CLEAN DEVELOPMENT MECHANISM

AM0072

Large-scale Methodology

Fossil Fuel Displacement by Geothermal Resources for Space Heating

Version 03.0

Sectoral scope(s): 01

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. The following table describes the key elements of the methodology:

Table 1. Methodology key elements

Typical projects	Introduction of a centralized geothermal heat supply system for space heating in buildings. The geothermal heat supply system can be a new system in new buildings, the replacement of existing fossil fuel systems or the addition of extra geothermal wells to an existing system.
Type of GHG emissions mitigation action	Renewable energy. Displacement of more-GHG-intensive thermal energy generation.

2. Scope, applicability, and entry into force

2.1. Scope

2. This methodology is for project activities that introduce a geothermal heat supply system for space heating in buildings.

2.2. Applicability

3. The methodology is applicable for space heating in buildings by introducing centralized geothermal heat supply system. The methodology can apply to new build facilities, or to a geothermal district heating system seeking to expand its operations through the addition of extra geothermal wells to the system.

4. The methodology is applicable under the following conditions:

(a) The geographical extent of the project boundary can be clearly established, in terms of the location of buildings connected to existing heating systems and new buildings to be constructed that will use geothermal heat, in the case of expansion of existing facilities, the location and capacity of existing geothermal wells, and heating system infrastructure can be clearly identified;

(b) Project will use geothermal resources for centralized space-heating system of residential areas, commercial areas and/or industrial areas;

(c) The methodology is applicable for installing new heating systems in new buildings and replacing existing fossil fuel space heating systems. Current use of fossil fuel(s) for space heating is partially or completely replaced by heat drawn from geothermal water, in the case of expansion of existing facilities the methodology is applicable to expanding the existing geothermal heating system;

(d) The installed heat capacity may increase as a result of the project activity. But this increase is limited to 10 per cent of the previous existing capacity; otherwise a new baseline scenario has to be determined for the new capacity;

(e) All fossil fuel heat-only boiler(s) used in the baseline must operate to supply the heat to the district heating system which is only used for heating of buildings

and/or hot tap water supply in the residential and/or commercial sector, but not for industrial processes;

(f) The use of GHG emitting refrigerants is not permitted under this methodology.

5. In addition, the applicability conditions included in the tools referred to below apply.

2.3. Entry into force

6. The date of entry into force of the revision is the date of the publication of the EB 73 meeting report on 31 May 2013.

3. Normative references

7. This baseline and monitoring methodology is based on the following approved baseline and monitoring methodologies and elements from the proposed new methodology:

(a) “NM0261: Fossil Fuel Displacement by Geothermal Resources for Space Heating” prepared by the Asian Development Bank;

(b) “AM0058: Introduction of a new primary district heating system” prepared by COWI A/S, Energy Department, Denmark;

(c) “AM0044: Energy efficiency improvement projects: boiler rehabilitation or replacement in industrial and district heating sectors”;

(d) “AMS-I.C: Thermal energy for the user”.

8. This methodology also refers to the latest approved versions of the following tools:

(a) “Combined tool to identify the baseline scenario and demonstrate additionality”;

(b) “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”;

(c) “Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion”.

9. For more information regarding the approved methodologies and the tools as well as their consideration by the Executive Board of the clean development mechanism (CDM) (hereinafter referred to as the Board) please refer to <http://cdm.unfccc.int/goto/MPappmeth>.

3.1. Selected approach from paragraph 48 of the CDM modalities and procedures

10. “Existing actual or historical emissions, as applicable”.

4. Definitions

11. For the purpose of this methodology, the following definitions apply:

(a) **Centralized space heating system** - A system which provides heat to the whole interior of a building (or portion of a building) from one point to multiple spaces;

(b) **Decentralized heat equipment** - Individual space heating equipment such as stoves for space heating that is distinct from other areas in a facility, building or apartment;

(c) **Fugitive emissions** - Emissions due to non-condensable gases from steam coming from geothermal vents;

(d) **Geothermal heating** - Space heating utilizing sources of hot water and hot steam that exist near the earth's surface;

(e) **Geothermal resource** - Heat stored beneath the Earth's surface;

(f) **Geothermal water** - Hot water that exists beneath the earth's surface;

(g) **Low temperature geothermal system** - System with reservoir temperature at 1 km depth below 150°C or enthalpy lower than 800kJ/kg.

5. Baseline methodology

5.1. Lifetime of existing heating equipment

12. In case, where the identified baseline scenario is the continued use of the heating equipment(s), project participants shall, consistent with the guidance by EB 8 and EB 22, determine whether the existing equipment would be replaced, retrofitted or modified during the project lifetime. In order to determine the point in time by when the existing equipment(s) would be replaced in the absence of the project activity, project participants should estimate the typical technical lifetime of the heating equipment for each of technology *i*, taking into account the following:

(a) The typical average technical lifetime of equipment should be determined taking into account common practices in the sector and country (e.g. based on industry surveys, statistics, technical literature, etc.); or

(b) The practices of the responsible company regarding replacement schedules may be evaluated and documented (e.g. based on historical replacement records for similar equipment).

13. The time of replacement/rehabilitation of the existing equipment, in the absence of the project activity, should be chosen in a conservative manner that is the earliest point in time should be chosen in cases where only a time frame can be estimated and should be documented in CDM-PDD.

14. If the remaining lifetime of the heating equipment is increased due to the project activity, the crediting period has to be limited to the earliest estimated remaining lifetime amongst the set of heating equipments, that is the earliest point in time when one of the existing equipments would need to be replaced/rehabilitated in the absence of the project activity.

5.2. Identification of the baseline scenario and demonstration of additionality

15. Project proponents shall determine the most plausible baseline scenario through the use of the "Combined tool to determine the baseline scenario and demonstrate additionality" by the application of the following steps:

5.2.1. Step 1: Identification of alternative scenarios

5.2.1.1. Step 1a: Define alternative scenarios to the proposed CDM project activity

16. Identify all alternative scenarios that are available to the project participants and that provide outputs or services (i.e. heat supply) with comparable quality as the proposed CDM project activity. For the purpose of identifying relevant alternative scenarios, provide an overview of other technologies or practices used for generation of heat that have been implemented prior to the start of the project activity or are currently underway in the relevant geographical area.

17. If the increase in capacity during project activity is more than 10 per cent of the previous existing capacity, a new baseline scenario has to be determined for the new capacity.

18. The following baseline scenario alternatives for heat supply to buildings should be assessed:

5.2.1.2. Options for the implementation of a new geothermal facility

(a) Implementation of the project activity without the benefits of the CDM;

(b) Introduction of a new integrated district heating system(s) connected by a new primary network:

   (i) Introduction of a district heating system;

   (ii) The replacement of the heat-only boilers in the existing network(s) by new heat-only boilers.

(c) Continued operation or rehabilitation of an existing [isolated] district heating network(s) or establishment of a new [isolated] district heating network(s). Such [isolated] district heating network(s) employ the following technologies:

   (i) Coal fired boilers in boiler houses, supplying several buildings through a heat distribution network;

   (ii) Natural gas fired boilers in boiler houses, supplying several buildings through a heat distribution network;

   (iii) Oil fired boilers in boiler houses, supplying several buildings through a heat distribution network;

   (iv) Decentralized cogeneration plants;

   (v) Renewable energy sources, such as biomass or solar thermal collectors, connected to a heat distribution network.

(d) Continued use or introduction of individual heat supply solutions:

   (i) Coal fired boilers for individual buildings;

   (ii) Coal fired stoves for individual apartments;

   (iii) Natural gas fired boilers for individual buildings;

   (iv) Natural gas fired stoves for individual apartments;

(v) Oil fired boilers for individual buildings;

(vi) Oil fired stoves for individual apartments;

(vii) Electricity (e.g. off-peak storage heating);

(viii) Individual heating devises using renewable energy sources, e.g. solar thermal collectors;

(ix) Individual heating devises using non-renewable biomass.

5.2.1.3. Solutions for expansion of a geothermal heat supply system

(a) Current wells and heat centrals with increased numbers of buildings connected;

(b) Current heat centrals with increased numbers of wells and buildings;

(c) Use of different heat supply systems as per options (2), (3) and (4) for the implementation of a new geothermal facility;

(d) General overall expansion, including new wells, new heat centrals and new buildings (the Project Activity without CDM).

