.5 | 0.5 | 7.5 | 24.49 | 7 |
| EE Bldg Des (exterior insulation) | 14.4 | 1.0 | 0.0 | 1.5 | 0.1 | 4.0 | 3.5 | 0.1 | 7.5 | 32.06 | 6 |
| HE Compressors (industrial) | 15.0 | 2.5 | 0.0 | 3.5 | 0.0 | 3.5 | 3.0 | 0.0 | 7.5 | 35.03 | 4 |
| EE Boilers/Heat recovery | 13.1 | 3.0 | 1.4 | 4.0 | 0.0 | 4.0 | 3.3 | 2.8 | 7.5 | 39.10 | 3 |
| WEIGHTS | 0.15 | 0.1 | 0.2 | 0.05 | 0.1 | 0.05 | 0.05 | 0.15 | 0.15 | 1 | |

Source: Author

<u>Additional references</u>

Additional information on carrying out MCA can be obtained from the following sources:

- UNDP (2010) Handbook for Conducting Technology Needs Assessment for Climate Change, UNDP, NY. Available at: https://www.undp.org/publications/handbook-conducting-technology-needs-assessment-climate-change - accessed 9 November 2021.
- Subash Dhar, Denis Desgain and Rasa Narkeviciute (2015) Identifying and prioritising technologies for mitigation – A hands on guidance to multi-criteria analysis (MCA), UNEP DTU partnership, Copenhagen. Available at: https://tech-action.unepdtu.org/publications/identifying-and-prioritising-technologies-for-mitigation/ - accessed 9 November 2021.
- CIFOR (1999) Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and Indicators. 9. The Criteria & Indicators Toolbox Series. Center for International Forestry Research (CIFOR). Available at: https://www.cifor.org/publications/pdf_files/Books/toolbox9.pdf - accessed 9 November 2021.

## Annex 1 – Example of the application of the MCA4Climate framework.

| Criteria | Indicators | Measurement scale | Weight | Sensitivity analysis | |
|---|---|---|---|---|---|
| Public Financing needs | Direct incremental cost, e.g. direct government budgeting | Rs/tCO2 | 0.15 | 0.2 | 0.15 |
| Implementation Barriers | Ease of Implementation e.g. non-financial barriers | Likert scale: 0 (highest barrier) – 100 (lowest barrier) | 0.15 | 0.1 | 0.1 |
| Climate-related | GHG reduction | tCO2 (to 2025) | 0.2 | 0.25 | 0.2 |
| Economic | - Catalysing private investments | Likert scale: 0 (lowest) – 100 (highest) | 0.15 | 0.05 | 0.05 |
| | - Reduction in energy import bill | MRs (million Rs) (to 2025) | 0.1 | 0.1 | 0.1 |
| | - Replicability | Likert scale: 0 (lowest) – 100 (highest) | 0.05 | 0.05 | 0.05 |
| Social | - Impact on health | Likert scale: 0 (lowest) – 100 (highest) | 0.05 | 0.05 | 0.05 |
| | - Job creation | Quantity (to 2025) | 0.10 | 0.15 | 0.15 |
| Political and Institutional | Contribute to political stability | Likert scale: 0 (lowest) – 100 (highest) | 0.05 | 0.05 | 0.15 |

