Multi-criteria assessment of energy sector nationally appropriate mitigation actions in Sri Lanka

Thusitha Sugathapala
Department of Mechanical Engineering, University of Moratuwa, Moratuwa 10400, Sri Lanka
E-mail: thusitha@uom.lk

Abstract. Sri Lanka has shown its commitment for greenhouse gas mitigation by publishing nationally determined contributions. Key share of mitigation targets is from the energy sector, amounting to about 40 Mt CO$_2$e during 2020-2030. 52 mitigation options (MOs), referred to as nationally appropriate mitigation actions (NAMAs), were identified with a total mitigation potential of 75 Mt CO$_2$e. Globally, the commonly used methodology for prioritization of NAMAs is the marginal abatement cost (MAC) analysis. However, this approach has received criticism over the effectiveness due to its inability to consider other important aspects such as barriers, enablers and co-benefits. The present study proposes a multi-criteria assessment (MCA) methodology involving more comprehensive characteristics of MOs and use of sustainability criteria/indicators to broaden the applicability of MAC analysis. The proposed methodology involves a stage-wise evaluation in three levels. Firstly, MOs identified are pre-screened based on technology maturity and information availability as indicators for chance of success in implementation. Among 52 MOs, 38 qualified for the next assessment level. These MOs are then undergone screening, where MAC and mitigation potential are combined with a scoring system together with a prescribed benchmark value as a qualifying criterion. Accordingly, 31 MOs are qualified, which represent a total mitigation potential of 62 Mt CO$_2$e. Finally, at third level, indicators in relation to barriers, enablers and co-benefits are used to derive an overall score of MCA. The results of MAC and MCA analyses are used in conjunction to prioritize MOs under three appealing levels as 7 highly, 14 moderately and 10 least, with a total mitigation potentials of about 17.1, 32.4 and 12.8 Mt CO$_2$e, respectively. Accordingly, the 21 high and moderate appealing MOs could contribute to the NDC targets. It is concluded that MCA methodology proposed is a sound approach in prioritizing MOs.

Keywords: Nationally appropriate mitigation actions, Nationally determined contribution, Marginal abatement cost, Multi-criteria analysis, Sustainability assessment

1. Introduction
Sri Lanka has demonstrated its commitment to support the global efforts on addressing climate change issues through publishing nationally determined contributions (NDCs), though national per capita greenhouse gas (GHG) emission is relatively low (1.1 t CO$_2$/year) compared to global average (4.8 t CO$_2$/year) [1]. The main drivers for the NDCs are not only resided with the global agendas, but also strongly associated with wide-ranging co-benefits in the local perspective, providing the pathway to sustainable development. In particular, the government has given high priority for mainstreaming both
renewable energy (RE) utilization and energy efficiency (EE) improvements across all the sectors of energy. These national priorities, in fact, paved the foundation for the development of NDCs [2].

The national initiatives highlighted above related to energy and environment sectors have been received assistance from global organizations through various programmes. In one such flagship project, GHG mitigation options (MOs) referred to as Nationally Appropriate Mitigation Actions (NAMAs) in the energy sector has been identified and prioritized based on marginal abatement cost (MAC) analysis [3]. Although MAC analysis is a leading tool to prioritize MOs [4], there are concerns regarding the inability to consider the potential barriers for implementation as well as other benefits and drivers (beyond GHG emission reduction benefits) in the prioritization process [5]. The absence of a methodology for such multi-criteria assessment (MCA) of MOs to support decision making has become a hindering factor for the practical implementation NAMAs and thus the realization of NDCs. The main objectives of this research study were to establish criteria and indicators for the assessment of MOs and to develop an MCA framework to prioritize NAMAs in the energy sector.

2. Nationally determined contributions in the energy sector

2.1. An overview of energy sector in Sri Lanka

Conventionally main sources of energy in Sri Lanka have been dominated by RE, particularly biomass for thermal energy applications and large hydro for electricity generation. However, during last few decades, with the increase in energy demand and limited development in the RE sector, the demand for fossil fuels, particularly oil for transport sector and coal for power sector has increased significantly. In 2017, the primary energy supply by source was reported as 43.9% petroleum oil, 10.8% coal, 36.5% biomass, 5.8% large hydro and the balance 3.1% new renewable energy (NRE) sources that include small hydro, solar, wind and modern biomass. Meanwhile the gross electricity generation by source on the same year was contributed by 34.1% coal, 20.5% large hydro, 34.7% oil, 9.8% NRE sources and balance 0.9% micro-power producers [6]. These data signify the major contribution of fossil fuels in the energy sector. As the fossil fuel supply is entirely dependent on importation, the energy sector has impacted adversely upon the balance of trade in the country.