5.2.1.4. Outcome of Step 1a

19. List of identified realistic and credible alternative scenarios for all buildings included in the project boundary.

5.2.1.5. Step 1b: Consistency with mandatory laws and regulations

20. The alternatives shall be in compliance with all mandatory applicable legal and regulatory requirements, even if these laws and regulations have objectives other than GHG reductions, for example to mitigate local air pollution (This sub-step does not consider national and local policies that do not have legally binding status). If an alternative does not comply with all mandatory applicable legislation and regulations, then show that, based on an examination of current practice in the country or region in which the mandatory law or regulation applies, those applicable mandatory legal or regulatory requirements are systematically not enforced and that non-compliance with those requirements is widespread in the country. If this cannot be shown, then eliminate the alternative from further consideration.

5.2.1.6. Outcome of Step 1b

21. List of alternative scenarios to the project activity that are in compliance with mandatory legislation and regulations taking into account the enforcement in the region or country and EB decisions on national and/or sectoral policies and regulations.

5.2.2. Step 2: Barrier analysis

22. Scenarios that face prohibitive barriers should be eliminated by applying “Step 2: Barrier analysis” of the latest approved version of the “Combined tool to identify the baseline scenario and demonstrate additionality”.

23. **Technology barriers** – technology utilized may be new untested and possibly perceived to be too risky an investment. Included in this barrier is a possible lack of available technical know-how to maintain or repair faulty systems.

24. **Acceptability barriers** – new technologies may not be acceptable to end-users. For example, the reliability on consistency of geothermal sources may be low due to uncommon nature of source. Therefore acceptability could be a barrier to the implementation of project activity.

25. **Financial barriers** – the project participant cannot receive enough funding or have access to funding sources in the financial market.

    (a) If there is only one alternative scenario that is not prevented by any barrier, and if this alternative is not the proposed project activity undertaken without being registered as a CDM project activity, then this alternative scenario is identified as the baseline scenario;

    (b) If there are still several alternative scenarios remaining project participants may choose to either:

        (i) **Option 1:** go to Step 3: “Investment analysis”; or

        (ii) **Option 2:** identify the alternative with the lowest emissions (i.e. the most conservative scenario) as the baseline scenario.

26. It is noted that in the case of projects which are expansion of an existing geothermal heat supply system, it is necessary to carry out the financial analysis in order to substantiate any barrier analysis. Barrier analysis alone is unlikely to be sufficient to demonstrate additionality.

5.2.3. Step 3: Investment analysis: Comparison of economic attractiveness of the remaining alternatives

27. Compare the economic attractiveness without revenues from CERs for alternatives that are remaining by applying “Step 3: “Investment analysis” of the latest approved version of the “Combined tool to identify the baseline scenario and demonstrate additionality”.

5.2.3.1. Outcome of Step 3

28. If after the sensitivity analysis it is concluded that: (1) the proposed CDM project activity is unlikely to be the most financially/economically attractive, then proceed to Step 4 (Common practice analysis).

29. For project activities that involve the expansion of existing geothermal systems, it should be noted that in any financial analysis sunk costs associated with the facilities constructed prior to the CDM project start date should be excluded. Such sunk costs would include past construction costs, operation costs and irreversible outflows. They should be documented and excluded from the investment analysis in line with the latest version of the “Guidelines on the assessment of investment analysis”.

30. Revenues accruing from the baseline facilities (i.e. those facilities that resulted in the sunk costs) should only be excluded from the financial analysis if it can be demonstrated that the same facilities would have continued to operate in the absence of the project activity.

5.2.4. Step 4: Common practice analysis

31. Provide an analysis to which extent similar activities to the proposed CDM project activity have been implemented previously or are currently underway using “Step 4: Common practice analysis” of the latest approved version of the “Combined tool to identify the baseline scenario and demonstrate additionality”.

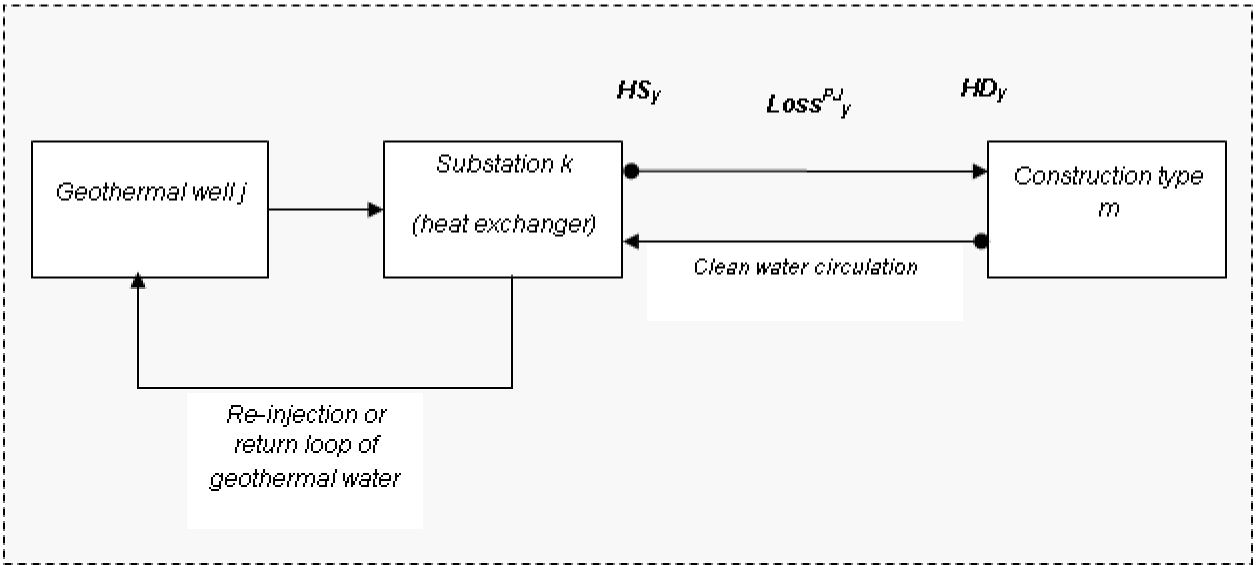
32. The previous steps shall be complemented with an analysis of the extent to which the proposed project type has already diffused in the relevant sector and geographical area. This test is a credibility check to demonstrate additionality which complements the barrier analysis (Step 2) and, where applicable, the investment analysis (Step 3).

33. Finally, for new build projects the methodology is only applicable if the most plausible baseline scenario is a fossil-fuel based heat supply system (single or multiple), which is not cogeneration. For projects that involve the expansion of existing facilities, the methodology is only applicable if the most plausible scenario is the use of fossil-fuel based heat supply systems (single or multiple), which are not cogeneration.

5.3. Project boundary

34. The spatial extent of the project boundary encompasses heat supplied to end-users of construction type *m*; that will be measured continuously at substation *k* as part of the monitoring plan. Figure 1 below defines the project boundaries and indicates substation *k* (heat exchanger) as the primary point of measurement for monitoring parameters.

Figure 1. Project boundary



35. The spatial extent of the project boundary includes:

(a) The site of geothermal heat extraction including, geothermal wells, re-injection wells, pumps, geothermal water storage tanks etc.;

(b) Centralized heating systems, including pipes, stations, sub-stations and buildings that are or will be connected to the geothermal heating system;

(c) Decentralized heating equipments, including fossil fuel fired stoves etc.

36. Any revision and/or change to the basic design of the heating system during the crediting period should be documented in a transparent manner in the monitoring reports. Changes may include the following:

(a) Changes in the measurement of the point of heat;

(b) Changes in the heating network;

(c) Other design deviations in the heating system.

37. The greenhouse gases included in or excluded from the project boundary are shown in Table 2.

Table 2. Emissions sources included in or excluded from the project boundary

<table>
<tr><th colspan="2">Source</th><th>Gas</th><th>Included</th><th>Justification/Explanation</th></tr>
<tr><td rowspan="3">Baseline</td><td rowspan="3">Fossil fuel used for space heating</td><td>CO_2</td><td>Yes</td><td>Main emission source</td></tr>
<tr><td>CH_4</td><td>No</td><td>Minor source. Neglected for simplicity and conservativeness</td></tr>
<tr><td>N_2O</td><td>No</td><td>Minor source. Neglected for simplicity and conservativeness</td></tr>
<tr><td rowspan="9">Project activity</td><td rowspan="3">Electricity used for geothermal extraction /operations</td><td>CO_2</td><td>Yes</td><td>Can be a significant emission source</td></tr>
<tr><td>CH_4</td><td>No</td><td>Minor source</td></tr>
<tr><td>N_2O</td><td>No</td><td>Minor source</td></tr>
<tr><td rowspan="3">Fuel used for geothermal extraction /operations</td><td>CO_2</td><td>Yes</td><td>Can be a significant emission source</td></tr>
<tr><td>CH_4</td><td>No</td><td>Minor source</td></tr>
<tr><td>N_2O</td><td>No</td><td>Minor source</td></tr>
<tr><td rowspan="3">Fugitive emissions from geothermal resource extraction</td><td>CO_2</td><td>Yes</td><td>Can be a significant emission source</td></tr>
<tr><td>CH_4</td><td>Yes</td><td>Can be a significant emission source</td></tr>
<tr><td>N_2O</td><td>No</td><td>Minor source</td></tr>
</table>

5.4. Baseline emissions

38. The project reduces CO_2 emissions by using geothermal heat to replace heat generated from the use of fossil fuel from various sources.

