CLEAN DEVELOPMENT MECHANISM

CDM-MP67-A20

Information note

Analysis and proposals on the revision of “Tool to calculate emission factor of electricity system”

Version 01.0

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1. Procedural Background

1. The Board at its eighty-first meeting, paragraph 83 (hereinafter referred to as EB81) requested the Methodologies Panel (Meth Panel) to consider the possibility of revising the “Tool to calculate emission factor of electricity system”[1] (herein after grid tool) while considering the following aspects:

   (a) The option of the simplified combined margin emission factor is applicable to least developed countries (LDCs), Small Island developing States (SIDS) or countries with fewer than 10 registered CDM projects at the starting date of validation (underrepresented countries, URCs) subject to the condition that the relevant data requirements to calculate the build margin cannot be met. The Meth Panel is requested to explain the rationale for limiting the tool to LDCs/SIDS/URCs and may explore whether it is possible to consider the broadening of the application of this option for other countries than those mentioned above;

   (b) The broadening of the applicability of this option of the simplified combined margin emission factor can be considered for isolated grids in any country. Furthermore, the Board requested the Meth Panel to explain if the emission factor tool is suitable to be applicable to isolated systems (i.e. single isolated versus group of two or more isolated systems).

2. In addition, EB81 requested the Meth Panel to analyse if "AM0104: Interconnection of electricity grids in countries with economic merit order dispatch" is applicable to actual projects without further clarifications or modifications.

3. Further, the Board at its eighty-third meeting, paragraph 45 (hereinafter referred as EB 83,) requested the Meth Panel to recommend a revision to grid tool addressing issues contained in the report of the sixty-sixth meeting of the Meth Panel at paragraph 19, in addition to the issues contained in the EB81 report paragraph 83, and to recommend the revised methodological tool to the Board for its consideration at a future meeting. The paragraph 19 of MP66 is reproduced below:

   “The Meth Panel recommended that the Board take note that it initiated work to address the mandate from the Board at EB 81 and EB 82 (Appendix 8; MAP project 223) on: i) the possibility of revising the “Tool to calculate the emission factor for an electricity system” (grid tool) for broadening the application of simplified combined margin (CM) option for grid/isolated systems also in countries that are not least developed countries/small island developing States/underrepresented countries; and ii) applicability of “AM0104: Interconnection of electricity grids in countries with economic merit order dispatch” to actual projects. Based on the work done on this mandate as well as the analysis carried out under the work stream related to standardized baselines (SBs), the Meth Panel agreed to request the Board to provide an additional mandate to expand the scope of the revision of the grid tool covering the following aspects, which will further enhance user-friendliness and provide more options for estimating emission factors:

[1] Available at: <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v4.0.pdf>.

(a) Project and SB assessment experience shows that the application of Simple Adjusted Operating Margin has not been consistent across projects. Therefore, the work will further clarify the procedure to determine the percentage of time when low-cost/must-run power units are on the operating margin (OM) (with illustrative diagrams) under the Simple Adjusted Operating Margin;

(b) Currently, the criteria for exclusion/inclusion of renewable energy plants for determining operating margin are based on the threshold of 50 per cent. Preliminary analysis shows that in some cases the threshold rule might not hold. The proposed work will further simplify the procedure by making it more precise as to how to consider inclusion/exclusion of low-cost/must-run plants for determining the operating margin;

(c) The work will explore providing an alternative option to determine the build margin emission factor taking into account past deviation requests approved by the Board. This will facilitate the determination of the build margin emission factor for cases where data for fuel consumption and electricity generation by each plant type are not readily available;

(d) During the assessment of some standardized baselines, the limitation of the grid tool was noted with regard to the definition of ‘connected electricity system’. For example in cases where no delineation of the grid has been provided by the DNA and no transmission constraint exists between importing and exporting electricity systems as defined in the tool, then the electricity systems together constitute a single electricity system. This makes the tool inapplicable to countries where electricity exchange with neighbouring countries exceeds the threshold and where neighbouring countries are reluctant to develop the common grid emission factor. The work will explore providing flexibility to DNAs for defining delineation of ‘connected electricity systems’;

(e) Stakeholders have communicated that they have experienced difficulty in determining the grid emission factor when off-grid plants are included. The work will explore further simplification of the relevant procedure;

(f) Project and SB assessment experience shows that the simplified provisions included in the grid tool are sometimes not visible and its application is not clear. The revision will aim to provide flow charts on the application of the grid tool with systematic illustrations of provisions (e.g. simplified provisions for off-grid default values, simplified OM, simplified CM option, etc.).”

2. Purpose

4. This document aims to inform the approaches taken for the revision of the tool to systematically address mandates received from the Board as mentioned above. The Meth Panel at its sixty-seventh meeting agreed to seek a public input but not limited to the proposals/recommendations contained in this document, among others, broadening the application of simplified combined margin emission factor and alternative procedure to include/exclude low cost/must-run power units to determine operation margin are the main focus.

5. After receiving public input on the document, the Meth Panel will continue working on the revision of the tool at its 68th meeting with an aim to recommend to the Board at a future meeting.

3. Key Issues and proposed solutions

3.1. Issue 1: Application of the simplified combined margin emission factor

6. EB 81 requested the Meth Panel to explain the rationale for limiting the provision of the simplified combined margin option in the tool to LDCs/SIDs/URCs and may explore whether it is possible to consider the broadening of the application of this option for other countries than those mentioned above.

7. The option of the simplified combined margin emission factor (CM EF) was introduced in the grid tool at EB 61 in response to the CMP request (decision 2/CMP.5, paragraph 34) to “further improve the “Tool to calculate the emission factor for an electricity system” for project activities hosted in countries with a paucity of relevant data, including by providing flexibility for the calculation of grid emission factors”[2].

3.1.1. Analysis and proposed solutions to Issue 1

8. The procedure to determine grid emission factor provided in the grid tool uses the combined margin (CM) approach which takes into account the effect of proposed CDM project (e.g., electricity production from a renewable or grid electricity displacement through demand side energy efficiency improvement) on existing marginal projects (operating margin (OM)) as well as future projects (build margin (BM)) together constituting avoided generation due to CDM project.

9. Appendix 1 provides a brief concept on Operating margin (OM), Build Margin (BM) and CM emission factors.

10. OM emission factor: is determined using one the following methods:

(a) Dispatch data Analysis: It calculates OM on an hourly basis using actual dispatch data ex post and applying it to the time-varying output of a CDM project;

(b) Simple OM (SOM): This is based the generation-weighted average CO2 emissions per unit net electricity generation (gCO2 per kWh based on 3 years average data or using annual data based on monitoring ex post) of all generating power plants serving the system, not including low-cost/must-run (LCMR) power plants/units (e.g., renewables). It is only to be used when low cost/must run resources constitute less than 50 per cent of the total grid generation;

(c) Adjusted simple OM (ASOM): The simple adjusted OM is a variation of SOM, where the power plants are separated into LCMR resources and other power sources, and a factor expressing the percentage of time when LCMR sources are on the margin is defined;

(d) Average OM (AOM): This is the weighted average CO2 emissions factor (gCO2 per kWh based on 3 years average data or using annual data based on

[2] See at <http://unfccc.int/resource/docs/2009/cmp5/eng/21a01.pdf>.

monitoring ex post) of for all electricity generation serving the system. This emissions factor includes low cost/must run resources. This methodology is considered appropriate and conservative when data is not available to calculate SOM or ASOM.

11. BM emission factor: It is determined using simple OM approach but based on the 5 (or more) most recent plants (excluding CDM) that together comprise at least 20 percent of the average electricity generation. Only the data that is required to determine BM in addition to one that is required to determine OM is the dates of commissioning of the power plants serving the grid system.

12. CM emission factor is the result of a weighted average of operating margin (OM) and the build margin (BM) emission factors. The following default values[3] are prescribed in the grid tool:

    (a) 0.75 x OM and 0.25 X BM, for intermittent, non-dispatchable generation, such as wind, solar and some hydropower for the first and subsequent crediting periods;

    (b) 0.5 x OM and 0.5 x BM, for all other projects, in the first crediting period, and 0.25 x OM and 0.75 x BM, for the second and third crediting periods.

13. In the case where it is demonstrated that data requirement to determine the build margin cannot be met CM equals to 100 per cent OM and OM is calculated using AOM method. This option is currently limited to the projects that are implemented in Least Developed Countries (LDCs) or Small Island developing States (SIDs) or in countries that had 10 or fewer registered CDM project activities as of 31 December 2010 (namely, underrepresented countries (URCs)).

14. The flowchart diagram in Appendix 2 also illustrates determination of grid emission factors (OM, BM and CM) based on the level of data availability

15. The rationale for limiting the provision of the simplified combined margin to LDCs/SIDs/URCs are as follows:

    (a) In response to CMP request (decision 2/CMP.5, paragraph 34) to further improve the grid tool for project activities hosted in countries with a paucity of relevant data, the meth panel in 2011 carried out survey of 125 DNAs and did not identify paucity of data as an issue in general but few DNAs from LDCs/URCs communicated that data to determine BM would be difficult (e.g. commissioning dates);

    (b) The meth panel at its forty-ninth took into account the survey mentioned above on data paucity and the fact that LDCs/SIDs can be characterized with relatively small power systems, likelihood of underinvestment or where construction of power plants is less likely to happen in the recent past. Thus, for LDCs/SIDs/URCs, where BM data is not available, AOM alone was considered as a proxy to CM emission factor and BM is assumed to be implicit/embodied in AOM itself. The panel recommended the simplified combined margin option restricted to LDCs/SIDs/URCs;

[3] The project participants can submit proposals for alternative weighting.

(c) The meth panel also noted that simplified small scale methodologies such as AMS-I.D which is for grid connected renewable power generation projects, provide option to calculate average grid emission factor using AOM method alone which is similar to simplified CM;

(d) It is found in the past that the deviation procedure was used where BM data requirement of the tool was not met and the Board approved alternative method to determine BM applicable for projects in the specific country[4].

16. Analysis show there are more than 6500 registered projects that have applied grid emission factor[5]. It is found that <u>only 3 countries so far have used simplified CM option</u> (2 LDCs, 1 URC) and no SBs from eligible countries have used this option.