# Annex 2 – Example of Technology Fact Sheet

<table>
<tr><th>Technology:</th><th>Central PV (MW scale) system with storage</th></tr>
<tr><td colspan="2">Technology characteristics</td></tr>
<tr><td>Introduction</td><td>The solar power source is via photovoltaic modules that convert light directly to electricity. However, this differs from, and should not be confused with concentrated solar power, the other large-scale solar generation technology, which uses heat to drive a variety of conventional generator systems. Both approaches have their own advantages and disadvantages, but to date, for a variety of reasons, photovoltaic technology has seen much wider use in the field.<br><br>A photovoltaic power station, also known as a central PV system, is a large-scale photovoltaic system (PV system) designed for the supply of merchant power into the electricity grid. They are differentiated from most building-mounted and other decentralised solar power applications because they supply power at the utility level, rather than to a local user or users. They are sometimes also referred to as solar farms or solar ranches, especially when sited in agricultural areas. The generic expression utility-scale solar is sometimes used to describe this type of project.</td></tr>
<tr><td>Technology characteristics/highlights</td><td>PV Power Farm System includes grid connected central inverter that connects directly to the utility grid and converts direct current (DC) output from PV arrays into alternative current (AC). The generated electricity can be sold to the utility grid according to the government's promotion policy of electricity generating from sustainable energy.<br>Many storage technologies have been considered in the context of utility-scale energy storage systems. These include:<ul><li>Pumped Hydro</li><li>Batteries (including conventional and advanced technologies)</li><li>Superconducting magnetic energy storage (SMES)</li><li>Flywheels</li><li>Supercapacitors / Ultracapacitors</li></ul>Each technology has its own particular strengths and operational characteristics. For example, pumped hydro is best suited for large-scale bulk electrical energy storage (if suitable geographic topology, geology and environmental conditions exist) and for longer hours of operation, whereas battery storage can be cheaper for shorter storage duration. The other technologies are either at development stage and more costly.
<table>
<tr><th></th><th></th><th colspan="2">Lithium Ion Battery Energy Storage</th><th colspan="2">Vanadium Flow Battery Energy Storage</th><th colspan="2">Pumped Hydro Energy Storage</th></tr>
<tr><td>Capacity</td><td>MW</td><td>400</td><td>400</td><td>400</td><td>400</td><td>400</td><td>400</td></tr>
<tr><td>Storage Duration</td><td>hrs</td><td>4</td><td>10</td><td>4</td><td>10</td><td>4</td><td>10</td></tr>
<tr><td>30-Year Total Levelized Cost (LCOS)</td><td>$/MWh</td><td>$144</td><td>$145</td><td>$149</td><td>$149</td><td>$151</td><td>$92</td></tr>
<tr><td>Engineering and Installation Time</td><td>years</td><td>0.5 - 1.0</td><td>1. 3 - 1.7</td><td>0.7 - 1.3</td><td>1.0 - 2.0</td><td>8 - 10</td><td>8 - 10</td></tr>
</table></td></tr>
<tr><td>Country specific applicability and potential</td><td>The impact of photovoltaic (PV) power generation with energy storage on the electric utility's load shape for load leveling purposes is explored. Results show that utilities employing storage technology for peak load shaving might benefit from use of photovoltaic power, the extent of its usefulness being dependent on the specific load shapes as well as the photovoltaic array orientations. Also, storage will allow for the variable nature of solar PV to be better managed leading to more grid stability.</td></tr>
<tr><td>Status of technology in country</td><td>There is no central PV system with storage technology in the country. However, standalone large-scale battery storage technology is being utilized by the national utility. Also, the country already has experience with on-grid solar PV producing 145.7 GWh in 2020 [Statistics Mauritius (2021) Energy and Water Statistics 2020]. The bulk on investments in renewable energies in</td></tr>
</table>

| **Technology:** | **Central PV (MW scale) system with storage** |
|---|---|
| | Mauritius is from the private sector. |
| Benefits to economic / social and environmental development | The direct impact will be on the reduction of the fuel import bill, hence improving the balance of payment and keeping more forex in the country. This will mean that there will be more government funds for capital project.<br><br>There will be a reduction of risk of spillage due to importation of fossil fuels into the country.<br><br>New personnel will have to be trained to be able work in this environment whereby creating new jobs. |
| Climate change mitigation benefits | There are direct $CO_2$ or other GHG emissions from such systems as there will reduce or eliminate the use of fossil fuels for producing electricity.<br><br>For the purpose of this exercise, a number of assumptions are used:<br>• Target: solar PV installed capacity is 50 MW; battery capacity is 10 MW for 4 hours storage (i.e. 80 MWh)<br>• Using a capacity factor of 0.2 and 95% availability, the annual production is 83,220 MWh<br>• It is further assumed that PV electricity displaces thermally-generated electricity using HFO. The emission factor is: 0.69 tCO2/MWh |
| Financial Requirements and Costs | In recent years, PV technology has improved its electricity generating efficiency, reduced the installation cost per watt as well as its energy payback time, and has reached grid parity in at least 19 different markets by 2014. PV is increasingly becoming a viable source of mainstream power. However, prices for PV systems show strong regional variations, much more than solar cells and panels, which tend to be global commodities.<br><br>Please use the following data for the purpose of this exercise:<br><br>• Solar farm installation costs are typically between $0.82 to $1.36 per watt [https://www.solarreviews.com/blog/what-is-a-solar-farm-do-i-need-one – 1 July]. For the purpose of this exercise use $0.9 per W.<br>• The cost of battery storage is US$ 150 / MWh (for 4 hours storage) [https://www.energy-storage.news/blogs/behind-the-numbers-the-rapidly-falling-lcoe-of-battery-storage – 1 July 2021]. |