5.4.1. Baseline heating system

39. There are three possibilities for the baseline as follows:

(a) Baseline scenario is identified as a fossil fuel based *centralized* heat supply system, different than cogeneration, using a single *decentralized* heat supply fossil fuel technology;

(b) The baseline scenario, is a fossil fuel based decentralized heat supply system with multiple technologies (of type *i)*, the baseline emissions are specified as the summation over the technology suffix *i;*

(c) The baseline scenario is identified as a combination of the two following alternatives:

(i) Fossil fuel based centralized heat supply systems, different than cogeneration, using a single decentralized heat supply fossil fuel technology (as described in baseline scenario a above); and

(ii) Existing geothermal centralized heat supply systems.

40. For the above situations, the baseline emissions BE_y in a year *y* are calculated as:

$$BE_y = \sum_i \left(HS^{BL}{}_{i,y}\right) \times EF_{CO2,i} / \eta_{BL,i} \qquad \text{Equation (1)}$$

Where:

BE_y	=	The baseline emissions from heat displaced by the project activity during the year *y* (t CO_2e/yr)
$EF_{CO2,i}$	=	The CO_2 emission factor per unit of energy of the fuel of technology *i* that would have been used in the baseline heating technology in (t CO_2/TJ). Where several fuel types are used in the boiler, use the fuel type with the lowest CO_2 emission factor
$\eta_{BL,i}$	=	The net thermal efficiency of the heating technology i using fossil fuel that would have been used in the absence of the project activity
$HS^{BL}{}_{i,y}$	=	The net output of heat generated by the baseline heat supply system using the technology *i*[1] measured at the end point of the heat facility, during the year *y* (TJ/yr)

41. In the case of projects that expand existing facilities, baseline heat supply from any existing geothermal heating facilities is excluded from equation (1). Only the net output of heat generated by the baseline fossil fuel fired heating system(s) are included. Any GHG emissions associated with this baseline geothermal space heating are dealt with in the project emissions section of this methodology.

5.4.2. Relationship between the baseline scenario and the project activity

42. The relationship between the baseline scenario and the project activity that the heat demand at the end-use points is common.

43. For project activities that involve a new heating systems:

$$HS_y - Loss^{PJ}{}_y = \sum_i HS^{BL}{}_{i,y} - Loss^{BL}{}_y \qquad \text{Equation (2)}$$

[1] For centralized heating, this technology can be various types of boilers and for decentralized cases the technology.

Where:

HS_y	=	Net quantity of heat supplied by the geothermal heat resource(s) in the project activity, during the year *y* (TJ/yr)
${Loss^{PJ}}_y$	=	The net distribution losses of the geothermal heat supply system during the year *y* (TJ/yr)
${Loss^{BL}}_y$	=	The net distribution losses of the heat supply system, in the absence of project activity, during the year *y* (TJ/yr)

44. For project activities that involve the expansion of existing geothermal facilities:

$$\left(HS_y \times DF_y\right) - \left({Loss^{PJ}}_y \times f_{BL:PJ,y}\right) = \sum_i {HS^{BL}}_{i,y} - {Loss^{BL}}_y \quad \text{Equation (3)}$$

Where:

DF_y	=	Discount factor for calculation of geothermal extraction that results from CDM (fraction)
$f_{BL:PJ,y}$	=	Weighting factor for calculating project emissions for projects (fraction)

5.4.3. Procedure to calculate discount factor for existing geothermal equipment (*DF_y*)

45. Certain projects will involve the construction of new geothermal facilities and their connection to pre-existing (i.e. non-CDM, baseline) geothermal facilities. The baseline geothermal facilities will continue to operate under the project activity. Consequently, since they will be part of the same heat supply system as the project activity, they will necessarily be included within the project boundary.

46. In such cases, because the ex post measurements of two parameters, heat supply (${HS^{BL}}_{i,y}$) and losses (${Loss^{PJ}}_y$), will need to be performed for the whole heat supply system, it is necessary to define a factor for attributing a proportionate amount of these parameters to the facilities constructed under the CDM.

47. The discount factor, *DFy*, is calculated based on: (i) the amount of heat that would have been supplied by the baseline geothermal wells; and (ii) the amount of heat from wells constructed under the CDM. However, the amount of energy that can be drawn from a geothermal well is not fixed – consumption is set based on expert evaluation of a well's potential (it's "design capacity"). Consuming too much energy can greatly reduce the useful lifespan of a well. Expert evaluation is performed to establish the level of sustainable consumption that should maximize the lifetime and energy consumption from the well.

48. Since some baseline wells may not have been fully exploited in this manner in the baseline, it is necessary to incorporate into the calculation of DF_y any potential expansion of space heating supply that would have happened in the baseline scenario.

49. The discount factor is calculated conservatively to prevent the project activity favoring the consumption of energy from wells that were constructed under CDM over those that have been identified as part of the baseline. The factor is derived from the actual heat extracted, or design capacity of the baseline geothermal wells, and the actual heat supply, or design capacity of the new geothermal wells in a given year *y*:

$$DF_y = \frac{min\{Ex_{NEW,y}; Ex_{NEW,design}\}}{max\ \{Ex_{BL,y}; Ex_{BL,design}\} + min\{Ex_{NEW,y}; Ex_{NEW,design}\}}$$ Equation (4)

Where:

$Ex_{BL,y}$	=	Actual quantity of heat extracted from baseline geothermal wells in year *y* (GJ)
$Ex_{BL,design}$	=	Design capacity for sustainable heat extraction from baseline geothermal wells (GJ)
$Ex_{NEW,y}$	=	Actual quantity of heat extracted from new geothermal wells (geothermal wells that would not have been developed in the baseline) (GJ)
$Ex_{NEW,design}$	=	Design capacity for sustainable heat extraction from new geothermal wells (geothermal wells that would not have been developed in the baseline) (GJ)

5.4.4. Procedure to calculate weighting factor calculating project emissions ($F_{BL:PJ,y}$)

50. Project emissions will necessarily be calculated for the whole heating system as all the geothermal wells will be sharing the same distribution system. Therefore, under project activities that involve the inclusion of pre-existing geothermal wells into a new system, it is necessary to exclude from project emissions calculations the emissions that result from electricity and fossil fuel consumption, and fugitive emissions from geothermal resource extraction that occur due to operation of the baseline wells and facilities (i.e. emissions that would have occurred in the baseline scenario). For this, the application of the discount factor (DF_y) calculated above would not be conservative. Therefore, the value of total emissions for the whole geothermal system from each of these parameters is discounted using a ratio based on actual extraction from baseline and CDM geothermal wells, as follows ($f_{BL:PJ,y}$):

$$f_{BL:PJ,y} = \frac{Ex_{NEW,y}}{Ex_{BL,y} + Ex_{NEW,y}}$$ Equation (5)

5.4.5. Procedure to determine the heat generated by technology *i* ($HS^{BL}_{i,y}$)

51. Project participant shall determine the amount of heat generated by each technology using the following steps:

(a) Assign weights for heat generated by technology *i.*

(i) **Option 1**: Energy production based on site survey

a. Step 1: conduct sampling survey of technologies used in the geographical area of the project activity. The sampling size should be determined by minimum 95 per cent confidence interval with 10 per cent maximum error margin. The procedures followed in the survey shall be documented in the CDM-PDD;

b. Step 2: assign weights (w_i) to each technology *i* based on total capacities (MW_{th}) by each technology;

(ii) **Option 2**: Assign weights based on available historical records

a. Step 1: list baseline technologies used in the buildings to be connected to the geothermal heating system;

b. Step 2: determine the total heating area of the project boundary;

c. Step 3: assign weights (w_i) to each technology i based on heating area serviced by each technology in the baseline (for existing geothermal facilities, the geothermal heating area should be excluded from the weighting procedure).

