Adaptation Benefit Mechanism Methodology

ABM- NM001: Reduction of food losses of stored potatoes through improved storage facilities

Version 1.0

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1. Introduction

Changes in ambient temperatures as well as extreme weather events, both effects of climate change, threaten agricultural production and productivity through shortages in freshwater resources and increased crop perishability and post-harvest losses. This results in increased food insecurity, malnutrition and a decrease of income. The installation of improved storage systems counteracts the negative impacts of climate change during the food storage period and decouples food losses from rising temperatures. This contributes to increasing the resilience of farmers and ensures a continuous supply of food and income.

This baseline and monitoring methodology has been developed for ABM activities focusing on the reduction of food losses of stored potatoes through making available funding to cover the high upfront investment for improved storage facilities that prevent the tubers from rotting due to increased ambient temperatures. The targeted beneficiaries are smallholder farmers and farmers' cooperatives that typically store their crops in simple, non-refrigerated facilities such as wooden sheds. In the project area, these groups are strongly dependent on the cultivation of potatoes which represents a key source of income and is a key pillar of food security.

Apart from the adaptation benefits, the project enables several sustainable development benefits, such as job creation, economic growth and the provision of access to sustainable energy. By fully relying on sustainable and green cooling technology, the activity also generates mitigation co-benefits. Thereby, it supports the requirement to align with the long-term temperature goal of the Paris Agreement, as stipulated by Article 6.8 of the Paris Agreement.

Table 1 describes the key aspects of the methodology.

Table 1. Methodology key elements

Typical activities:	Installation of an improved storage technology that improves the shelf life of ware and seed potatoes and reduces the risk of rotting due to inappropriate storage conditions, such as high storage temperatures. Such storage facilities can include, among others, cooling technology powered by solar photovoltaic (PV) and use of refrigerants with negligible global warming potential (GWP) and no adverse environmental effects that guarantees adequate storing conditions for ware and seed potatoes, as well as (in some circumstances) diffused light stores (DLS). The storage facility is used by farmers to store the harvested potatoes for seed, home consumption or sale for a longer period (longer than two months). It replaces simple storage facilities, such as simple wooden sheds, which do not guarantee appropriate storage conditions.

Associated Adaptation Benefits	The ABM activity will contribute to reduced impacts of higher ambient temperatures due to climate change resulting in reduced vulnerability and strengthened resilience of farmers by
	• Direct benefits
	  ▪ Reduction of losses of stored crops that would occur due to increased temperatures
	• Indirect benefits
	  ▪ Increased food availability for farmers and other consumers
	  Increased income for farmers due to reduced perishability and post-harvest losses

Associated SDG Benefits	• SDG 2: Zero hunger
	  ▪ S.2.3.2: Average income of small-scale food producers, by sex and indigenous status
	• SDG 7: Affordable and clean energy
	  ▪ S.7.1.1: Proportion of population with access to electricity
	• SDG 8: Decent work and economic growth
	  ▪ S.8.1.1: Annual growth rate of real GDP per capita
	  ▪ S.8.4.2: Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP
	• SDG 12: Responsible consumption and production
	  ▪ S.12.3.1: Global food loss index

Other Benefits	• Avoidance of fuel imports • Avoidance of greenhouse gas emissions and mitigation of the same
Adaptation Benefit quantified for issuance of Adaptation benefits (ABs)	There are two possibilities to determine ABs: ABs are calculated as (I). the quantity of ware and seed potatoes (tonnes) protected from decay due to increased temperature control by the activity; **OR** (II). the amount of saved wealth (USD) due to decreased risk of rotting of ware and seed potatoes.

2. Scope, applicability, and entry into force

2.1. Scope

The methodology covers the introduction of improved storage practices and technologies which extend the shelf life of ware and seed potatoes and reduce the risk of rotting due to inappropriate storage conditions, such as high storage temperatures. Principally, different technologies are eligible, such as Diffused Light Storage (DLS) or artificial cooling systems. In case of the installation of green cooling technology, the cold store employs an energy efficient cooling system which utilizes environmentally friendly refrigerants having no ozone depleting potential (ODP) and negligible global warming potential (GWP) and which is powered by solar PV.