The steady increase in the use of fossil fuel has been a key concern in the energy sector, not only due to the drain of foreign reserves for importation but also due to adverse impacts on environment, both urban air pollution at local level and climate change associated with GHG emissions at global level. Accordingly, the Government of Sri Lanka has taken a series of interventions in the areas of policies, regulations, and action plans in the energy and environment sectors. One such key policy intervention is related to the national commitments for global efforts in combatting climate change issue arisen from GHG emissions, which highlights the country’s anticipation of achieving the development objectives while moving in a low carbon development pathway. Sri Lanka, as with other member countries of United Nations Framework Convention on Climate Change, prepared NDCs covering the key areas of mitigation, adaptation, loss & damage and means of implementation, which was submitted in September 2016 [2]. In the area of mitigation, the energy sector is expected to make the major contribution, as detailed in the next section.

2.2. Greenhouse gas mitigation targets

In NDCs of Sri Lanka, five sectors, namely energy (electricity generation), transport, industry, forests and waste, have been identified under mitigation sector. The overall targets of reducing GHG emissions are 20% in the energy sector, while 10% in the remaining four sectors during the implementation period of 2020 to 2030. The total reduction target in the energy sector during the 10-year period is 39.38 Mt CO₂ (9.17 Mt unconditional and 30.21 Mt conditional), for which seven key intervention areas were identified, covering RE developments (including solar, wind, hydro and biomass), electricity demand side management (DSM) and converting oil-fired plants to liquefied natural gas (LNG). Further, development of policies for enhancing RE contribution in the power sector is also highlighted [2].
In line with NDCs, the government has prepared a Readiness Plan 2017-2019 for the implementation of chosen NDCs, as a host of groundwork and preparations need to be carried out to ensure successful implementation and to achieve the set targets by 2030. There are sixty four specific actions identified together with responsible agencies, output indicators and timeline [7]. Subsequently, the government has facilitated a project to identify and prioritize specific NAMAs (which is the implementation modality of NDCs) in the energy sector [3]. There are total of fifty two MOs identified through a comprehensive stakeholder consultation process, among which there are twenty three energy supply options (twenty two RE and one LNG) and twenty seven end-use EE options, with a total mitigation potential of 7.5 Mt CO$_2$/year (which is well above the NDC target of 3.94 Mt CO$_2$/year). For each option, the MAC value, which represents the cost of reducing one unit of GHG relative to a BAU case (expressed by US$/t-CO$_2$) and annual GHG abatement potential (expressed by t-CO$_2$/year) are estimated. The results of all the options are presented graphically in marginal abatement cost curve (MACC), which illustrates GHG abatement costs of various abatement options as a function of cumulative GHG abatement potentials, in ascending order of cost-effectiveness, which varies from -284.9 US$/t-CO$_2$ (for a the case of replacing CFL lamps with LED lamps) to 18,387.3 US$/t-CO$_2$ (for the case of installing new biogas digester of capacity 8 to 20 m$^3$) [8].

2.3. Implementation of mitigation options

Cost effectiveness of GHG mitigation, as indicated by MACs of NAMAs, provides a sound base for prioritizing the MOs identified in energy sector. In addition to the MACs, the mitigation potentials should also be a prioritizing criterion as the final target of implementation of NAMAs is the total GHG mitigated during 2020-2030 period. In overall, these two parameters represent impacts of implementation of mitigation option. Yet, it is apparent that the feasibility of implementation would be affected by many other aspects such as barriers, government priorities, co-benefits (such as social, local environment, local economy), level of commercialization of the associated technologies, etc. that the importance of the MOs has to be evaluated in a broader context involving multiple criteria than merely carbon benefits. Above notions provided the basis for the methodology used in the present study for the prioritization of NAMAs in the energy sector, particularly to assist the decision makers for selecting MOs for implementation.

3. Materials and method

3.1. Overall methodology

As the NDCs are evolved around the broader objective of sustainable development, the driving factors and governing parameters of MOs identified involve criteria and indicators related to the three facets of sustainability, namely social, economic and environmental. Therefore, the evaluation of MOs would be better materialized by a sustainability assessment methodology. A variety of sustainability assessment tools has been developed and exists in practice for different purposes [9]. One such tool that has received commendation internationally referred to as sustainability assessment of technology (SAT) methodology is used in the present study. This methodology is based on the principle of integrating sustainability concepts in technology assessment. It uses an evolving assessment process involving three stages as screening, scoping and detailed assessment. Further, it incorporates assessments at both strategic level and operational level, thereby allowing its usage by different actors at different decision making levels [10]. The figure 1 illustrate the framework of the overall methodology proposed for the evaluation, prioritization and implementation of MOs.

Due to the presence of variety of criteria and indicators affecting the relative importance of MOs and the comprehensiveness of SAT methodology, decisions have to be taken in a well-defined, consistent and logical way and multi-criteria assessment (MCA) methodologies can contribute to such objective. A wide range of sustainability assessment methods and tools have been over the past decades, with special focus on MCA [11]. In the present analysis, two of the tools, namely weighted sum model (WSM) and analytic hierarchy process (AHP), were used.
3.2. Scope and main steps

The scope of work presented in this paper includes the stages up to prioritization of MOs of the overall methodology presented in Figure 1 above. Accordingly, the strategic and operational level assessments are carried out in three steps, for the selection of preferred options for implementation, as given below:

Step 1- Pre-screening: A grading system for practicability is introduced for pre-screening of MOs at strategic level. Here, the objective is to reduce the number of NAMAs to a manageable level for more comprehensive assessment, by eliminating the ones having more risks of implementation due to low maturity of the technology and lack of sufficient data to develop specific projects. The grading system used in each criterion is in three levels as high, medium and low, and the options receiving no low grading for both criteria are selected for the next stage of assessment.