(b) Determine the net output of heat generated by the baseline heat supply system using the technology *i* using one of the equations below.

$$HS^{BL}{}_{i,y} = w_i \times \sum_i HS^{BL}{}_{i,y} \ or\ HS^{BL}{}_{i,y} = w_i \times \left(HS_y - Loss^{PJ}{}_y + Loss^{BL}{}_y\right)^{2}$$ Equation (6)

52. If it is not possible to determine heat produced by each technology using the procedure described above then project proponents have to assume that all the thermal energy is supplied by the most efficient baseline technology used in the buildings to be connected to the geothermal heating system.

53. Distribution loss in the baseline scenario could be measured ex ante for the current system, if the continuation of current practice is using fossil fuels. On the other hand, the distribution loss of the project activity is measured ex post.

54. Ex ante measurement parameters

(a) $\eta^{BL}{}_i$;

(b) $EF_{CO2,I}$;

(c) $Loss^{BL}{}_{y}$.

55. Ex post measurement parameters

(a) HS_y;

(b) $Loss^{PJ}{}_y$.

[2] Substituting value of $\sum_i HS^{BL}{}_{i,y}$ from equation (2).

5.4.6. Step 1: Determine the baseline ex ante parameters of the project

5.4.6.1. Sub-step 1.a: For each identified technology *i*, efficiency of the baseline units shall be determined by adopting one of the following criteria:

56. The net thermal efficiency of the fossil fuel technology *i* (η^{BL}_i) remains fixed for the duration of the crediting period.

57. Project participants will determine η^{BL}_i based on historical data of fuel consumption and output energy.

5.4.6.1.1. In case the type of heating system use boilers

58. The baseline thermal efficiency for each boiler included in the project boundary shall be determined using the following formula:

$$\eta_{BL,his,i} = \frac{TE_{BL,his,i}}{FC_{BL,his,i}} \quad \text{Equation (7)}$$

Where:

$\eta_{BL,his,i}$	=	Average baseline thermal efficiency of boiler
$TE_{BL,his,i}$	=	Average historic net thermal energy output from the baseline boiler *i* (MJ/yr)[3]
$FC_{BL,his,i}$	=	Average historic fossil fuel consumption from the baseline boiler *i* (MJ/yr)

59. Wherever possible, the above calculation shall be based on historical data for the project activity site for the most recent three years before the implementation of the project activity. The average thermal output and fuel consumption value for the 3 years will be used in the equation. This data shall be reported in the CDM-PDD.

60. Total thermal output for each baseline boiler will be determined from actual measured baseline data for steam flow, pressure and temperature, using acceptable standard methods as outlined in ASME PTC 4-1998[4] or BS845[5] or other recognized national or international standard. The measurement procedure for thermal output shall be in accordance with guidance provided in the monitoring methodology. An overall uncertainty coefficient will be determined for thermal efficiency as directed in the national or international standard chosen and the efficiency adjusted upwards to compensate as per equation below.

$$\eta_{BL,i} = \eta_{BL,his,i} \times u_i \quad \text{Equation (8)}$$

[3] In case no data on steam/hot water, returned condensate/hot water is not available, use the default value of boiler efficiency (from Table 4) for new natural gas fired boiler.

[4] American Society of Mechanical Engineers Performance Test Codes for Steam Generators: ASME PTC 4 – 1998; Fired Steam Generators.

[5] British Standard Methods for Assessing the Thermal Performance of Boilers for Steam, Hot Water and High Temperature Heat Transfer Fluids.

Where:

$\eta_{BL,i}$	=	Net thermal efficiency of the boiler technology *i* using fossil fuel that would have been used in the absence of the project activity
u_i	=	Conservativeness factor, chosen from table 3 below, associated with the estimated uncertainty of the thermal efficiency measurement

61. In the case that actual baseline data for a boiler at the project activity site is not available, the following data can be used (from highest to lowest priority):

(a) Actual measurements of thermal efficiency and adjusted for conservativeness (project participants shall select (and justify) the appropriate conservativeness factor from the Table 3 below). Methods from recognized international standards shall be used to determine thermal efficiency, and uncertainty estimated (as directed in the standard). This uncertainty level shall be used to select the appropriate conservativeness factor from the table. For example, an uncertainty of 40 per cent would mean that the project participant must multiply the baseline thermal efficiency by 1.12;

(b) A conservative thermal efficiency based on other boilers in the region, which are similar to that of the boiler on the project activity site (in terms of age, technology, capacity, etc.). This shall be justified using data and/or published reports. The uncertainty level in this case will be assumed to be greater than 100 per cent unless based on assessment of the above data/information an independent expert justifies a lower level of uncertainty. The DOE is to check the credentials of the independent expert at the time of validation and also verify that there is no conflict of interest.

62. Note: this option is only valid for small boilers according to the definition provided by USEPA (output capacity below 29 MW). Large boilers are not allowed to use this option.

Table 3: Conservativeness factors[6]

Estimated uncertainty range (%)	Assigned uncertainty band (%)	Conservativeness factor where higher values are more conservative
Less than or equal to 10	7	1.02
Greater than 10 and less than or equal to 30	20	1.06
Greater than 30 and less than or equal to 50	40	1.12
Greater than 50 and less than or equal to 100	75	1.21
Greater than 100	150	1.37

(c) The highest efficiency value provided by two or more manufacturers for units with similar specifications;

(d) Use the default values from Table 4 below.[7]

[6] Annex 3 (pg. 24) of the following document (FCCC/SBSTA/2003/10/Add.2) Technical guidance on methodologies provides detailed guidance on the table of conservativeness factors: <http://unfccc.int/resource/docs/2003/sbsta/10a02.pdf>.

[7] References are contained in appendix 1.

Table 4: Default baseline efficiency for different boilers

Heat supply technology	Default efficiency
New natural gas fired boiler (w/o condenser)	92%
New oil fired boiler	90%
Old natural gas fired boiler (w/o condenser)	87%
New coal fired boiler	85%
Old oil fired boiler	85%
Old coal fired boiler	80%

63. For the purposes of this methodology, “old” boilers are boilers with an individual age of at least 15 years. Newer boilers are to be considered as “new”.

5.4.6.1.2. In case the type of heating system use boilers

64. There are two possibilities in such a system, they are:

    (a) The baseline in the project activity is the use of stoves in all buildings. A default thermal efficiency value of 85 per cent shall be used for all the stoves;

    (b) The baseline scenario includes the use of stoves along with boilers using the same fuel. The baseline thermal efficiency for each stove included in the project boundary shall be the same as the highest efficiency of boiler determined based on the previous step.

65. Project participants should justify their choice of the baseline efficiency in the CDM-PDD.

5.4.6.2. Sub-step 1.b: Fossil fuel emission factors for each identified technology *i*, shall be determined using the following guidelines for data sources

Table 5. Data source for fossil fuel emission factors for each identified technology

Data source	Conditions for using the data source
Values provided by the fuel supplier in invoices	This is the preferred source
Measurements by the project participants	If (a) is not available
Regional or national default values	If (a) is not available These sources can only be used for liquid fuels and should be based on well-documented, reliable sources (such as national energy balances)
IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol.2 (Energy) of 2006 IPCC Guidelines on National GHG Inventories	If (a) is not available

5.4.6.3. Sub-step 1.c: Baseline Losses ($Loss^{BL}_{i,y}$) for each identified technology *i* shall be determined using the following guidelines:

66. **Option 1:** a conservative value of 0 per cent of losses can be used when historic information is not available.

$Loss^{BL}_{y}$=0

67. **Option 2:** the baseline losses will be the lowest value between the following calculated values:

$$Loss^{BL}{}_{y} = min\{Loss^{BL}{}_{a,y};\ Loss^{BL}{}_{b,y}\}$$ Equation (9)

(a) Case A

$$Loss^{BL}{}_{a,y} = [(HS_{-1} - HD_{-1}) + (HS_{-2} - HD_{-2}) + (HS_{-3} - HD_{-3})]/3$$ Equation (10)

(b) Case B

$$Loss^{BL}{}_{b,y} = \left[1 - \frac{\left[\left({HD_{-1}}/{HD_{-1}}\right) + \left({HD_{-2}}/{HS_{-2}}\right) + \left({HD_{-3}}/{HS_{-3}}\right)\right]}{3}\right] \times HS_{y}$$ Equation (11)

68. Where *HS* specifies the heat generated and supplied to the distribution system and *HD* is the aggregated heat demand at the end-use points and is estimated for most recent three years (-1, -2, -3) before implementation of project activity.