2.2. Applicability

1. The methodology is only applicable in line with Article 6.8 of the Paris Agreement. Thus, activity developers need to demonstrate that the activity:

    (a) is an integrated, innovative and transformational action that has significant potential to deliver higher adaptation ambitions;

    (b) supports the implementation of NDCs of host Parties and contributes to achieving the long-term temperature goal of the Paris Agreement;

    (c) is conducted in a manner that respects, promotes and considers respective obligations of Parties on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity, consistent with the eleventh preambular paragraph of the Paris Agreement;

    (d) minimizes and, where possible, avoids negative environmental, economic and social impacts.

2. The methodology is applicable to small-scale potato farmers in regions which are generally suitable for potato production and are undergoing an increase in mean temperature due to climate change. Activity developers need to show that available climate models for the area project a temperature increase in the activity area until the end of the technical lifetime. During this period, it can plausibly be shown that potato production is still viable given projected changes in temperature.

3. The activity must only cover potato production of small-scale farmers and farmers' cooperatives', with average field size below 2 ha.[1]

4. The potatoes must be stored for a period longer than two months.

5. Activity developers must demonstrate that the activity takes place in a climate change vulnerability context, addresses that vulnerability context, and displays a clear, direct and

[1] According to Rapsomanikis, George (2015): The economic lives of smallholder farmers. An analysis based on household data from nine countries, FAO, Rome; Janssens, S.R.M.; Wiersema, S.G., Goos, H., Wiersma, W. (2013): The value chain for seed and ware potatoes in Kenya. Opportunities for development. LEI Wageningen UR, Den Haag

coherent link between the intervention and the said vulnerability context. This needs to be demonstrated by a results chain analysis.

6. Activity developers must demonstrate that in the activity area the maximum ambient air temperature is likely to exceed a critical value of 12.0°C[2] during the average storage period throughout the technical lifetime of the improved storage technology.

7. Activity developers must show that there is no private or public finance available at that moment or planned within the next five years to fully cover the costs for installation of the improved storage facility as well as installation, operation and maintenance costs (co-financing is acceptable).

8. Improved storage facilities must guarantee adequate storage conditions for ware and seed potatoes to reduce rotting as follows:

    (a) Storage temperature of 8°C must be guaranteed.[3] [4]

    (b) If green cooling technology is to be installed:

    (c) Cooling technology must utilize refrigerants with no ODP and a negligible GWP.

    (d) Cooling technology shall demonstrate a high energy efficiency.

    (e) Cold store and cooling equipment must be powered by renewable energy (solar PV or wind).

    (f) The activity operator must guarantee safe handling and operation of system including regular servicing of the equipment and, if necessary, provide adequate training to the operating and servicing personnel.

9. Activities must be greenfield activities where no improved storage facilities are existing yet and are not mandated by law or are considered common practice.

10. Activities are deemed automatically additional if it is demonstrated that all of the following conditions are met:

    (a) The farm size is below 2 ha.

    (b) Cooling technology utilizes a natural refrigerant whose supplies is guaranteed, and avoiding regulated substances.

    (c) There is a financing gap that prevents smallholders and communities to invest in improved storage facilities and to fully cover the costs for installation of the facility including the ancillary systems as well as installation, operation, and maintenance costs.

[2] According to Winkler et al. (2018) storage temperature should start at 12°C, Winkler, J.A., Soldo, L., Tang, Y. et al. (2018): Potential impacts of climate change on storage conditions for commercial agriculture: an example for potato production in Michigan, in: Climatic Change, 151, p. 275–287

[3] According to Winkler et al. (2018) a base temperature of 8°C need to be reached for long-term storage.

[4] If DLS shall be applied, it must be demonstrated how storage temperature of 8°C can be continuously ensured over the entire storage period.

3. Normative references

This methodology is based on elements from the CDM methodology “AMS-III.AB.: Avoidance of HFC emissions in Standalone Commercial Refrigeration Cabinets (Version 1.0), AMS-III.X.: Energy Efficiency and HFC-134a Recovery in Residential Refrigerators” (Version 2.0).

4. Definitions

For the purpose of this methodology following definitions shall apply:

(a) **Improved storage facility** – A storage facility which is leading to lower food losses than storage facilities used under business as usual conditions.