17. This implies that the application of the simplified CM option is limited i.e., calculation of GEFs in LDCs/SIDs/URCs by and large is based on weighted average CM (i.e., weighted average of OM and BM) which may imply that:

(a) BM data is generally available. This may be due to the reason that the determination of BM is indeed straightforward because it can be derived using OM data (i.e., annual data from each power plant on electricity generation and fuel type or fuel consumption. Only additional data that is required to determine BM in addition to one that is required to determine OM is the dates of commissioning of the power plants serving the grid system; and/or

(b) Application of simplified CM, which is AOM is too conservative though this is not evident.

18. On the other hand, the analysis also shows that that only 70 LDCs/SIDs/URCs out of 192 (i.e., one third) so far have CDM projects that have applied grid emission factors (GEFs) (see footnote 5). Thus, taking into account the potential use of grid emission factors in remaining countries of LDCs/SIDs/URCs the application of simplified CM option in future may not be undermined.

19. Thus, in response to EB 81 mandate on broadening the application of the simplified CM option for other countries than LDCs/SIDs/URCs, the meth panel considered the following two options :

(a) **Option 1:** Retain the current provision of the simplified CM options (do nothing) because of the reasons below:

(i) BM data is generally available;

(ii) Application of simplified CM option so far is quite limited;

(iii) Deviation procedure is available to request for adjusting provisions of the grid tool taking into account specific situations of grid system;

[4] See at: <http://cdm.unfccc.int/UserManagement/FileStorage/AM_CLAR_QEJWJEF3CFBP1OZAK6V5YXPQKK7WYJ>.

[5] See at: <http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136>.

(iv) It is not evident that simplified CM always lead to conservative grid emission factor;

(v) Taking into account the above, broadening the application of current simplified CM option for countries other than LDCs/SIDs/URCs may increase the risk of environmental integrity.

(b) **Option 2:** For countries other than LDCs/SIDs/URCs, where data requirement to determine BM cannot be met, the current simplified CM is not applicable however the conservative default BM emission factor based on the best available technology (BAT) is proposed for the calculation of weighted average CM[6]. For countries/regions where natural gas is available and where at least 80 per cent of the power installed capacity is based on fossil fuel sources, default of 0.326 t CO_2/MWh (CCGT) is proposed. It is assumed in these countries/regions, natural gas plants are the prospective power plants whose construction/future operation (BM) would be affected by CDM projects. Similarly, for countries/regions where gas is not available and where at least 80 per cent of the installed capacity is based on fossil fuel sources, default 0.568 tCO_2/MWh (oil fired combined cycle) is proposed as conservative default BM emission factor[7].

20. Further, analysis is conducted to examine how many countries would be eligible to apply the proposed option 2 above; it is found that about 11 countries may possibly apply this option in the case the requirement to determine BM data is not met. See Appendix 3.

21. The meth panel also considered alternative method of determining BM EF where specific data on electricity generation by plant type is not available. The Board provided the guidance[8] in request to deviation request for the purpose of determining BM in the case of a specific host country where electricity generation data by plant-type is not available. This approach has been used across all gird connected CDM registered projects in the host country:

(a) Use of capacity additions during last 1 - 3 years for estimating the build margin emission factor for grid electricity;

(b) Use of weights estimated using installed capacity in place of annual electricity generation;

(c) Use the efficiency level of the best technology commercially available in the provincial/regional or national grid of the host country, as a conservative proxy, for each fuel type in estimating the fuel consumption to estimate the build margin (BM).

22. The approach from the approved deviation request mentioned above though in principle can also be expanded for countries other than LDCs/SIDs/URCs for determining BM

[6] The default weights of w_{OM} and w_{BM} shall be the same as those currently prescribed in the tool as indicated under paragraph 12 above.

[7] The default emission factors of gas and oil fired combined cycle power plants are derived based on highest efficiency values prescribed under Appendix 1 of the grid tool.

[8] <http://cdm.unfccc.int/UserManagement/FileStorage/AM_CLAR_QEJWJEF3CFBP1OZAK6V5YXPQKK7WYJ>.

where electricity generation data by plant type is not available, it is not evident that the application of the approach might not bring simplicity but to some extent a flexibility to determine BM. The approach is still data demanding (data on capacity addition, efficiency level of the best technology commercially available in the provincial/regional or national grid of the host country etc. The meth panel considers that a further clarification would be provided in the tool that the deviation request on the application of the grid tool approved by the Board for one country can be used by other countries, if applicable.

3.1.2. Recommendation to Issue 1 (Application of simplified CM)

23. The meth panel recommends option 2 and the following default BM EF values for countries other than LDCs/SIDs/URCs, where data requirement to determine BM cannot be met

(a) **Case 1:** If the share of renewable energy in total installed capacity in a grid/project electricity system is less than or equal to 20 per cent take the default values of:

$EF_{grid,BM,y}$= 0.326 tCO2/MWh (NG-fired CCGT, based on best available technology) - if natural gas is previously used for electricity production in country/region in which project is implemented;

$EF_{grid,BM,y}$ = 0.568 tCO2/MWh (oil-fired CCGT based on best available technology) - if natural gas is not previously used for electricity production in country/region in which project is implemented.

(b) **Case 2:** If share of renewable energy in total installed capacity in a grid/project electricity system is more than or equal to 20 per cent, take the default values for BM emission factor as zero;

Note: This option 2 also forms the part of recommendation under Issue 2 (b), see section 3.2.4 below.

3.2. Issue 2: Eligibility of the grid tool to isolated grid/systems

24. EB 81 requested the Meth Panel:

(a) To explain if the grid tool is suitable to be applicable to isolated systems (i.e. single isolated versus group of two or more isolated systems);

(b) To consider the broadening of the applicability of the simplified CM option for isolated grids in any country.

3.2.1. Analysis and proposed solutions to Issue 2 (a) – applicability of grid tool to isolated grid/system

25. To assess whether the grid tool is applicable to isolated systems (i.e. single isolated versus group of two or more isolated systems), firstly the provisions of the following large scale methodologies that are applicable to isolated grid/systems are analysed:

(a) AM0104” Interconnection of electricity grids in countries with economic merit order dispatch”;

(b) AM0045 “Grid connection of isolated electricity system”;

(c) AM0103 "Renewable energy power generation in isolated grids".

26. Analysis shows that:

(a) Under AM0045, which is for the expansion of an interconnected electricity grid to isolated systems through construction of new transmission line(s), it has strict applicability conditions to ensure that project would displace 100 per cent fossil fuel fired plants and electricity from renewable energy plants is not displaced. It thus uses weighted average emission factor of fossil fuel plants displaced. The grid tool is not applied;

(b) AM0104 in terms of project activity is similar to AM0045. However, the evaluation of impact in the isolated grid due to CDM project is determined by the weighted average CM approach using the grid tool. Thus, it is not needed to demonstrate (unlike in AM0045) that the project displaces 100 per cent fossil fuel fired plants and electricity from renewable energy plants is not displaced. However, the total installed power capacity in the previously isolated grid shall be less than 10 per cent of the total installed power capacity in the main grid prior to project implementation;

(c) In the case of AM0103, which is for power generation using renewable energy sources connected to a new or an existing isolated grid, simplified option with default emission factor values for isolated grid/system are introduced in the methodology instead of referring to the grid tool. Unlike the case in AM0104 and AM0045, the project activity here is renewable and the isolated system should be predominantly fossil fuel;

(d) Across these methodologies, "Isolated grid/system" is inferred as a grid that has no interconnection with any grid prior to the implementation of the project activity.

27. The above implies that different applicable methodologies have different approaches to determine baseline emission factor of isolated gird/system depends upon project types and the characteristics of isolated grid/system. A simple method requires rigour applicability criteria and vice versa. However, only AM0104 refers to the grid tool for determination of baseline emission factor of isolated grid/system.

28. The following is the assessment whether the application of the tool is compatible to isolated grid/system covered under AM0104:

(a) The project applying AM0104 involves construction of transmission line to interconnect existing main grid with existing isolated grid. Also, the baseline scenario defined in the methodology is the continuation of the current situation that is no interconnection is constructed and electricity demand of the isolated grid is met by power units connected to the isolated grid. The power exchange between the main grid and isolated grid is not expected i.e., after implementation of the project activity, the interconnection line is used to deliver electricity from the main grid to the previously isolated grid;

(b) Hence, the displacement of electricity generation in isolated/grid system due to the electricity supply from the main grid was considered as similar to the displacement effect in a “grid/project electricity system”[9] due to the introduction of a new power plant which is evaluated by the grid tool through OM and BM effect.

3.2.2. Recommendation to Issue 2 (a)

29. The meth panel is of a view that the current provision of grid tool in general is compatible to determine emission factor of any grid system as long as it complies with the relevant definitions provided under the grid tool (see for example footnote 9).

3.2.3. Analysis and proposed solutions to Issue 2 (b) – simplified CM option for isolated grids in any country

30. The above analysis also infers that the evaluation of impact of a CDM project in isolated grid/system using CM approach has no difference than the evaluation of impact of a CDM project in a national/interconnected grid system. In other words isolated grid/system can also be as large/complex as national/interconnected grid.

    (a) AM0104 is limited to isolated grid with installed power capacity less than 10 per cent of the total installed power capacity in the main/connecting grid. Table 1 Appendix 4 shows that 10 per cent of total installed capacity could constitute a fairly large system as compared to total installed capacity in many countries;

    (b) The isolated grid/system defined under AM0104 could correspond to relatively large non-interconnected system and can be as complex as interconnected system, unlike off-grid system defined in the tool and elsewhere in small scale methodologies. The non-interconnected system could have access to similar technologies that are implemented in the interconnected system in the host country;

    (c) An isolated grid system of an advanced developing country would not necessarily be comparable to system in LDCs/SIDs and hence provision of simplified CM currently limited to LDCs/SIDs may not be desirable to be expanded to isolated grid/system solely on this basis.

3.2.4. Recommendation to Issue 2 (b)- simplified CM option for isolated grids in any country

31. The meth panel considered not to expand the application of simplified CM (where BM data is not available) for isolated grid/system located in countries other than LDCs/SIDs/URCs

32. However option 2 proposed under the recommendation to issue 1 above (i.e., use of default BM EF) would accommodate AM0104 project in countries other than LDCs/SIDs/URCs where emission factor is determined as per the grid tool and data requirement to calculate BM cannot be met.