5.4.6.3.1. Baseline heat demand (HD_{BL}) determination for each baseline year (for year -1 ,-2,-3) on n[th] space heat exchanger is determined as follows:

$$HD_{BL} = \sum_{n} Q_n \times T_n \times CF$$ Equation (12)

Where:

Q_n	=	Heat input to space heat exchanger *n* (for year -1 ,-2,-3) (GW)
T_n	=	Number of hours per year heat utilization at heat exchanger n
CF	=	Conversion factor from GWh to TJ (3.6)

$$Q_n = \frac{FR_n \times \Delta t_n \times 4.18}{3.6} \times 10^{-9}$$ Equation (13)

Where:

FR_n	=	Yearly (for year -1 ,-2,-3) average (prior to implementation of project activity) flow rate of water to space heat exchanger *n* (kg/hr)
Δt_n	=	Yearly (for year -1 ,-2,-3) average (prior to implementation of project activity) temperature difference between the inlet and outlet of heat exchanger *n* (C) Centigrade

5.4.7. Step 2: Determine the baseline ex post parameters of the project

5.4.7.1. Sub-step 2.a: Estimate net quantity of heat supplied by the geothermal heat resource in the project activity

69. The net quantity of heat supplied by the project activity is estimated based on the heat provided by the geothermal well. For projects that involve the expansion of a geothermal heating system, the net quantity of heat supplied by the geothermal resource is calculated first for the whole system, including baseline and CDM facilities in the calculations. The baseline emission reductions are then calculated by discounting this amount.

70. This option considers flow rates, temperature and usage time for each geothermal well to be considered by the project activity.

$$HS_y = min\{H_{CAP}, HS_{y,estimated}\}$$ Equation (14)

71. $HS_{y,estimated}$ can be determined by the use of the flow and temperature of water supplied by the substation heat exchanger *k* to the demand side space heating.

$$HS_{y,estimated} = \sum_j \left(Q_{j,d,y} \times T_j \times CF\right)$$ Equation (15)

Where:

$HS_{y,estimated}$	=	Estimated quantity of heat supplied by the geothermal heat resource(s) in the project activity, during the year *y* (TJ)
$Q_{j,d,y}$	=	Heat supplied at the downstream of heat exchanger (upstream of which is connected with water supply from the geothermal well *j)* (GW)
T_j	=	Number of hours per year heat utilization at well *j*
CF	=	Conversion factor from GWh to TJ (3.6)

$$Q_{j,d,y} = \frac{FR_{j,d,y} \times \Delta t_{j,d,y} \times 4.18}{3.6} \times 10^{-9}$$ Equation (16)

Where:

$FR_{j,d,y}$	=	Average flow rate at the downstream of heat exchanger(upstream of which is connected with water supply from the geothermal well *j*) in year *y* (kg/hr)
$\Delta t_{j,d,y}$	=	Average temperature difference between inlet and outlet temperatures at the downstream of heat exchanger (upstream of which is connected with water supply from the geothermal well *j*) in year *y* (C)

72. To ensure that the geothermal well is providing the required amount of energy a cap is defined.

73. The basis to define the cap is from the space heating design, which considers the net heating area, the heating index, the type of construction that will utilize the heat and the time used throughout the year for each construction type.

$$H_{CAP} = \left(\sum_{m} A_m \times HI_m \times T_j\right) \times CF + {Loss^{PJ}}_y - H_{ff}$$ Equation (17)

Where:

H_{CAP}	=	The net quantity of heat supplied by the geothermal heat resource(s) in the project activity, during the year *y* (TJ)
A_m	=	Net heating area for construction type *m* (m^2)
HI_m	=	Heating index for construction type *m* (GW/m^2)
T_j	=	Number of hours per year heat utilization at well *j*
CF	=	Conversion factor from GWh to TJ (3.6)
${Loss^{PJ}}_y$	=	Heat distribution losses from substation *k* to space heating areas (To be determined in Sub-step 2.b)
H_{ff}	=	Heat supplied by fossil fuel boiler, in case a boiler is used to meet the heat demand of network

5.4.7.2. Sub-step 2.b: Project emissions losses (${Loss^{PJ}}_y$)

74. Heat distribution losses will be obtained as the difference between the heat supplied by the geothermal heat source and the aggregated heat demand of the end-use points.

$${Loss^{PJ}}_y = HS_y - HD_y$$ Equation (18)

Where:

HD_y	=	Aggregate space heat demand within the area of supplied heat (TJ)

5.4.7.2.1. Heat demand determination in project scenario on l^{th} space heating exchanger can be determined as follows:

$$HD_{PR} = Q_l \times T_l \times CF$$ Equation (19)

Where:

Q_l	=	Heat input to space heat exchanger *m* (GW)
T_l	=	Number of hours per year heat utilization at heat exchanger *l*
CF	=	Conversion factor from GWh to TJ (3.6)

$$Q_l = \frac{FR_l \times \Delta t_l \times 4.18}{3.6} \times 10^{-9}$$ Equation (20)

Where:

FR_l	=	Flow rate of water from substation heat exchanger to space heat exchanger *l* (kg/hr)
Δt_l	=	Average temperature difference between outlet and inlet of heat exchanger *l* (C)

75. If it is not possible to determine HD_y, the heat losses ($Loss^{PJ}_y$) are determined based on heat losses from pipeline, valves, fittings based on maximum of following options:

(a) Design heat losses as provided by manufacturer/supplier of heating network;

(b) Measurement and estimation of surface heat losses (through radiation and convection) by measuring surface temperature (maximum), surface area of pipeline, valves and fittings (use engineering handbooks for calculating surface area of valves and fittings). Follow the recognized engineering handbooks/publications or national or international standards for calculation of surface heat losses.

5.4.8. Step 3: Calculate baseline emissions from heat produced

76. Baseline emissions from displacement of fossil fuels are calculated using equation (1).

$$BE_y = \sum_i \left(HS^{BL}{}_{i,y} \times EF_{CO2,i} / \eta_{BL,i} \right)$$ Equation (21)

77. For project activities that involve the expansion of existing geothermal facilities, emissions reductions can only be claimed if they can be attributed to the energy extracted from the new geothermal facilities brought online under CDM.

78. The methodology assumes that existing geothermal wells would be exploited to the degree described by the design capacity in the absence of the CDM project activity. This is performed by calculating the following parameter $EX_{BLwells,y}$ as follows:

$$EX_{BLwells,y} = HS_y \times (1 - DF_y)$$ Equation (22)

Where:

$EX_{BLwells,y}$	=	Heat extraction from pre-existing geothermal wells being operated fully, yet sustainably (TJ)

79. Such that baseline emissions from displacement of fossil fuels are calculated as follows for projects involving expansion of existing facilities:

$$BE_y = \sum_i \left((HS^{BL}{}_{i,y} - EX_{BLwells,y}) \times EF_{CO2,i} / \eta_{BL,i} \right)$$ Equation (23)

5.5. Project emissions

80. Project emissions are calculated taking into consideration fugitive carbon dioxide and methane released from geothermal vents (PE_{FE}), electricity consumption from the use the pumps to extract the geothermal water (PE_{EC}) and fossil fuel used to operate the geothermal facility (PE_{FF}).

$$PE_y = PE_{FE,y} + PE_{EC,y} + PE_{FF,y} \quad \text{Equation (24)}$$

Where:

PE_y	=	Project emissions during the year *y* (t CO_2e/yr)
$PE_{FE,y}$	=	Fugitive emissions of carbon dioxide and methane due to release of non-condensable gases from geothermal resources (t CO_2e/yr)
$PE_{EC,y}$	=	Project emissions from additional electricity consumption as a result of the project activity (t CO_2e/yr)
$PE_{FF,y}$	=	Project emissions from fossil fuel consumed as a direct result of the operations of the project activity (t CO_2e/yr)

81. For project activities that involve the expansion of existing facilities, project emissions are calculated as follows:

82.

$$PE_y = \left(PE_{FE,y} + PE_{EC,y} + PE_{FF,y}\right) \times f_{BL,PJ,y} \quad \text{Equation (25)}$$

83. Project emissions will necessarily be calculated for the whole heating system as all the geothermal wells will be sharing the same distribution system. Therefore, under project activities that involve the inclusion of pre-existing geothermal wells into a new system, it is necessary to exclude from project emissions calculations the emissions that result from electricity and fossil fuel consumption, and fugitive emissions from geothermal resource extraction that occur due to operation of the baseline wells and facilities (i.e. emissions that would have occurred in the baseline scenario). For this, the application of the discount factor (DF_y) calculated above would not be conservative. Therefore, the total emissions for the whole geothermal system from each of these parameters is discounted using a ratio based on actual extraction from baseline and CDM geothermal wells, as follows ($f_{BL,PJ,y}$).