(b) **Cold store** – A room which is artificially cooled by using cooling technology in order to preserve food at low temperatures.

(c) **Energy efficient and climate-friendly cooling technology –** A technology that utilizes cooling equipment with a high energy efficiency ratio (EER) and refrigerants with no ODP and negligible GWP below 5.

(d) **Solar photovoltaic (PV) powered technology -** A technology that produces electricity from solar sources that is used to power the cold store and cooling technology.

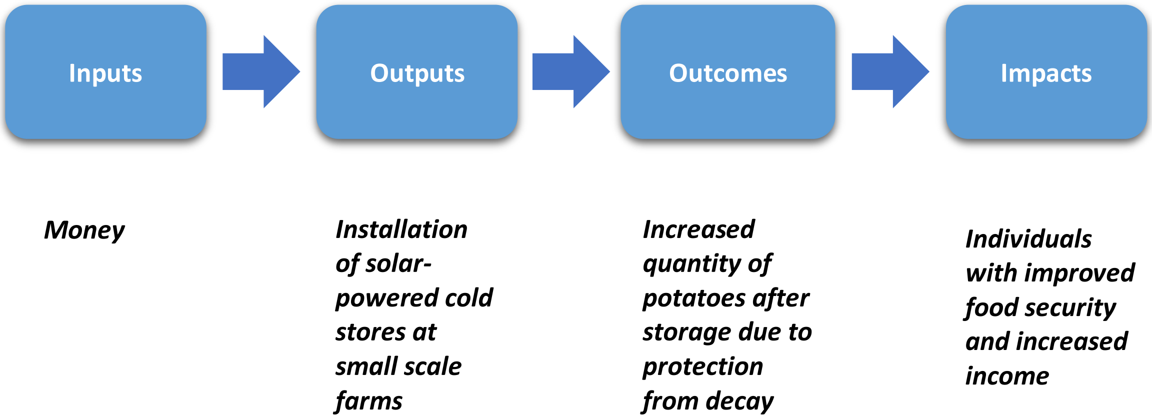
(e) **Greenfield activities** – Greenfield activities are new activities constructed and operated at a site where no cold store or no cooling technology was installed prior to the implementation of the activity.

(f) **Diffused Light Storage (DLS)** – A seed potato storage technology made from locally available materials. The concept of a DLS involves storing seed potato in a natural, diffused light (indirect sunlight) structure with good ventilation. Tubers are stored in shelves, trays or crates up to three layers high.

5. Result chain for adaptation benefits

The methodology is based on the assumption that smallholder farmers and farmer cooperatives have been experiencing heavy losses and will experience increasingly higher crop losses during the storage phase due to rising temperatures caused by climate change. Especially in the case of potato cultivation, farmers do not have the necessary storage technologies to counteract crop post-harvest losses. As a result, appropriate improved storage technologies are implemented and used, thereby increasing the quantity of potatoes available for use/sale after the harvest. Ultimately, the decrease in potato losses leads to improved food security and higher incomes of smallholder farmers (see graph below).

Figure 1: Result chain for the adaptation benefits



6. Baseline methodology

6.1. ABM activity boundary

The physical, geographical site of the improved storage technology and the geographical area dedicated to potato production by small-scale farmers and farmer cooperatives delineates the activity boundary.

6.2. Adaptation Benefits

6.2.1. Definition of Adaptation Benefit

Adaptation benefits are calculated using Certified Adaptation Benefits (ABs) as measurement unit. One AB equals to

(I). the volume of ware and seed potatoes (tonnes) protected from decay due to increased temperature by the activity (1 AB = 1 tonne); **OR**

(II). the amount of saved wealth (USD) due to decreased risk of rotting of ware and seed potatoes (1 AB = 1 USD).

6.2.2. Definition of the adaptation baseline scenario

The activity proponent shall demonstrate that in the absence of the activity the communities where the improved storage technology will be installed would have been using simple potato storage facilities.

6.2.3. Adaptation baseline

The quantity of potatoes that can be stored in adequate storage facilities is considered 0 since no cold store with adequate storage conditions or cooling system exists in the activity area in the baseline year.