[9] **A grid/project electricity system** as per the grid tool is defined as the spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity and that can be dispatched without significant transmission constraints.

3.3. Issue 3: Applicability of AM0104 to actual projects

33. EB 81 requested the Meth Panel to analyse if AM0104 is applicable to actual projects without further clarifications or modifications.

3.3.1. Analysis and proposed solutions to Issue 3

34. Taking into account the fact that the mandate from the Board has been triggered during the consideration of the project 9051, the following is the assessment:

(a) The project applying AM0104 is applicable if all the requirements of the methodology as well as the requirements prescribed in the tools referred in the methodology are met. For example, the methodology refers to the tool to calculate baseline emission factor of isolated grid. In this case, all the provisions/requirement of the tool for the purpose shall also be followed/ met. Paragraph 4 of AM0104 states “In addition, the applicability conditions included in the tools referred to below apply”;

(b) In this context, the panel analysed the CDM pipeline project applying AM0104 and found only one project PA 9051. It is found that project does not meet the requirement of AM0104 in totality since it does not meet the current requirement of the tool:

(i) As required by the methodology, the grid emission factor of the previously isolated grid was calculated following the grid tool ver. 2.2.1. The PDD claimed that the option of simplified CM was used as the data requirements for step 5 (calculation of BM) cannot be met;

(ii) However, the grid tool states that the simplified CM method can only be used under the following two conditions: a) the project activity is located in a LDCs/SIDs/URCs and b) a requirement to determine BM cannot be met;

(iii) It is considered that the method of simplified CM is not applicable to the underlying project activity as the project is not located in LDC/SIDs/URC.

3.3.2. Recommendation to Issue 3

35. Recommendation to Issue 1 (paragraph 23) cover determination of CM emission factor for any countries, where data requirement to determine BM cannot be met.

3.4. Issue 4: Delineation of project electricity system and connected electricity systems by DNAs (EB 83 mandate, paragraph 45)

36. During the assessment of some SBs, the limitation of the grid tool was noted with regard to the definition of ‘connected electricity system’. For example in cases where no delineation of the grid has been provided by the DNA and no transmission constraint exists between importing and exporting electricity systems as defined in the tool, then the electricity systems together constitute a single electricity system. This makes the tool inapplicable to countries where electricity exchange with neighbouring countries exceeds the threshold and where neighbouring countries are reluctant to develop the common grid emission factor.

3.4.1. Analysis and proposed solutions to Issue 4

37. According to the grid tool, the transmission constraint or transmission capacity criteria are used to demarcate the two electricity systems- project and connected electricity system. Meaning that, if there is no transmission constraint between connected and project electricity system and/or if the transmission capacity of the transmission line connecting the two electricity systems is greater than 10 per cent of the installed capacity either of the project electricity system or of the connected electricity system, then the electricity systems together constitute a single electricity system.

38. Appendix 5 provides analysis of various scenarios with examples of two interconnected countries without having transmission constraints and shows potential implication of developing grid emissions factor for a single country without accounting another. It shows that delineation of the project electricity system leaving up to the DNAs by omitting other requirement of the grid tool regarding the boundaries in one case would lead to a very conservative emission factor and in another case the opposite.

39. For example in the case of countries intending to develop grid emission factor under standardized baseline framework and where electricity exchange with neighbouring countries exceeds the threshold, does not exhibit any transmission constraints and where neighbouring countries are reluctant to develop the common grid emission factor, the DNAs can submit deviation request[10] in the submission of proposed standardized baseline for the host country.

3.4.2. Recommendation to Issue 4

40. The meth panel is of the view that a generic rule to cover the issue will be difficult and thus agreed not to recommend revising the grid tool on this issue but handle the issue on case by case basis such as deviation request (see footnote 10).

3.5. Issue 5: Alternative approaches for inclusion/exclusion of low-cost/must-run power units, determination of lambda (λy)[11] (EB 83 mandate, paragraph 45)

41. The criteria for exclusion/inclusion of low-cost/must run resources (LCMR) for determining operating margin are currently based on the threshold of 50 per cent. However, analysis shows that in some cases the threshold rule might not hold i.e., even with the share of LCMR greater than 50 per cent, the LCMR sources are not appeared on the margin.

42. The grid tool provides different approaches for determining operating margin emission actor (OM EF). The shares of electricity generation from LCMR sources and data availability are factors that determine the choice of the approach.

[10] The revised procedure “Development, revision, clarification and update of standardized baselines “ that is coming into effect on 01 September 2015 now provides provisions for deviation request <http://cdm.unfccc.int/filestorage/e/x/t/extfile-20150603142041555-Meth_Proc07.pdf/Meth_Proc07.pdf?t=NjR8bnBuZXNofDA1ojT_UaaaNXbd32FkwKC->.

[11] Factor expressing the percentage of time when LCMR sources are on the margin.

43. In the case where the share of electricity generation from LCMR is greater than 50 per cent, three approaches are available to determine OM EF: Simple Adjusted OM (SAOM), Dispatch Analysis OM (DAOM) and Average OM (AOM).

44. SAOM and DAOM provide relatively precise emission factor for the purpose of the CDM, but require hourly data to be applied. On the other hand, AOM approach is less data intensive but would lead to too conservative emission factor for grid with predominant LCMR sources[12].

45. For grids with share of LCMR higher than 50 per cent, analysis of CDM pipeline projects and standardized baseline submissions show that that SAOM is the preferred choice. However, project and SB assessment experience shows that the application of SAOM has not been consistent across projects.

3.5.1. Analysis and proposed solution to Issue 5 (Alternative approaches for inclusion/exclusion of low-cost/must-run power units, determination of lambda (λy))

46. The proposed work will further simplify the procedure by making it more precise as to how to consider inclusion/exclusion of low-cost/must-run plants for determining the operating margin.

47. The simplified approach proposed below is under the framework of SAOM and provides:

(a) A more robust and universal criterion to exclude LCMR sources for the estimation of OM EF;

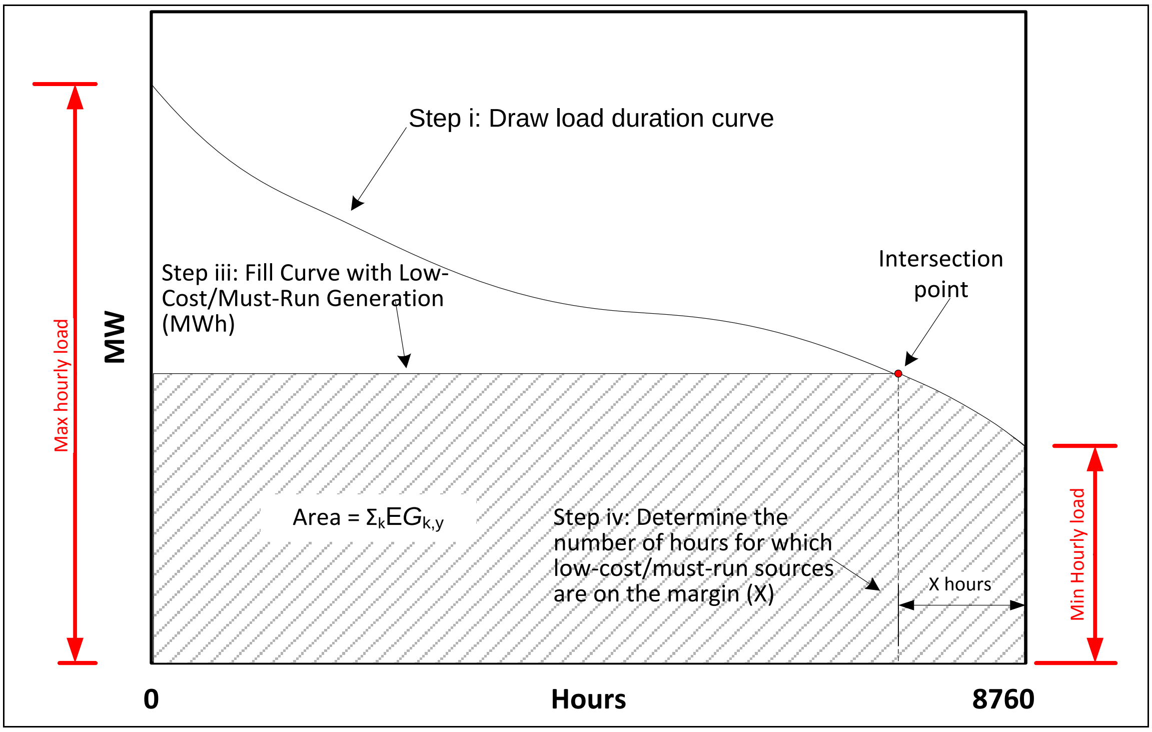
(b) The set of conservative values of lambda replacing extensive data requirements for SAOM;

(c) An elaborated step-by- step procedure with corresponding illustrative diagrams has now been provided to determine lambda (λy) i.e., the percentage of time when LCMR units are on OM in year y.

48. For the SAOM, the grid tool requires lambda to be determined by constructing the load duration curve as shown in the figure 1 below.

[12] Appendix 1 provides a brief concept on SOM, SAOM, DAOM and AOM.