5.5.1. Step 1: Calculate project emissions from fugitive emissions resulting from non-condensable gases from the geothermal vents during the year *y*

$$PE_{FE,y} = \left(W_{main,CO2} + W_{main,CH4} \times GWP_{CH4}\right) \times m_{FE,y} \quad \text{Equation (26)}$$

Where:

$PE_{FE,y}$	=	Project emissions due to release of carbon dioxide and methane from the geothermal vents during the year *y* (t CO_2e/yr)

$W_{main,CO2}$	=	Average mass fractions of carbon dioxide in the produced geothermal vent
$W_{main,CH4}$	=	Average mass fractions of methane in the produced geothermal vent
GWP_{CH4}	=	Global warming potential of methane
$m_{FE,y}$	=	The quantity of geothermal gas produced during the year *y* (t/yr)

84. Note: fugitive emissions from low temperature geothermal systems is considered negligible.

5.5.2. Step 2: Calculate project emissions from additional electricity consumption as a result of the project activity

85. Project emissions from electricity consumption (PE_{EC}) used to pump geothermal water and operate the geothermal facility shall be calculated using the latest approved version of the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption". Electricity consumption from each relevant source should be monitored and summed up to EC_y.

5.5.3. Step 3: Calculate project emissions from fossil fuel consumed as a direct result of the operations of the project activity

86. Project emissions from fossil fuel consumption (PE_{FF}) used to operate the geothermal facility will be calculated using the latest approved "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion".

5.6. Leakage

87. No leakage emissions have been identified for the project activity (L_y = 0).

5.7. Emission reductions

88. Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad \text{Equation (27)}$$

Where:

ER_y	=	Emission reductions in year *y* (t CO_2e/yr)
BE_y	=	Baseline emissions in year *y* (t CO_2e/yr)
PE_y	=	Project emissions in year *y* (t CO_2/yr)
LE_y	=	Leakage emissions in year y (t CO_2/yr)

5.8. Changes required for methodology implementation in 2nd and 3rd crediting periods

89. Should the project proponent choose a renewable crediting period, the changes required for methodology implementation in the 2nd and 3rd crediting periods will be done as follows:

90. The validity of the baseline will be assessed in terms of any changes in national and/or sectoral regulations between two crediting period, i.e. whether it would have been implemented in the absence of the project activity. The procedure outlined under baseline scenario selection and demonstration of additionality above should be used for this purpose. This has to be at the start of the new crediting period.

91. The baseline will be updated at the start of the second and third crediting period; there shall be no change in the methodology for determining the baseline emissions.

5.9. Data and parameters not monitored

Data / Parameter table 1.

Data / Parameter:	$\mathbf{TE_{BL,his,i}}$
Data unit:	MJ/yr
Description:	Average historic net thermal energy output from the baseline boiler *i*
Source of data:	Actual measurements and steam tables
Measurement procedures (if any):	Heat generation is determined as the difference of the enthalpy of the steam or hot water generated by the energy production facility(s) minus the enthalpy of the feed-water. The respective enthalpies should be determined using steam tables and/ or based on the mass (or volume) flows and the temperature. Recognised international standards such as BS845 or ASME PTC 4-1998 should be used. Overall uncertainty should also be determined as directed in the international standard
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Wherever possible, the average based on historical data of the most recent three years before the implementation of the project activity should be used

Data / Parameter table 2.

Data / Parameter:	$\mathbf{FC_{BL,his,I}}$
Data unit:	MJ/yr
Description:	Average historic fossil fuel consumption from the baseline boiler *i*
Source of data:	Actual measurements
Measurement procedures (if any):	Wherever possible, all data is to be crosschecked with fuel purchase receipts. In most cases fuel data is recorded in mass or volume units. To convert it into energy content actual measured or local data for net calorific values (NCV) of fossil fuels is to be used. If measured or local data of NCV is not available, regional data should be used, and in its absence IPCC defaults can be used from the latest version of the IPCC Guidelines for National Greenhouse Gas Inventories
Monitoring frequency:	-

QA/QC procedures:	-
Any comment:	Wherever possible, the average based on historical data of the most recent three years before the implementation of the project activity should be used

`Data / Parameter table 3.

<table>
<tr><td>Data / Parameter:</td><td>$EF_{CO2,i}$</td></tr>
<tr><td>Data unit:</td><td>t CO_2/TJ</td></tr>
<tr><td>Description:</td><td>CO_2 emission factor per unit of energy of the technology i, that would have been used in the baseline heating technology without the project activity</td></tr>
<tr><td>Source of data:</td><td>The following data sources may be used if the relevant conditions apply:
<table>
<tr><th>Data source</th><th>Conditions for using the data source</th></tr>
<tr><td>(a) Values provided by the fuel supplier in invoices</td><td>This is the preferred source</td></tr>
<tr><td>(b) Measurements by the project participants</td><td>If (a) is not available</td></tr>
<tr><td>(c) Regional or national default values</td><td>If (a) is not available.

These sources can only be used for liquid fuels and should be based on well-documented, reliable sources (such as national energy balances)</td></tr>
<tr><td>(d) IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol.2 (Energy) of 2006 IPCC Guidelines on National GHG Inventories</td><td>If (a) is not available</td></tr>
</table></td></tr>
<tr><td>Measurement procedures (if any):</td><td>For (a) and (b): Measurements should be undertaken in line with national or international standards
For (a): if the fuel supplier does provide the NCV value and the CO_2 emissions factor on the invoice and these two values are based on measurements for this specific fuel, the CO_2 factor should be used. If option (a) is not available then options (b), (c) or (d) should be used</td></tr>
<tr><td>Monitoring frequency:</td><td>-</td></tr>
<tr><td>QA/QC procedures:</td><td>-</td></tr>
<tr><td>Any comment:</td><td>Where several fuel types are used in the boiler, use the fuel type with the lowest CO_2 emission factor. Fixed as part of the first monitoring period</td></tr>
</table>

Data / Parameter table 4.

Data / Parameter:	**$\eta_{BL,i}$**
Data unit:	Dimensionless
Description:	The net thermal efficiency of heating technology *i*, using fossil fuel that would have been used in the absence of the project activity
Source of data:	Follow the guidance given in the methodology
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	**$Loss^{BL}_{i,y}$**
Data unit:	TJ/yr
Description:	The net distribution losses of the heat supply system, in the absence of project activity, during the year *y*
Source of data:	Historical records
Measurement procedures (if any):	Calculated using historical data of heat supply and heat demand
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 6.

Data / Parameter:	**Subscript i**
Data unit:	-
Description:	Type of technology used in the baseline scenario
Source of data:	Sourced from project proponent within the project boundary
Measurement procedures (if any):	Listing of technology types used in the baseline scenario for space heating
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Data shall be stored in an excel sheet/database

Data / Parameter table 7.

Data / Parameter:	**Subscript j**
Data unit:	-
Description:	Geothermal well number
Source of data:	As indicated in the project technical feasibility study
Measurement procedures (if any):	Identified by geothermal experts

Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Distinct geothermal well with distinct properties of temperature, pressure and flow volume

Data / Parameter table 8.

Data / Parameter:	**Subscript m**
Data unit:	-
Description:	Space heating construction type
Source of data:	Local government development plan or as indicated in the technical feasibility of the project activity
Measurement procedures (if any):	Identified by local urban planners under a short to medium term development plan for the area
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Areas designated for space heating under the categories of residential, commercial and industrial space heat

Data / Parameter table 9.

Data / Parameter:	**Subscript n and l**
Data unit:	-
Description:	Space heating construction type (heat exchanger) used in baseline
Source of data:	Local government development plan or as indicated in the technical feasibility of the project activity
Measurement procedures (if any):	Identified by local urban planners under a short to medium term development plan for the area
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Areas designated for space heating under the categories of residential, commercial and industrial space heat

Data / Parameter table 10.

Data / Parameter:	**Subscript k**
Data unit:	-
Description:	Sub-station number
Source of data:	As indicated in the project technical feasibility study
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	Includes a heat exchanger as part of the sub-station

Data / Parameter table 11.

Data / Parameter:	$Loss^{PJ}_{y}$
Data unit:	TJ/yr
Description:	Net distribution loss of the geothermal heat supply system during the year *y*
Source of data:	Monitoring records of heat supply and demand or heat loss measurement
Measurement procedures (if any):	(a) Either based on monitoring of heat supply and demand; or (b) Measurement and estimation of surface losses. Follow the authentic engineering handbooks/ publications or national or international standards for calculation of surface heat losses
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 12.