The baseline is calculated using the concept of Storage Degree Days (SDDs). SDDs accumulate when ambient temperatures exceed the specific storage base temperature for crops. Rising ambient temperatures therefore can lead to an increase in SDD accumulation.[5]

The baseline is determined as follows

(I.) as the quantity of potatoes that are in good quality after storage:

$$NB_{P,y} = QB_{P,y} * \left(1 - \frac{SDD_y - SDD_{pre-cc}}{SDD_{pre-cc}}\right) \tag{1}$$

Where

$NB_{P,y}$ = quantity of good quality potatoes after storage in year y (tonnes)
$QB_{P,y}$ = quantity of potatoes stored in storing facility in year y (tonnes)
SDD_y = Storage Degree Days during storage period in year y in °C[6]
SDD_{pre-cc} = Average Storage Degree Days during storage period in pre-climate change period (for at least 3 years pre-1990) in °C

$$SDD_y = \sum \Delta SDD_{y,d} \tag{2}$$

Where

$\Delta SDD_{y,d}$ = daily incremental SDD during storage period in year y in °C

$$\Delta SDD_{y,d} = max\,(t_{average,d,y} - t_{base}, 0) \tag{3}$$

Where

$t_{average,d,y}$ = average temperature on day d in year y in °C
Data on projected average daily temperatures may be derived from official documents including climate change modelling, trends and scenarios for the activity country or region, such as for example National Adaptation Plans (NAPs), Adaptation Communications (ACs) or National Communications to the UNFCCC.

[5] According to Lesinger et al. (2020): Impact of climate change on storage conditions for major agricultural commodities across the contiguous United States

[6] "SDDs are accumulated whenever ambient temperatures are higher than the storage base temperature required for potatoes." (Lesinger et al. 2020)

t_{base} = storage base temperature required for potatoes (12 °C)[7]

$$SDD_{pre-cc} = average\ (\Delta\ SDD_{pre-cc,d}) \tag{4}$$

Where

$\Delta SDD_{pre-cc,d}$ = daily incremental SDD during storage period in the pre-climate change period (before 1990) in °C

(II.) as the amount of economic losses of the potatoes in storage:

$$Eclos_{BL,P,y} = QB_{P,y} * (\frac{SDD_y - SDD_{pre-cc}}{SDD_{pre-cc}}) * MV_{BL,P,y} \tag{5}$$

Where

$Eclos_{BL,P,y}$ = economic losses of potatoes due to climate change in storage in year y (USD)
$MV_{BL,P,y}$ = market value of potatoes in the activity area during storage period in year y (USD/tonne)

6.2.4. Adaptation activity scenario

The adaptation activity scenario is determined as follows:

(I.) as the quantity of potatoes that can be stored in the improved storage facility and thus are protected from rotting due to temperature increases:

$$N_{P,y} = Q_{PSt,y} * (1 - PL_{St,y}) \tag{6}$$

Where

$N_{P,y}$ = Quantity of potatoes protected from rotting due to temperature increases by the activity in year y (tonnes)
$Q_{PSt,y}$ = Quantity of potatoes stored in improved storage facility in year y (tonnes)
PL_{Sty} = Average potato losses in year y (share) in improved storage;

[7] According to Winkler et al. (2018) storage temperature should start at 12°C, Winkler, J.A., Soldo, L., Tang, Y. et al. (2018): Potential impacts of climate change on storage conditions for commercial agriculture: an example for potato production in Michigan, in: Climatic Change, 151, p. 275–287

If no country specific, reliable data exists for ex-ante determination of average potato losses in the respective improved storage facility, a default value of 5% may be applied[8]

(II.) as the amount of economic losses of potatoes in storage:

$$Eclos_{P,y} = Q_{PSt,y} * PL_{St,y} * MV_{P,y} \quad (7)$$

Where

$Eclos_{P,y}$ = economic losses of potatoes in storage in year (USD)
$MV_{P,y}$ = market value of potatoes in the activity area during storage period in year y (USD/tonne)

6.2.5. Quantification of the Adaptation Benefits of the activity

Adaptation benefits are calculated as follows:

(I.) the quantity of ware and seed potatoes (tonnes) protected from rotting due to temperature increases by the activity

$$AB_y = N_{P,y} - NB_{P,y} \quad (8)$$

Where

AB_y = total volume of ABs generated in year y (tonnes)

(II.) as the amount of saved wealth due to decreased risk of rotting of potatoes

$$AB_y = SW_{P,y} = Eclos_{BL,P,y} - Eclos_{P,y} \quad (9)$$

Where

$SW_{P,y}$ = saved wealth in activity year y (USD)
AB_y = total volume of ABs generated in year y (USD)

6.2.6. Adaptation Benefit issuance period

The issuance of ABs shall be realized over the lifetime of the improved storage facility, but shall not exceed a duration of maximum 15 years.

[8] Khanal and Bhattarai (2020) identified average losses of potatoes to be on average 4.38% (±0.68%) improved stores; Khanal, Shraddha; Bhattarai, Kabindra (2020): Study on post-harvest losses of potato in different storage conditions, in: Journal of Food Science and Technology Nepal, 12, p. 14-19

6.3. Mitigation co-benefits

6.3.1. Definition of the mitigation co-benefits

Mitigation co-benefits (i.e., emission reductions) are calculated using t/CO_2eq as measurement unit. Definition of the mitigation co-benefits associated with the use of an improved storage facility is described in the following sections.

6.3.2. Definition of the mitigation baseline scenario

Baseline emissions are assumed equal to the emissions that would be generated if the temperature in the improved storage facility would be achieved by a technology with low energy efficiency. If the improved storage facility uses artificial cooling on the basis of electricity, the most-prevalent refrigerant for cold stores and connection to the electricity grid would be assumed.

6.3.3. Baseline emissions

The baseline emissions consist of direct and indirect emissions. Direct baseline emissions are calculated for refrigerants with a high GWP (GWP > 1000) that would be used in a similar cooling system (i.e., with similar technical specifications, such as cooling capacity), applying the same emissions factors for leakage during servicing and disposal of the cooling system as for the cooling technology implemented under the activity scenario. Indirect baseline emissions are calculated assuming that the cold store is connected to the local electricity grid and would consume the same amount of electricity as generated by the PV system installed under the activity scenario.

$$BE_{y} = BE_{dir,y} + BE_{ind,y} \tag{10}$$

Where

BE_y = total baseline emissions in year y (tCO_2e)
$BE_{dir,y}$ = direct baseline emissions in year y (tCO_2e)
$BE_{ind,y}$ = indirect baseline emissions in year y (tCO_2e)

Direct baseline emissions:

$$BE_{dir,y} = BE_{SB,y} + BE_{DB,y} \tag{11}$$

Where

$BE_{SB,y}$ = baseline emissions for the cold store entering the servicing boundary within the year y (tCO_2e)
$BE_{DB,y}$ = baseline emissions for the cold store entering the disposal boundary within the year y (tCO_2e)

$$BE_{SB,y} = R * EF_{SB} * GWP_{ref} * \frac{1}{1000} \quad (12)$$

$$BE_{DB,y} = R * EF_{DB} * GWP_{ref} * \frac{1}{1000} \quad (13)$$

Where

R = initial refrigerant charge (kg)
EF_{SB} = fugitive emission factor of refrigerant during servicing of cooling system expressed as fraction of initial charge (%)
EF_{DB} = fugitive emission factor of refrigerant during disposal of cooling system expressed as fraction of initial charge (%)
GWP_{ref} = global warming potential of high GWP refrigerant

Indirect baseline emissions:

$$BE_{ind,y} = EC_{BL,y} * EF_{grid,y} * (1 + TD_y) \quad (14)$$

Where

$EC_{BL,y}$ = baseline electricity consumed in year y (MWh)
$EF_{grid,y}$ = electricity grid emission factor for year y (tCO_2e/MWh)
TD_y = average technical grid losses in year y (%)

For DLS systems, baseline emissions are deemed to be zero.