Figure 1. Construction of the load duration curve



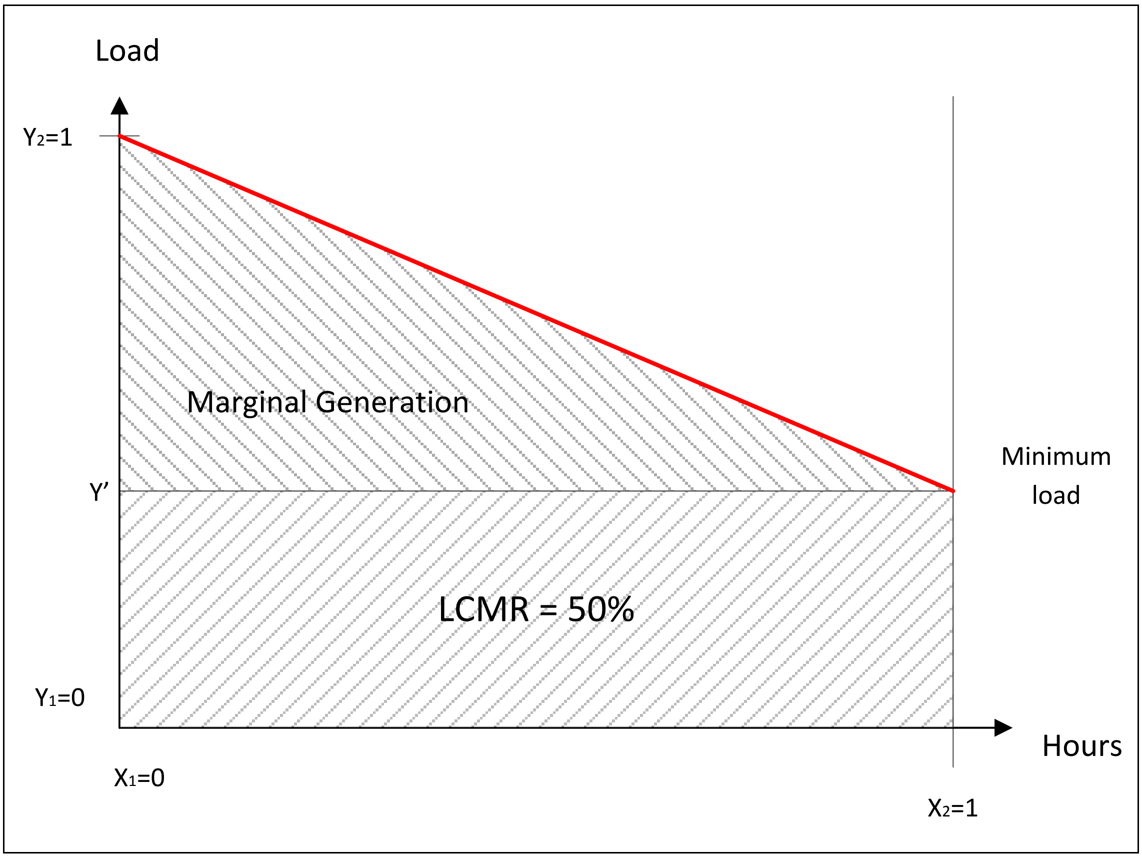
49. With reference to the figure 1, lambda equals to the number of hours (out of the total of 8760 hours) to the right of the intersection point over the total of 8760.

50. The grid tool assumes that if power generation from LCMR sources is less than 50 per cent, LCMR generation sources are not likely to be on the margin; lambda would equal to zero and LCMR can be excluded from the calculation.

51. Based on this assumption, the simplified linear load duration curve is built in a normalized way as presented in the figure 2 below[13].

13 The concept and the linear equations derived in this section are based on: Sharma S., Shrestha R.M., 2006. Baseline for electricity sector CDM projects: Simplifying estimation of operating margin emission factor. Energy Policy 34, 4093–4102.

Figure 2. Simplified linear load duration curve



52. To determine the point of the minimum load (Y’) for the case where LCMR constitutes 50 per cent but do not appear on the margin, the area under LCMR generation equals to the area under the generation from the marginal sources (figure 2). Therefore:

$$Y' \times X_2 = \frac{(Y_2 - Y') \times X_2}{2} \rightarrow Y' = \frac{(Y_2 - Y')}{2} \rightarrow Y' + \frac{Y'}{2} = \frac{Y_2}{2} \rightarrow 3Y' = Y_2 \rightarrow \boldsymbol{Y' = 0.33Y_2}$$

53. This implies that if the minimum system load is equal to or greater than one third of maximum system load, LCMR will not appear on the margin if they contribute less than 50 per cent of the total generation.

54. For the cases where the ‘‘minimum system load’’ is greater than one-third of the maximum system load and the LCMR source is possibly on the margin, the conservative default values of lambda corresponding to shares of the LCMR are proposed based on the following model.

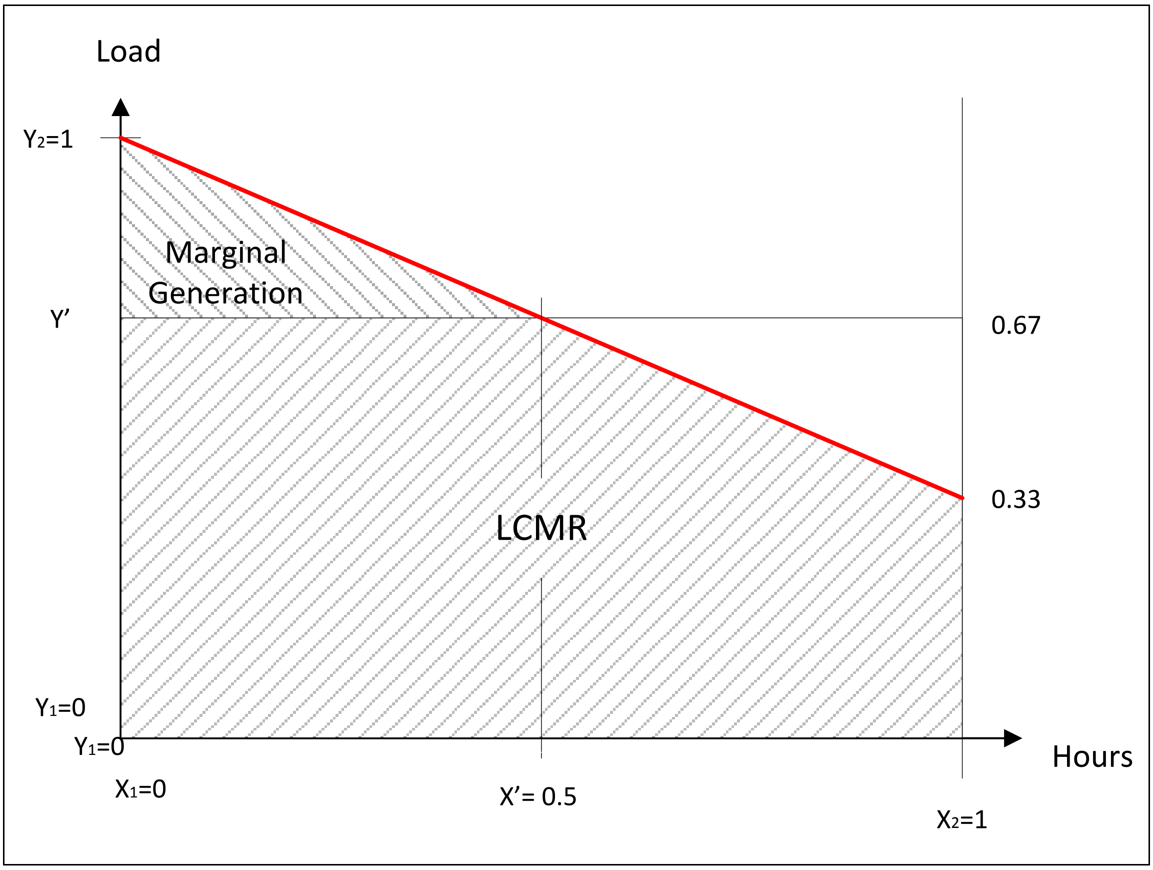
55. The function of linear simplified load duration curve from the figure above is expressed by the following equation:

$$y = 1 - 0.67 \times x$$

56. By using this function, the values of lambda and the share of LCMR generation are derived as it is illustrated by an example (see figure 3 below).

57. Here lambda is set to 0.5.

Figure 3. Lambda and the share of LCMR generation



58. The area covered by the LCMR sources, and the area covered by total generation are determined by applying the following equations:

$$Y' = 1 - 0.67 \times X' \ \rightarrow Y' = 1 - 0.67 \times 0.5 \ \rightarrow \boldsymbol{Y' = 0.67}$$

$$LCMR_{area} = (0.67 - y_1) \times (x_2 - x_1) - \frac{(0.67 - 0.33) \times (x_2 - 0.5)}{2} = 0.581$$

$$Total\ generation_{\ area} = (x_2 - x_1) \times (0.33 - y_1) + \frac{(x_2 - x_1) \times (y_2 - 0.33)}{2} = 0.665$$

59. Therefore the LCMR share in total annual generation is:

$$\mathrm{LCMR_{share}} = \mathrm{LCMR_{area}} / \mathrm{Total\ generation}_{\ \mathrm{area}} = \frac{0.58}{0.67} = 87.41\%$$

60. Applying the approach illustrated in the example above, the set of x values (lambda) and corresponding LCMR shares (See Table 1 below) are determined. In other words, if share of LCMR generation is known hence the default Lambda value.

Table 1. Default lambda values

Share of LCMR	Lambda
100.00%	1
99.87%	0.95
99.50%	0.9
98.87%	0.85
97.98%	0.8
96.85%	0.75
95.47%	0.7
93.83%	0.65
91.94%	0.6
89.80%	0.55
87.41%	0.5
84.76%	0.45
81.86%	0.4
78.72%	0.35
75.32%	0.3
71.66%	0.25
67.76%	0.2
63.60%	0.15
59.20%	0.1
54.54%	0.05
0 to 50%	0

61. The table above however does not provide lambda values for the cases where LCMR shares would fall between set points. Therefore the values are expanded as shown in Table 2 below.

Table 2. Default lambda values for the range of LCMR shares

Share of LCMR	Lambda
99.87% to100.00%	1
99.50% to 99.87%	0.95
98.87% to 99.50%	0.9
97.98% to 98.87%	0.85
96.85% to 97.98%	0.8
95.47% to 96.85%	0.75
93.83% to 95.47%	0.7

Share of LCMR	Lambda
91.94% to 93.83%	0.65
89.80% to 91.94%	0.6
87.41% to 89.80%	0.55
84.76% to 87.41%	0.5
81.86% to 84.76%	0.45
78.72% to 81.86%	0.4
75.32% to 78.72%	0.35
71.66% to 75.32%	0.3
67.76% to 71.66%	0.25
63.60% to 67.76%	0.2
59.20% to 63.60%	0.15
54.54% to 59.20%	0.1
50% to 54.54%	0.05
0% to 50%	0

62. Conservativeness of the default values is demonstrated by the applying the same share of LCMR across different values of the ratio of minimum system load to maximum system load (See Table 3 below), i.e. different shapes of the load duration curve in order to determine lambda.