Data / Parameter:	w_I
Data unit:	-
Description:	Heat generation ratio for baseline heating technology *i*
Source of data:	Sampling survey in the geographical area of the project activity. The sampling size should be determined by minimum 95% confidence interval with 10% maximum error margin, or heating area serviced by each baseline technology *i* used in the buildings to be connected to the geothermal heating system
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 13.

Data / Parameter:	FR_n
Data unit:	kg/h
Description:	Three year average (prior to implementation of project activity) flow rate of water to space heat exchanger *n* (kg/hr)
Source of data:	Flow meter
Measurement procedures (if any):	Readings taken from flow meters installed at pipeline of inlet or outlet to space heat exchanger *n*. This is based on three year average meter reading
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	The flow meter readings should ensure the flow in and out of space heat

Data / Parameter table 14.

Data / Parameter:	Δt_n
Data unit:	C (Centigrade)
Description:	Yearly (for year -1 ,-2,-3) average (prior to implementation of project activity) temperature difference between the inlet and outlet of heat exchanger *n*
Source of data:	Temperature meters
Measurement procedures (if any):	Readings taken from temperature meters installed at pipeline of inlet and outlet of space heat exchanger *n*
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	The temperature meter readings should be installed at the immediate inlet and outlet point of space heat exchanger

Data / Parameter table 15.

Data / Parameter:	$\mathbf{T_n}$
Data unit:	Hours
Description:	Number of hours per year heat utilization at heat exchanger *n* (for year -1 ,-2,-3 prior to implementation of project activity)
Source of data:	Historical records
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	In case there is no historical data a default value of 2000 hours per year could be applied

Data / Parameter table 16.

Data / Parameter:	$\mathbf{Ex_{BL,design}}$
Data unit:	GJ
Description:	Design capacity for sustainable heat extraction from baseline geothermal wells
Source of data:	Post-construction extraction capacity report
Measurement procedures (if any):	n/a
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

6. Monitoring methodology

92. This methodology monitors parameters for calculation for both baseline emissions and project emissions.

93. All heat supplied to final consumers shall be measured at each substation *k* as part of the monitoring plan. For each isolated district heating network connected to a heat exchange station (*k*), the quantity of heat supplied should be measured continuously. If point of heat measurement are changed (e.g. due to a change in the heating network) or added during the crediting period, this should be documented transparently in the CDM-PDD and the monitoring reports.

94. Note that meters should be installed in a manner that ensures that only the quantity of heat supplied for space heating purposes and supplied by geothermal well only is metered and additional quantities of heat supplied for hot tap water demand within the project boundary.

95. All monitored data should be recorded in an electronic database (e.g. Excel sheets) with specifications of the points of measurement, the variable name and description, the corresponding value and unit as well as the time of measurement, the period for which the measurement is valid and the persons who are responsible for making the measurements and carry out the records. An extract of the complete database shall be included in each monitoring report.

96. Moreover, the corresponding meters will be subject to regular maintenance and calibration in order to ensure measurements with a low degree of uncertainty.

97. In addition, the monitoring provisions in the tools referred to in this methodology apply.

6.1. Data and parameters monitored

Data / Parameter table 17.

Data / Parameter:	$\Delta t_{j,d,y}$
Data unit:	C (Centigrade)
Description:	Average temperature difference between inlet and outlet temperatures at the downstream of substation heat exchanger in year (C)
Source of data:	Temperature meters installed at downstream inlet and outlet points of substation heat exchanger
Measurement procedures (if any):	Temperatures to be monitored at inlet and outlet points at downstream of heat exchanger *j*
Monitoring frequency:	Hourly
QA/QC procedures:	-
Any comment:	The heat exchanger should handle the heat supplied by geothermal well only and not by any other source. The temperature readings should be taken at immediate inlet and outlet point of heat exchanger

Data / Parameter table 18.

Data / Parameter:	$FR_{j,d,y}$
Data unit:	kg/h
Description:	Average flow rate at the downstream of heat exchanger(upstream of which is connected with water supply from the geothermal well *j*) in year *y* (kg/hr)
Source of data:	Flow meter
Measurement procedures (if any):	Readings taken from flow meters installed at downstream of heat exchanger
Monitoring frequency:	Hourly
QA/QC procedures:	Corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty
Any comment:	The heat exchanger should handle the heat supplied by geothermal well only and not by any other source

Data / Parameter table 19.

Data / Parameter:	T_j
Data unit:	Hours
Description:	Hours per hear heat utilization in well *j*
Source of data:	Data logged in the Geothermal plant
Measurement procedures (if any):	The actual number of hours heating is demanded from the residential areas
Monitoring frequency:	Yearly
QA/QC procedures:	Time given for heating services provided will be measured
Any comment:	-

Data / Parameter table 20.

Data / Parameter:	A_m
Data unit:	m^2
Description:	Net heating area for construction type *m*
Source of data:	Local development plan and/or project feasibility study. Actual measurements may also be available
Measurement procedures (if any):	Yearly measurement
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 21.

Data / Parameter:	HI_m
Data unit:	w/m^2
Description:	Heating index for construction type *m*

Source of data:	Standard index for construction type *m* as provided by the standards institute of that region or country
Measurement procedures (if any):	-
Monitoring frequency:	-
QA/QC procedures:	Data to be validated by space heating experts at the project site
Any comment:	-

Data / Parameter table 22.

Data / Parameter:	$\mathbf{H_{ff}}$
Data unit:	TJ
Description:	Heat supplied by fossil fuel boiler, in case a boiler is used to meet the heat demand of network
Source of data:	On site metering of heat (e.g. flow of steam/hot water multiplied by enthalpy) at the outlet of the boiler
Measurement procedures (if any):	-
Monitoring frequency:	Yearly
QA/QC procedures:	Meter reading should be crosschecked against fossil fuel consumption
Any comment:	Yearly average data to be used

Data / Parameter table 23.

Data / Parameter:	$\mathbf{FR_l}$
Data unit:	kg/hr
Description:	Flow rate of water from substation heat exchanger to space heat exchanger *m*
Source of data:	Flow meters reading in the heat exchanger *m*
Measurement procedures (if any):	Readings taken from flow meters installed at inlet or outlet of heat exchanger
Monitoring frequency:	Hourly
QA/QC procedures:	Corresponding meters have to be subject to regular maintenance in order to ensure measurements with a low degree of uncertainty
Any comment:	The reading should indicate the flow in heat exchanger *l* only

Data / Parameter table 24.

Data / Parameter:	Δt_l
Data unit:	C
Description:	Average temperature difference between outlet and inlet of heat exchanger *m*
Source of data:	Temperature meters installed at inlet and outlet points of heat exchanger *m*
Measurement procedures (if any):	Readings taken at immediately inlet and outlet points of heat exchanger

Monitoring frequency:	Hourly
QA/QC procedures:	-
Any comment:	The temperature readings should be taken at immediate inlet and outlet point of heat exchanger

Data / Parameter table 25.

Data / Parameter:	$\mathbf{w_{main,CO2}}$, $\mathbf{w_{main,CH4}}$
Data unit:	t/t geothermal non-condensable gas produced
Description:	Average mass fraction of carbon dioxide in the produced non-condensable gases
Source of data:	Project activity site/analysis results of samples taken
Measurement procedures (if any):	Non-condensable gases in geothermal reservoirs usually consist mainly of CO_2 and H_2S. They also contain a small quantity of hydrocarbons including predominantly CH_4 and CO_2. Non-condensable gases sampling should be carried out in production wells and at the steam field-power plant interface using ASTM Standard Practice E1675 for Sampling 2-Phase Geothermal Fluid for Purposes of Chemical Analysis (as applicable to sampling single phase steam only). The CO_2 and CH_4 sampling and analysis procedure consists of collecting non-condensable gases samples from the main line with glass flasks, filled with sodium hydroxide solution and additional chemicals to prevent oxidation. Hydrogen sulphide (H_2S) and carbon dioxide (CO_2) dissolve in the solvent while the residual compounds remain in their gaseous phase. The gas portion is then analyzed using gas chromatography to determine the content of the residuals including CH_4. All alkanes concentrations are reported in terms of methane. The non-condensable gases sampling and analysis should be performed at least every three months and more frequently, if necessary
Monitoring frequency:	Every four months
QA/QC procedures:	Measurements compared to studies conducted of the geothermal capacity by geothermal specialists. Samples are taken with a minimum 95% confidence level with an uncertainty of ±5
Any comment:	-

Data / Parameter table 26.