Step 2- Screening: This level of assessment at operational level uses quantitative results derived in MAC analysis, namely MACs in US$ t CO2e and the GHG mitigation potentials in t CO2e, by introducing 0 to 5 score system, with linear variations between benchmarks, to normalize the amounts in each indicator and combining with equal weights derive an overall score (referred to as MACC score). This overall parameter represents the effectiveness of GHG mitigation. Here the qualifying score is taken as greater than 1.0.

Step 3- Scoping: The scoping level assessment is introduced to consider the aspects beyond those considered in MAC analysis. There are two main aspects considered in this level of assessment. Firstly, a detailed barriers analysis is undertaken to establish the level of difficulty in implementing selected MOs (which primarily represents the efforts required for implementation). Secondly, the national priority given to each mitigation option is considered as the enabler that could improve the efforts of implementation. Thirdly, co-benefits (such as local environmental and socio-economic benefits) are considered as a mean of incorporating sustainability aspects in technology selection. The overall scoring of the scoping analysis (referred to as MCA score) is estimated in 0 to 5 score system, combining the scores derived in the analyses of barriers (with and without the national priorities) and co-benefits with equal weights.
4. Result and analysis

4.1. Pre-screening assessment
Based on the feedback of the stakeholders, together with the grading system and selection criteria presented in Section 3 above, MOs identified are graded under the two criteria as the technology maturity and the information availability. Among fifty-two MOs, thirty-eight were able to receive grading of high or medium for both criteria and thus qualify for the next level of assessment. These options include eighteen energy supply options (seventeen RE and one LNG) and twenty end-use EE options, with a total mitigation potential of about 6.30 Mt CO$_2$/year.

4.2. Screening assessment
In this stage, a score in 0 to 5 scale is assigned to each of the two indicators in MACC analysis, namely MAC and GHG abatement potential to derive the overall MACC score through equal weights for each of the thirty-eight MOs qualified through pre-screening. The results show that the MACC score varies from 0.0 to 5.0, covering the full spectrum. With a qualifying score of 1.0, thirty-one MOs are selected for the next level of assessment. The options qualified for the final evaluation include fifteen energy supply options (fourteen RE and one LNG) and sixteen end-use EE options, with a total mitigation potential of about 6.23 Mt CO$_2$/year.

4.3. Scoping assessment
At the final stage, MCA assessment is undertaken by considering three distinct aspects, namely barriers and enablers reflecting the efforts for the implementation, and the co-benefits reflecting impacts of implementation. In barrier analysis, six barrier categories were considered in analysis each mitigation option, namely technical, financial/market, policy/regulatory/institutional, information/education/capacity, social/behavioural, and environmental. The total score for a given mitigation option is estimated by multiplying the scores by weights of each barrier category derived by AHP methodology. This score represents the level of efforts/challenge required to remove the barriers. Further, national priority is considered as another factor that could influence the efforts required to implement a given mitigation option. Finally, under co-benefits, two criteria are selected that represent the local environment benefits and socio-economic benefits. The combined scores of these criteria give the overall MCA score. The results show that the MCA score varies from 2.2 to 3.9 (out of 5.0).

4.4. Prioritization of mitigation options

Figure 2. Prioritization of MOs in the energy sector based on MACC and MCA scores
The prioritization of MOs is done based on the overall MACC and MCA scores derived through SAT methodology. The MACC and MCA scores are considered as two dimensions of the characteristics of the MOs. Accordingly, they are not combined to derive a single score, but use in conjunction and ranges are defined in each for prioritization. MOs are grouped into three appealing groups as highly (H), moderately (M) and least (L), based on the two set of scores, as illustrated in Figure 2. There are 07 options in H category, 14 options in M category and 10 options in L category with total mitigation potentials of 1.71, 3.24 and 1.28 Mt CO₂/yr, respectively. The H and L categories collectively have mitigation potential of 4.95 Mt CO₂/yr, thus could contribute to the NDC target of 3.94 Mt CO₂/yr.

5. Conclusions
The applicability of the results of MAC analysis could be broaden by incorporating other decisive factors such as barriers, enablers, and co-benefits. SAT methodology and MCA used in the present study provides a sound basis for evaluation and prioritization of mitigation options by incorporating criteria and indicators to capture the characteristics in the broader context of sustainability. The final results highlight that, among the 52 MOs identified in NAMAs in the energy sector, the 07 highly appealing and 14 moderately appealing ones, as defined through the present methodology, could collectively contribute to the sectoral target of 3.94 Mt CO₂/yr. The overall methodology proposed in the study could be used further to assist the implementation of the prioritized mitigation options to assure the final GHG mitigation targets are attained during the 2020-2030 period.

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