Table 3. Lambda values with different ratios of minimum to maximum load

ratio of minimum to maximum system load	LCMR share	Lambda
67%	87%	0.2
50%	87%	0.4
33%	87%	0.5
10%	87%	0.6

63. Thus, it can be seen from the table 3 above that if curve appears to be more flat than the default one, for example LCMR share of 87 per cent with minimum to maximum system load ratio of 67 per cent would result in lambda of 0.2. However if default value is applied to this case, it would be is 0.5, (which corresponds to the reference/default curve having min system load equals 1/3 of max load) which is conservative. It is to be noted that higher the value of lambda more conservative it would be in terms of OM emission factor.

64. The application of the default values proposed above is further tested with CDM registered projects that have applied SAOM. It is found that default value is conservative as compared to the actual values. Compare the last two columns in Table 4 below.

Table 4. Application of default values in registered CDM project

Country	CDM reference number	year	max hourly load, MW	min Hourly load, MW	Ratio of min to max load	LCMR share	λy	λy based on the proposed default value of for the same share of LCMR
Philippines	8532	2011	1297	514	39.63%	66.23%	0.0078	0.2
Colombia	3816	2008	9107	3854	42.32%	84.71%	0.31	0.45
Costa Rica	9343	2010	1522.8	566	37.20%	92.68%	0.534	0.65
Ecuador	9086	2010	2879	1212	42.11%	55.23%	0	0.1

65. Therefore the proposed approach can be applied to load duration curves where the ‘‘minimum system load’’ is not less than one-third of the maximum system load.

66. Another outcome is derived from the linear simplified load duration curve above. In some cases the actual load duration curve is more flat than the one considered above, i.e. the minimum load (Y’) is greater than one-third of the maximum load. LCMR sources would not always appear on the margin in these cases even if its share would be greater than 50 per cent. That was particularly observed for the project activity 9086 in Ecuador where the share of LCMR is 55 per cent, but lambda equals zero, because average generation provided by LCMR over the year is smaller than minimum grid load.

67. Therefore a more robust and universal criterion is to exclude LCMR sources from the estimation of EF for OM if average load supplied (MW) by LCMR sources ($\sum EG_{LCMR}/8760$) less than minimum system load. This rule is applicable if the data for minimum system load for the year is available.

3.5.2. Recommendation to Issue 5 (Alternative approaches for inclusion/exclusion of low-cost/must-run power units, determination of lambda (λy))

68. The meth panel considered to provide following criteria to exclude/include LCMR sources in the calculation of OM EF:

Step 1: Exclude LCMR and use simple OM if

(a) low-cost/must-run resources constitute less than 50 per cent of total grid generation (excluding electricity generated by off-grid power plants) in: 1) average of the five most recent years, or 2) based on long-term averages for hydroelectricity production; (current provisions) **or;**

(b) low-cost/must-run resources constitute more than 50 per cent of total grid generation (excluding electricity generated by off-grid power plants) but average load supplied by low-cost/must-run resources ($\sum EG_{LCMR}/8760$) supplied over the three most recent years is less than the average minimum system load of the grid over the three most recent years.

Step 2: If one of the criteria above doesn't satisfy, include LCMR and use SAOM

69. Two options are recommended to determine lambda (λ_y):

(a) λy shall be calculated using the step-wise procedure provided in Appendix 7. This procedure is the same as the one currently available in the grid tool for SAOM but it is now elaborated with illustrative diagrams **or;**

(b) Use default values of lambda (using Table 2 above) based on the share of electricity generation from low-cost/must-run in total generation derived using 1) average of the five most recent years, or 2) based on long-term averages for hydroelectricity production. Default value can only be applied if the ''minimum system load'' is <u>not less than one-third</u> of the "maximum system load" in a project electricity/ grid system demonstrated based on the three most recent years data.

3.6. Issue 6: Consideration of import as LCMR source

70. The meth panel noted that under SAOM, "import" is accounted as low-cost must run (LCMR) source while not under the simple SOM method.

3.6.1. Analysis and proposed solution to Issue 6

71. The grid tool defines "imports" as electricity transfers from a "connected electricity system" to a "project electricity system". Further, as per the definition of connected electricity system, electricity transfer from a "connected electricity system" to a "project electricity system" has a significant transmission constraint or limited transmission capacity. The "import" source thus may imply as a non-dispatchable source.

3.6.2. Recommendation to Issue 5

72. The meth panel thus recommends that "import" source to be treated as a LCMR source under both SAOM and SOM.

3.7. Issue 7: Illustration/further elaboration of the current provisions of the grid tool

73. Project and SB assessment experience shows that the simplified provisions included in the grid tool are sometimes not visible and its application is not clear including procedure for determining the grid emission factor when off-grid plants are included.

3.7.1. Analysis and proposed solution to Issue 7

74. The meth panel considered to provide flow charts on the application of the grid tool with systematic illustrations of provisions of determining OM, BM and CM including simplified provisions for off-grid plants. The flowcharts are contained in Appendix 2 and Appendix 6.

3.7.2. Recommendation to Issue 7

75. The meth panel recommends including flowcharts as contained in Appendix 2 and Appendix 6 in the revision of the grid tool.

Appendix 1. Concepts of Operating Margin, Build Margin and Combined margin

1. Introduction

1. The procedure to determine grid emission factor provided in the grid tool uses the combined margin (CM) approach which takes into account the effect of proposed CDM project *(e.g., electricity production from a renewable or grid electricity displacement through demand side energy efficiency improvement)* on existing marginal projects (operating margin (OM)) as well as future projects (build margin (BM)) - together constituting avoided generation due to CDM project. A key assumption that a CDM project activity that supply electricity to a grid or saves grid electricity can displace or avoid the operation of existing grid connected power plants (OM effect) and the construction and operation of new power plants (BM effect).

2. The <u>OM emission factor</u> is defined as the average CO2 emissions factor of net electricity production from existing generation capacity that will be avoided as a result of a CDM project.

3. The <u>BM approach</u> makes a ‘‘best guess’’ as to what type of electric facility would have otherwise been built (or built sooner) in a grid system had the CDM project not been implemented. This also infers that the CDM project activity would affect construction of other projects either through delay or replacement of the planned investments in the grid system. The incremental new capacity displaced by a project activity, and its associated generation, are referred to as the build margin. The build margin is defined in the grid tool as the emission factor that refers to the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity. The method requires the identification of 5 or more most recent power plants that together comprise at least 20 per cent of the total average electricity generation of the grid system.

2. Determination of OM emission factor

2.1. Dispatch Analysis

4. Dispatch analysis approach involves calculating a time-varying marginal emissions rate (on an hourly basis or by load categories such as peak, shoulder, and base periods) and applying it to the time-varying output of a CDM project. The most accurate estimate of the OM emission factor is obtained using system dispatch model. For example, it would be more accurate for peak-load reducing projects where peak-load generation is particularly carbon-intensive.

2.2. Simple OM

5. In the absence of a dispatch model, a simple OM can be assumed to be an adequate proxy for the OM. The simple OM emission factor is defined as the generation-weighted average CO2 emissions per unit net electricity generation (gCO2 per kWh) of all generating power plants serving the system, not including low-cost/must-run power

plants/units.[1] It is only to be used when low cost/must run resources constitute less than 50 per cent of the total grid generation.

2.3. Adjusted simple OM

6. An alternative to the simple OM is the simple adjusted OM. The simple adjusted OM is a variation of the simple OM, where the power plants (including imports) are separated into low-cost/must-run resources and other power sources, and a factor expressing the percentage of time when low-cost/must-run power units are on the margin is defined. In countries where RE accounts for a significant share of the energy mix (>50%), an adjustment factor (λ) is used as a proxy for the share of LCMR generation output that is potentially on the margin and can be displaced by CDM project.

2.4. Average OM

7. An alternative proposal for the OM is based on the average electricity emissions factor, which is the weighted average CO2 emissions factor for all electricity generation in the country. This emissions factor includes low cost/must run resources. The approach assumes that a CDM project avoids a proportional fraction of all generating units on a system. This methodology is considered appropriate and conservative when data is not available to calculate a simple or adjusted simple OM.

2.5. Determination of BM emission factor

8. This approach is a proxy for a ''best guess'' as to what type of electric facility would have otherwise been built (or built sooner) had the CDM project not been implemented. The method requires the identification of 5 or more most recent power plants that together comprise at least 20 per cent of the total average electricity generation of the grid system.

3. Determination of Combined Margin (CM) emission factor

3.1. Weighted average CM

9. The CM is the result of a weighted average of two emission factors pertaining to the electricity system: the operating margin (OM) and the build margin (BM) emission factors. The assumption here is that the CDM project activity would affect the operation of existing grid connected power plants as well as affect construction of other projects either through delay or replacement of the planned investments in a power sector.

10. The following default values are recommended for weighting:

    (a) 0.75 x OM and 0.25 X BM, for intermittent, non-dispatchable generation, such as wind, solar and some hydropower for the first and subsequent crediting periods;

    (b) 0.5 x OM and 0.5 x BM, for all other projects, in the first crediting period, and 0.25 x OM and 0.75 x BM, for the second and third crediting periods.