Data / Parameter:	$\mathbf{m_{FE,y}}$
Data unit:	tonnes/year
Description:	The quantity of geothermal non-condensable gas produced during the year *y*
Source of data:	Project activity site/meters installed at geothermal station
Measurement procedures (if any):	The non-condensable gas quantity discharged from the geothermal wells should be measured with a venture flow meter (or other equipment with at least the same accuracy)

Monitoring frequency:	Daily
QA/QC procedures:	Measurements compared to studies conducted of the geothermal capacity by geothermal specialists
Any comment:	-

Data / Parameter table 27.

Data / Parameter:	**EC_y**
Data unit:	MWh
Description:	Electricity consumption for the year *y* in operating the geothermal heating system
Source of data:	Electricity meter
Measurement procedures (if any):	Electricity meter will be installed at the geothermal well and substation. Readings will be done monthly
Monitoring frequency:	Hourly
QA/QC procedures:	Readings will be verified using monthly electricity bills
Any comment:	-

Data / Parameter table 28.

Data / Parameter:	**$FC_{i,j,y}$**
Data unit:	Mass or volume unit per year (e.g. ton/yr or li/yr)
Description:	Quantity of fuel type *I* combusted in process *j* during year *y*
Source of data:	Onsite measurements
Measurement procedures (if any):	Use mass or volume meters
Monitoring frequency:	Continuously; Yearly
QA/QC procedures:	The consistency of metered fuel consumption quantities should be cross-checked
Any comment:	To be monitored only if fossil fuel is used by the project activity or as a result of the project activity

Data / Parameter table 29.

Data / Parameter:	**$w_{C,i,y}$**
Data unit:	tC/mass unit of the fuel
Description:	Weighted average mass fraction of carbon in fuel type *i* in year *y*

Source of data:	The following data sources may be used if the relevant conditions apply: <table><tr><th>Data Source</th><th>Conditions for using the data source</th></tr><tr><td>(a) Values provided by the fuel supplier in invoices</td><td>This is the preferred source</td></tr><tr><td>(b) Measurements by the project participants</td><td>If (a) is not available</td></tr><tr><td>(c) IPCC default values</td><td>If (a) is not available</td></tr></table>
Measurement procedures (if any):	Measurements should be undertaken in line with national or international fuel standards
Monitoring frequency:	Yearly
QA/QC procedures:	Verify if the values under (a) and (b) are within the uncertainty range of the IPCC default values as provided in Table 1.2, vol.2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories in (b) should have ISO 17025 accreditation or justify that they can comply with similar quality standards
Any comment:	To be monitored only if fossil fuel is used by the project activity or as a result of the project activity

Data / Parameter table 30.

Data / Parameter:	$\rho_{i,y}$
Data unit:	Mass unit/volume unit
Description:	Weighted average density for fuel type *i* in year *y*

<table>
<tr><td>Source of data:</td><td>The following data sources may be used if the relevant conditions apply:
<table>
<tr><th colspan="2">Data Source</th><th>Conditions for using the data source</th></tr>
<tr><td>(a)</td><td>Values provided by the fuel supplier in invoices</td><td>This is the preferred source if the carbon fraction of the fuel is not provided</td></tr>
<tr><td>(b)</td><td>Measurements by the project participants</td><td>If (a) is not available</td></tr>
<tr><td>(c)</td><td>Regional or national default values</td><td>If (a) is not available

These sources can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances)</td></tr>
<tr><td>(d)</td><td>IPCC default values att he upper limit of the uncertainty at a 95% confidence interval as provided in Tale 1.2 of Chapter 1 of Vol.2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories</td><td>If (a) is not available</td></tr>
</table>
For (a) and (b): The NCV should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
For (c): Review appropriateness of the values annually
For (d): Any future revision of the IPCC Guidelines should be taken into account.</td></tr>
<tr><td>Measurement procedures (if any):</td><td>For (a) and (b): Measurements should be undertaken in line with national or international fuel standards</td></tr>
<tr><td>Monitoring frequency:</td><td>Yearly</td></tr>
</table>

QA/QC procedures:	Verify if the values under a) and (b) are within the uncertainty range of the IPCC default values as provided in Table 1.2, vol.2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories in b) should have ISO 17025 accreditation or justify that they can comply with similar quality standards
Any comment:	To be monitored only if fossil fuel is used by the project activity or as a result of the project activity

Data / Parameter table 31.

Data / Parameter:	$Ex_{BL,y}$
Data unit:	GJ
Description:	Actual quantity of heat extracted from baseline geothermal wells in year *y*
Source of data:	Actual measurements
Measurement procedures (if any):	To be performed in line with national standards
Monitoring frequency:	Continuously
QA/QC procedures:	Calculated based on operational data. Calculations to be made available to DOE at verification
Any comment:	-

Data / Parameter table 32.

Data / Parameter:	$Ex_{NEW,y}$
Data unit:	GJ
Description:	Actual quantity of heat extracted from new geothermal wells in year *y*
Source of data:	Actual measurements
Measurement procedures (if any):	To be performed in line with national standards
Monitoring frequency:	Continuously
QA/QC procedures:	Calibration of equipment to be in line with manufacturer’s guidelines
Any comment:	-

Data / Parameter table 33.

Data / Parameter:	$Ex_{NEW,design}$
Data unit:	GJ
Description:	Design capacity for sustainable heat extraction from new geothermal wells
Source of data:	Post-construction extraction capacity report

Measurement procedures (if any):	Analysis to be in line with regional or national standards
Monitoring frequency:	-
QA/QC procedures:	To be updated in line with national regulations
Any comment:	-

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Appendix 1. Source of data and reference for the default efficiency values provided in table 1

Table 1. Source of data and reference for the default efficiency values

Heat supply system	LHV Efficiency	Source
Gas fired boilers	75-92%	Efficiency of gas boilers. Source: Beijing Heating Energy Conservation Project, World Bank 2005 - internal working note
Oil fired boilers	82% (Range: 65-90%)	Average value of sample measurements in 80 existing oil-fired boilers in Peru. Source: Herold / Schneider / Vizcarra (2003): Improving Energy Efficiency in Peruvian Boilers with the CDM. GTZ/Öko-Institut, Berlin, January 2003
Coal fired boiler	85%	Age: new, condition: excellent, remaining lifetime: many years. Poland. Source: Coal to Gas Conversion Project, GEF Project Document, Report No: 13054, 1994/10/31
Coal fired boiler	65%	Age: middle, condition: good, remaining lifetime: several years. Poland. Source: Coal to Gas Conversion Project, GEF Project Document, Report No: 13054, 1994/10/31
Coal fired boiler	50%	Age: old, condition: poor/fair, remaining lifetime: none/few years. Poland. Source: Coal to Gas Conversion Project, GEF Project Document, Report No: 13054, 1994/10/31
Coal-fired boiler	80%	Efficiency of heat-only boiler in good condition. Estimate of Chinese expert. Source: Personal communication from COWI

Heat supply system	LHV Efficiency	Source
Coal fired boiler	45-75%	Average efficiency of heat-only boilers (depending on size, year, location as well as operation and management). Estimate of Chinese expert. Source: Personal communication from COWI
Coal-fired boiler	above 80%	Efficiency level for coal-fired industrial boilers in developed countries. Source: China: Efficient industrial boilers, GEF Focal area: Climate Change, <http://www.gefweb.org/COUNCIL/council7/wp/china_br.htm>
Coal fired boiler	60-65%	Typical efficiency levels for Chinese coal-fired industrial boilers. Source: China: Efficient industrial boilers, GEF Focal area: Climate Change, <http://www.gefweb.org/COUNCIL/council7/wp/china_br.htm>
Coal fired boiler	65% (70-80%)	Efficiency of a coal fired industrial boiler (under operation) in 2000 (2010). Source: China Medium and Long Term Energy Conservation Plan, November 25, 2004, National Development and Reform Commission, Table 2. Energy Efficiency Indicators of Major Energy Consuming Equipment
Coal fired boiler	50-75%	Efficiency of coal boilers. Source: Beijing Heating Energy Conservation Project, World Bank 2005 - internal working note

Document information

Version	*Date*	*Description*
03.0	31 May 2013	EB 73, Annex 6 The revision corrects mistakes in equations 13, 16 and 20 by changing ^-8 to ^-9.
02	16 October 2009	EB 50, Annex 8 The methodology was revised in response to AM_REV_0155, to broaden the applicability to project activities that expand the operation of an existing geothermal heating system through adding extra geothermal wells.
01.1	8 October 2008	Editorial revision to: Correct the title of "Tool to calculate baseline, project and/or leakage emissions from electricity consumption"; Correct the definition of the equation HS_y.
01	26 September 2008	EB 42, Annex 3 Initial adoption.

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