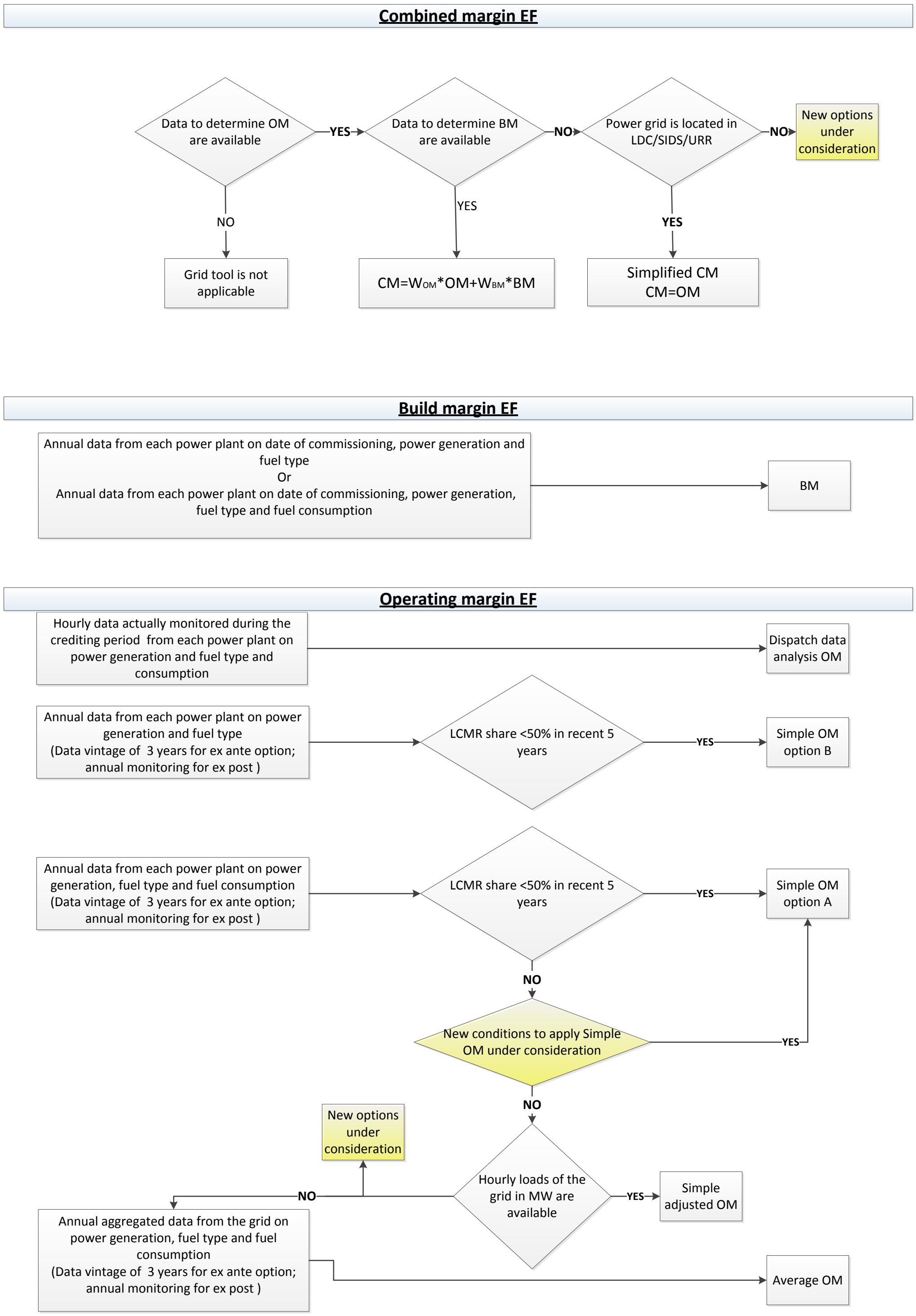
[1] Low-cost/must-run resources are defined as power plants with low marginal generation costs or power plants that are dispatched independently of the daily or seasonal load of the grid. They typically include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. If coal is obviously used as must-run, it should also be included in this list, i.e. excluded from the set of plants.

11. The project participants can submit proposals for alternative weighting.

3.2. **Simplified** CM

12. Here CM equals to 100 per cent OM and it is calculated using average operating margin method i.e., build margin is in built in the simplified CM. This option is limited to the case where data requirement for determining BM is not available provided projects are implemented in Least Developed Countries (LDCs) or Small Island developing States (SIDs) or in countries that had 10 or fewer registered CDM project activities as of 31 December 2010.

Appendix 2. Data requirement and options to determine Grid Emission factors (OM, BM and CM)



Appendix 3. List of countries (other than LDCs/SIDs/URCs) that could potentially use default BM emission factor

1. The following non-Annex I countries are excluded from the list because either they are already eligible to use simplified CM option or they already have grid emission factors calculated (i.e., BM data available):

   (a) LDCs;

   (b) SIDS;

   (c) Underrepresented countries;

   (d) Countries where the grid emission factor is already calculated either by the project proponent or by the DNA (CDM regular projects, SBs,)

Table. List of countries (other than LDCs/SIDs/URCs) that could potentially use default BM emission factor

Country	Possible BM EF (tCO2/MWh)
Bahamas	0.35
Saint Vincent and the Grenadines	0.35
Venezuela, RB	0
Iraq	0
Syrian Arab Republic	0.35
Congo	0
Cote d’Ivoire (Ivory Coast)	0
Sudan	0
Brunei	0.35
Democratic People's Republic of Korea	0
Lao People's Democratic Republic	0

Appendix 4. Installed capacity in selected countries

Table. Total installed capacity in selected countries

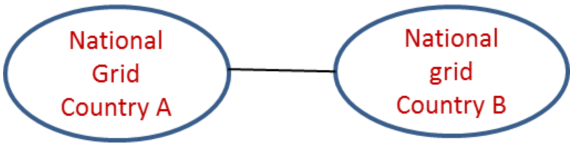
Country	Total Installed capacity GW	10% of Installed capacity (GW)
China	1198	119.8
India	241	24.1
Brazil	120	12
Korea	94	9.4
South Africa	46	4.6
Mexico	61	6.1
Argentina	33	3.3
Chile	18	1.8

Note: More than 100 countries have total installed capacity less than 1.0 GW.
Source: Based on IEA and EIA (data from 2011).

Appendix 5. Delineation of Project electricity system and connected electricity system

1. This section only provides examples for illustration purposes and does not cover all possible scenarios.

Figure 1. Case A



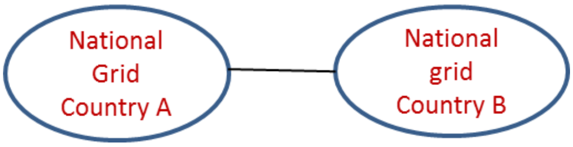
2. **Case A:** Country A-grid is connected to country B-grid but the interconnecting line has significant transmission constraint or transmission capacity as defined under the tool. CDM project is being implemented in country A. In this case the impact of CDM project in country A is assumed to have negligible displacement effect (OM, BM) in country B’s grid due to transmission constraints between the two electricity systems. Here.

   (a) Country B-grid is defined as “connected electricity system” and Country A-grid is defined as “project/grid electricity system”;

   (b) The power flow between the tie-line is considered either **export or import;**

   (c) Grid emission factor of country A can be determined without consent from country B’s DNA.

Figure 2. Case B

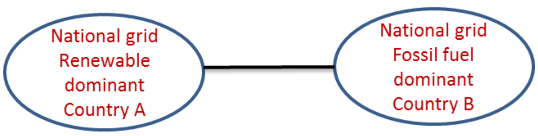


3. **Case B:** This is similar to case A but it has no transmission constraints i.e., an implementation of CDM project in country A or in Country B can have similar displacement effects in country A-grid as well as in country B-grid. So, OM and BM needs to be evaluated considering both electricity systems as a single grid system. Here:

   (a) Country-A grid and country-B grid together constitute a single grid system (project electricity system) and hence a single grid emission factor;

   (b) A common grid emission factor is developed with consents from both the countries.

Figure 3. Case C (special case of case B)



4. **Case C:** This is exactly the case B without any transmission constraints i.e, country-A grid and country-B grid together constitute a single grid system (project electricity system). Hence in order to apply the grid tool correctly, the electricity systems of both countries should be considered as one electricity system and one common grid emission factor:

   (a) It is assumed that country B which is indeed net power exporter would not accept to have common grid emission factor since combining both grids will result in a lower grid emission factor for country B;

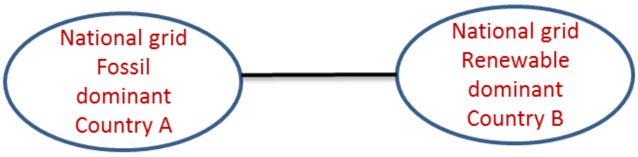
   (b) Country A decided to develop grid emission factor for its own without accounting country B’s grid system based on the following:

      (i) Country A is hydro-dominant and weighted average CM emission factor is developed using Average OM method and considered BM emission factor = 0.

   (c) This results into a conservative emission factor, if country B is not accounted as a part of “project electricity system”;

   (d) Such a case has been accepted by the EB in the form of deviation request (See approved SB - ASB0005 Belize) based on the environmental integrity ground.

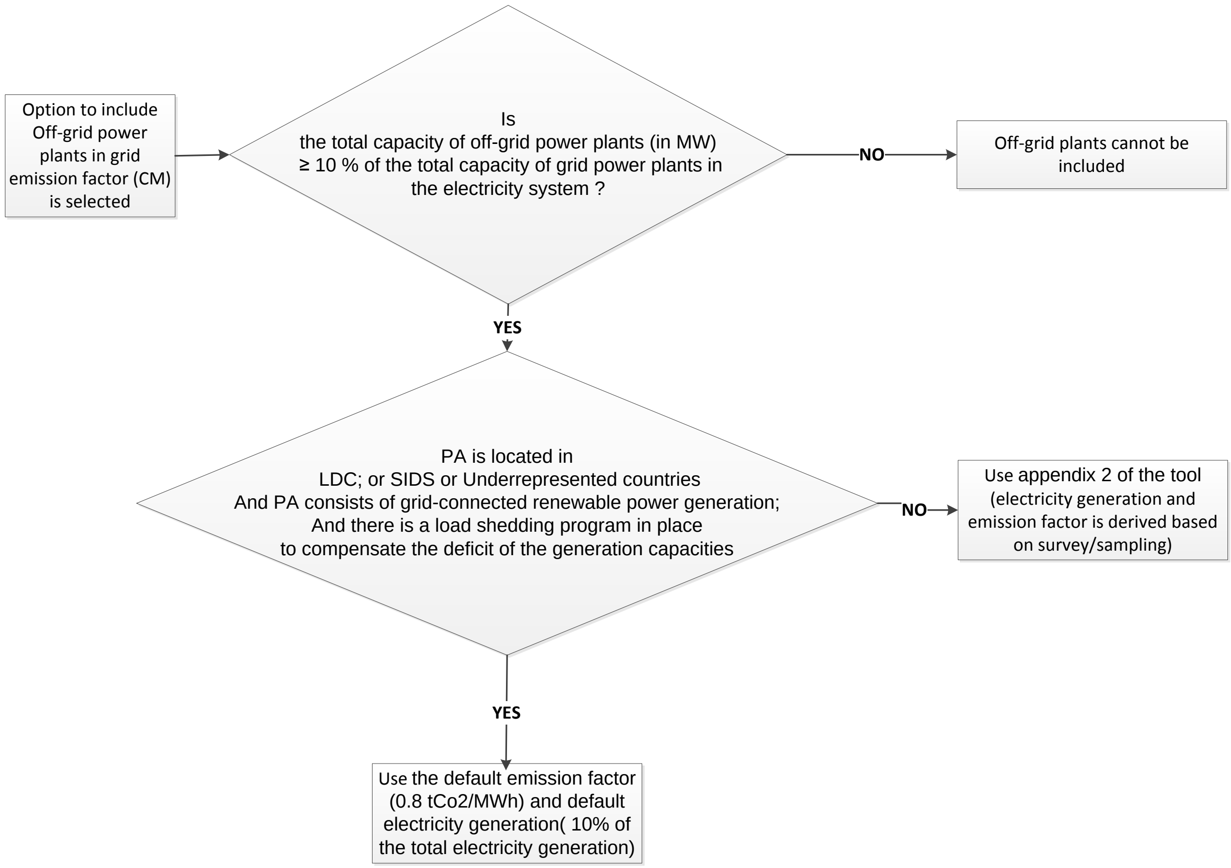
Figure 4. Case D



5. **Case D:** This is exactly the opposite situation to case E. Here country A is fossil fuel dominant and country B is renewable rich. There is no transmission constraint. Here, accepting a similar deviation like in case E i.e, not considering country B-grid as a part of project electricity system would not be conservative. A project implemented in country A would like to displace operation of power plants both in country A and country B.

6. Exception may apply similar to case E only in the case if it is justified that Country A is a net power exporter (based on x years data).

Appendix 6. Inclusion of off-grid power plants into the calculation of grid emission factor



Appendix 7. Step wise procedure to determine λ_y

1. The simple adjusted OM emission factor ($EF_{grid,OM\text{-}adj,y}$) is an approach, where the power plants/units (including imports) are separated in low-cost/must-run power sources (k) and other power sources (m). As under Option A of the simple OM, it is calculated based on the net electricity generation of each power unit and an emission factor for each power unit, as follows:

$$EF_{grid,OM-adj,y} = \left(1 - \lambda_y\right) \times \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} + \lambda_y \times \frac{\sum_k EG_{k,y} \times EF_{EL,k,y}}{\sum_k EG_{k,y}} \quad \text{Equation (1)}$$

Where:

$EF_{grid,OM\text{-}adj,y}$	=	Simple adjusted operating margin CO_2 emission factor in year y (t CO_2/MWh);
λ_y	=	Factor expressing the percentage of time when low-cost/must-run power units are on the margin in year y;
$EG_{m,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh);
$EG_{k,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit k in year y (MWh)
$EF_{EL,m,y}$	=	CO_2 emission factor of power unit m in year y (t CO_2/MWh);
$EF_{EL,k,y}$	=	CO_2 emission factor of power unit k in year y (t CO_2/MWh);
M	=	All grid power units serving the grid in year y except low-cost/must-run power units;
K	=	All low-cost/must run grid power units serving the grid in year y;
Y	=	The relevant year as per the data vintage chosen in Step 3

2. $EF_{EL,m,y}$, $EF_{EL,k,y}$, $EG_{m,y}$ and $EG_{k,y}$ should be determined using the same procedures as those for the parameters $EF_{EL,m,y}$ and $EG_{m,y}$ in Option A of the simple OM method above.

3. If off-grid power plants are included in the operating margin emission factor, off-grid power plants should be treated as other power units m, where $EG_{m,y}$ and $EF_{EL,m,y}$ should be determined using approach outlined under the section *“Simple OM”.*

4. Net electricity imports must be considered low-cost/must-run units *k.*

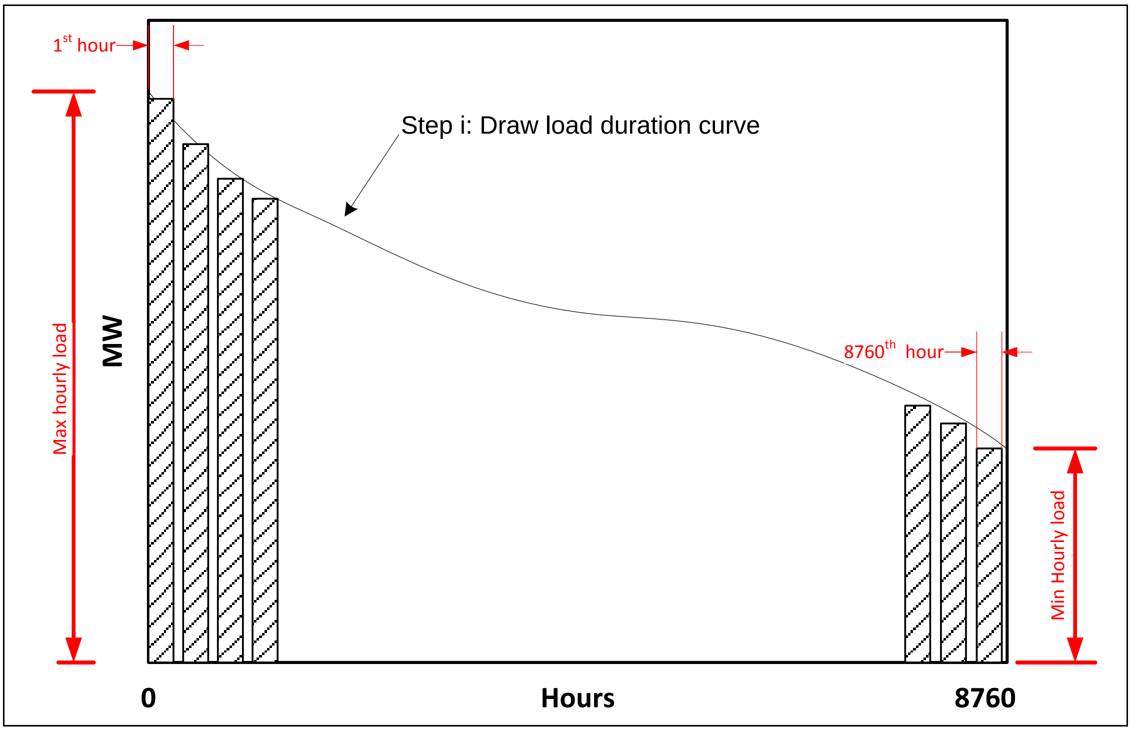
5. The parameter λ_y is defined as follows:

$$\lambda_y(\%) = \frac{Number\ of\ hours\ \mathrm{low-cost/must-run}\ are\ on\ the\ margin\ in\ year\ y}{8760\ hours\ per\ year} \quad \text{Equation (2)}$$

6. The λ_y shall be calculated using the following procedure:

(a) **Step (i)** - Plot a **load duration curve**. Collect chronological load data (typically in MW) for each hour of the year *y*, and sort the load data from the highest to the lowest MW level. Plot MW against 8760 hours in the year, in descending order (see also the figure below);

Figure 1. Step (i)



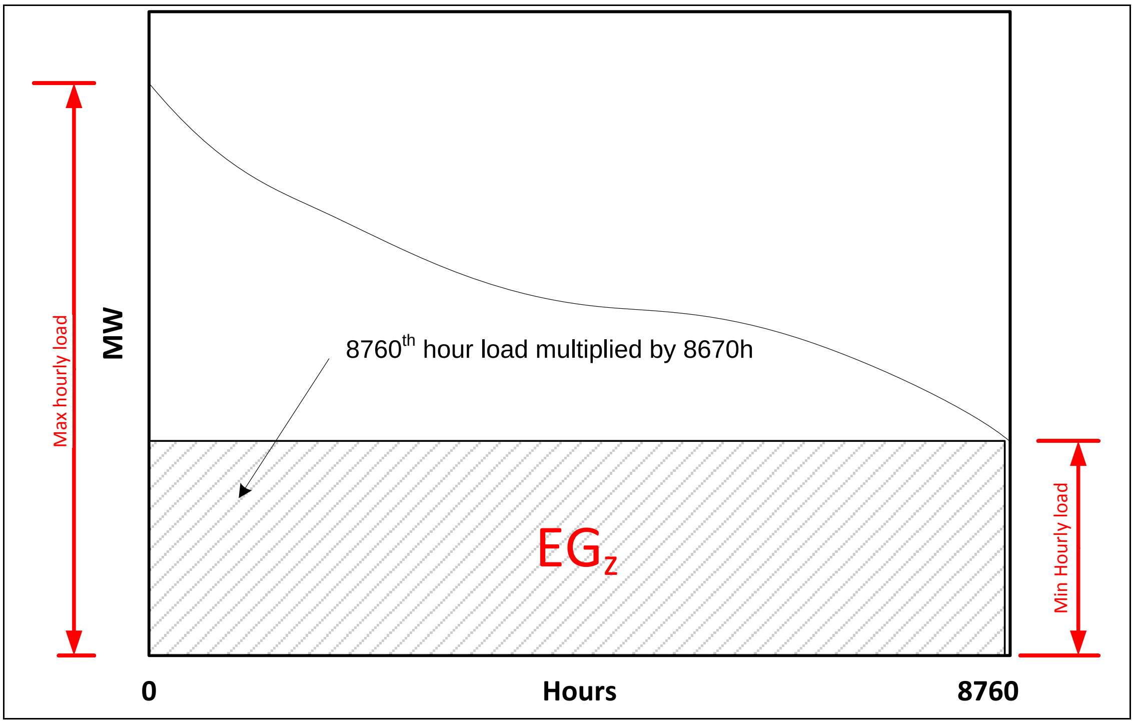
(b) **Step (ii)** - Collect electricity generation data from each low-cost/must-run power plant/unit. Calculate the total annual generation (in MWh) from low-cost/must-run power plants/units (i.e. $\sum_k EG_{k,y}$);

(c) **Step (iii) –** Find out the intersection point connecting horizontally to the load distribution Y axis; in the curve where area (MW times hours) under the curve equals the total generation (in MWh) from low-cost/must-run power plants/units. The following sub steps can be used to find the intersection point:

(i) As the load changes every hour from highest load to lowest load in a year; the intersection can be defined by adding incremental areas in MW times hour in every hour over the area corresponding to lowest load i.e. the first area. For the first area from the sorted load data, take the lowest MW level and multiply it by hours in a year (e.g. 8760) (see figure below);

$$EG_Z = EL_Z \times Z \quad \text{Equation (3)}$$

Figure 2. Step (iii) (i)



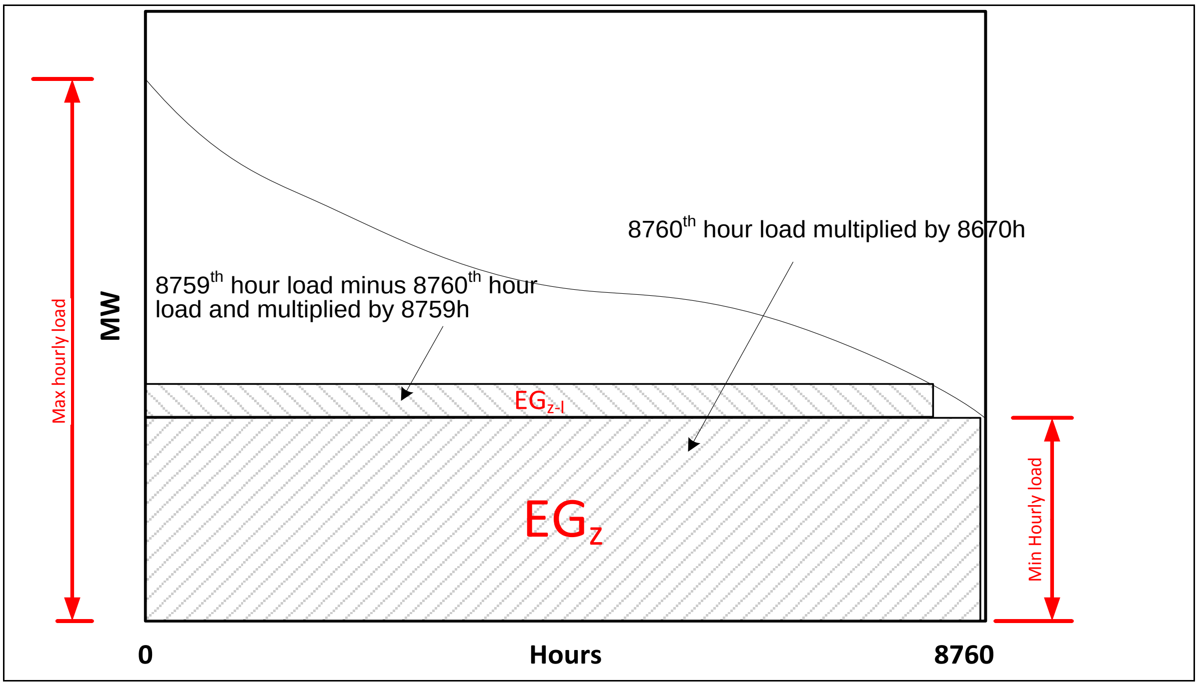
(ii) For the following areas from the sorted load data take the level next to the one from the previous step, subtract the load from the previous level and multiply the result by number of hours that corresponds to this level (see also the figure below):

$$EG_{Z-L} = (EL_{Z-L} - EL_Z) \times (Z - L) \qquad \text{Equation (4)}$$

Where:

EG_{Z-L}	=	Electricity generation during the year at the level of Z-L load (MWh);
EL_{Z-L}	=	load of the grid in at the level of Z-L load(MW);
EG_Z	=	Electricity generation during the year at the level of minimal recorded load (MWh);
EL_Z	=	Minimal recorded load of the grid in year y (MW);
Z	=	Number of hours in year y (h);
L	=	Rank of the recorded load in the sorted list of loads starting from the lowest. For the first step L=0.

Figure 3. Step (iii) (ii)

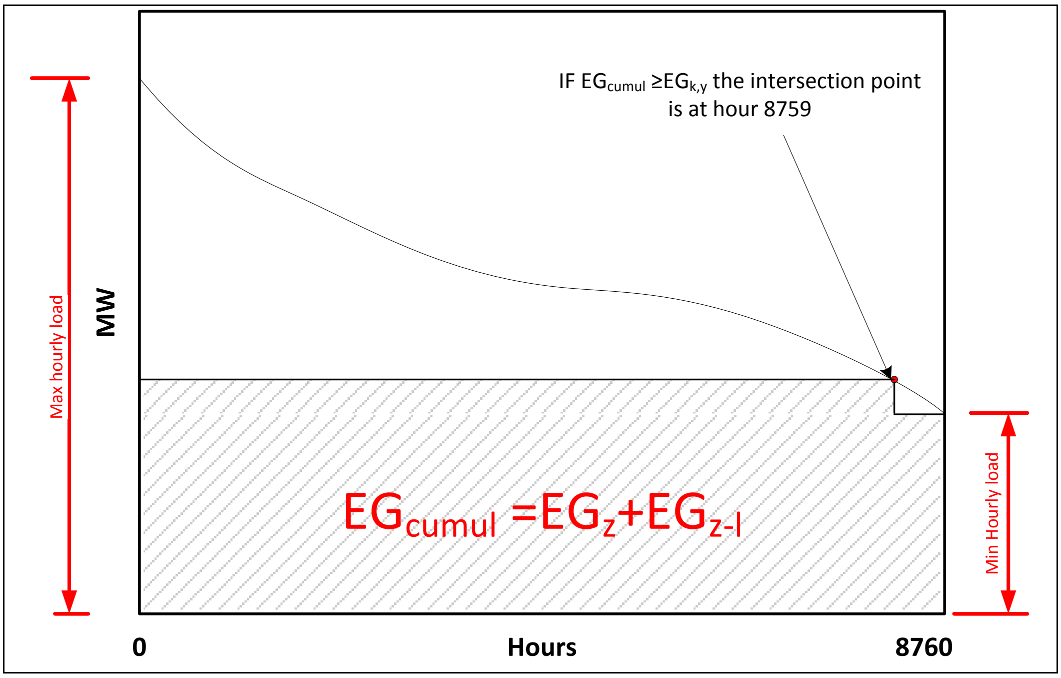


(iii) Calculate the cumulative electricity generation:

$$EG_{cumul} = \sum_{L+1}^{Z} EG_{Z-L} + EG_{Z,L}$$ Equation (5)

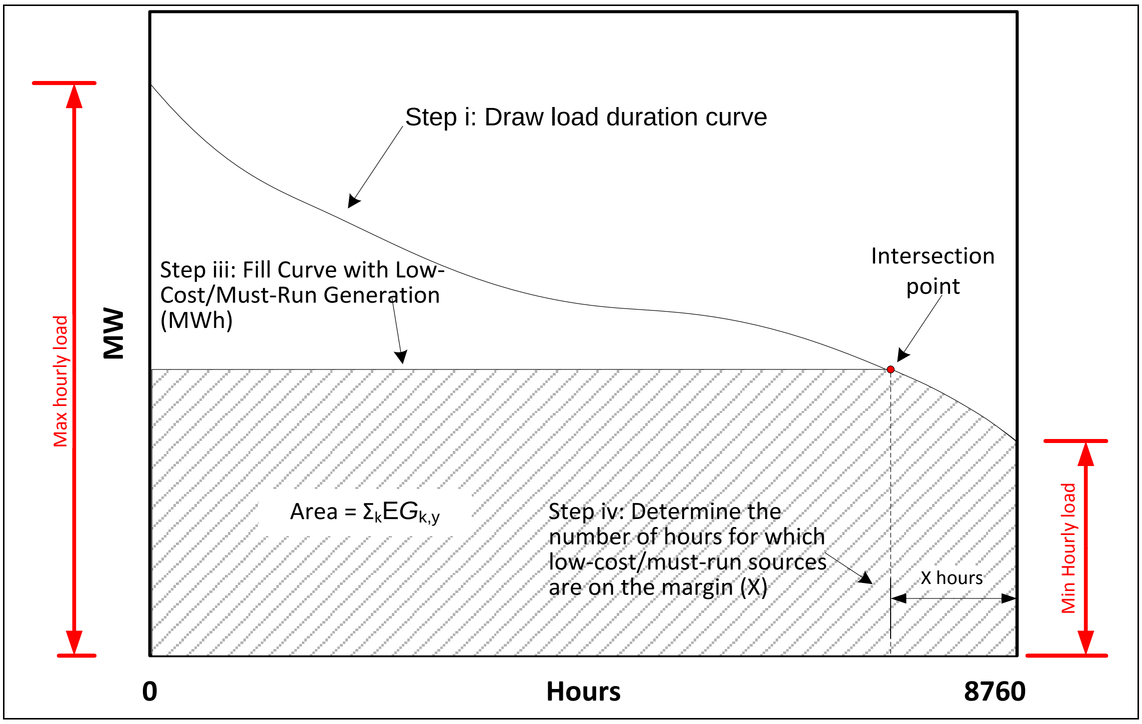
(iv) Check the cumulative electricity generation against the total generation (in MWh) from low-cost/must-run power plants/units (i.e. $\sum_k EG_{k,y}$) till $EG_{cumul} \geq \sum_k EG_{k,y}$ (See also the figure below).

Figure 4. Step iii (iv



(d) **Step (iv) -** Determine the “Number of hours for which low-cost/must-run sources are on the margin in year y. At the step where cumulative electricity generation reaches the level of the total generation (in MWh) from low-cost/must-run power plants/units, i.e. $EG_{cumul} \geq \sum_k EG_{k,y}$ determine the value of *Z-L*. This is the number of hours for which low-cost/must-run sources are on the margin in year y (see also the figure below).

Figure 5 Step (iv)



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