6.3.4. Activity emissions

Activity emissions consist of direct and indirect emissions. Direct emissions are calculated for the negligible GWP refrigerant used in the cooling system, applying the same emissions factors for leakage during servicing and disposal as in the baseline scenario. It is assumed that indirect emissions do not occur as the cooling system is based on renewable sources of energy.

$$AE_y = AE_{dir,y} + AE_{ind,y} \quad (15)$$

Where

AE_y = total activity emissions in year y (tCO_2e)
$AE_{dir,y}$ = direct activity emissions in year y (tCO_2e)
$AE_{ind,y}$ = indirect activity emissions in year y (tCO_2e)

Direct activity emissions:

$$AE_{dir,y} = AE_{SB,y} + AE_{DB,y} \quad (16)$$

Where

$AE_{SB,y}$ = activity emissions for the cold store entering the servicing boundary within the year y (tCO_2e)

$AE_{DB,y}$ = activity emissions for the cold store entering the disposal boundary within the year y (tCO_2e)

$$AE_{SB,y} = R * L_{SB,y} * GWP_{neg.ref} * \frac{1}{1000} \quad (17)$$

$$AE_{DB,y} = R * L_{DB,y} * GWP_{neg.ref} * \frac{1}{1000} \quad (18)$$

Where

R = initial refrigerant charge (kg)

$GWP_{neg.ref}$ = global warming potential of hydrocarbon (HC) or other negligible GWP refrigerants

$L_{SB,y}$ = leakage of refrigerant during servicing of cooling system expressed as fraction of initial charge (%)

$L_{DB,y}$ = leakage of refrigerant during disposal of cooling system expressed as fraction of initial charge (%)

Indirect activity emissions:

No indirect activity emissions are assumed since the cooling system is based on renewable energy (PV/wind), thus

$$PE_{ind,y} = 0 \quad (19)$$

For DLS systems, baseline emissions are deemed to be zero.

6.3.5. Quantification of the mitigation co-benefits

Mitigation benefits of the activity are calculated as follows:

$$ER_y = BE_y - AE_y \quad (20)$$

Where

ER_y = emission reductions in year y (tCO_2e)

BE_y = baseline emissions in year y (tCO_2e)
PE_y = activity emissions in year y (tCO_2e)

7. Monitoring methodology

Relevant parameters shall be monitored as indicated in the table below. The applicable requirements specified in the “General guidelines for SSC CDM methodologies” (e.g., calibration, sampling) are also an integral part of the monitoring guidelines specified below and therefore shall be referred to by the activity participants.

Monitoring shall take place over the lifetime of the improved storage facility. The average lifetime of the facility is assumed to be 10-15 years.

7.1. Data and parameters monitored

Data / Parameter table 1.

Data / Parameter:	**$t_{average,d,y}$**
Data unit:	°C
Description:	Continuous recording of outside temperature
Source of data:	Nearest weather station
Measurement procedures (if any):	Recording of daily minimum and maximum temperature
Monitoring frequency:	Daily recording
QA/QC procedures:	
Any comment:	-

Data / Parameter table 2.

Data / Parameter:	**t_{base}**
Data unit:	°C
Description:	Continuous operation of the improved storage facility to reach a temperature below 12°C
Source of data:	-
Measurement procedures (if any):	Continuous measurement of inside temperature by automated temperature recording through sensor
Monitoring frequency:	Continuous monitoring, hourly measurement and at least monthly recording
QA/QC procedures:	
Any comment:	-

Data / Parameter table 3.

Data / Parameter:	**$Q_{PST,y}$**
Data unit:	tonnes
Description:	Quantity of potatoes stored in improved storage facility in year y

Source of data:	Operator of improved storage facility
Measurement procedures (if any):	Inventory/recording of improved storage facility
Monitoring frequency:	Every time the improved storage facility is loaded
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	**$PL_{St,y}$**
Data unit:	%
Description:	Loss factor in improved storage facility
Source of data:	Operator of improved storage facility
Measurement procedures (if any):	Inventory/recording of improved storage facility operator
Monitoring frequency:	Every time the improved storage facility is unloaded
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	**$MV_{P,y}$**
Data unit:	USD/tonne
Description:	Market value of potatoes in the activity area in year y
Source of data:	a) Local market/ buyers b) Regional/ national data, e.g., FAO statistics
Measurement procedures (if any):	-
Monitoring frequency:	yearly/ during storage period
QA/QC procedures:	-
Any comment:	-

Data / Parameter table 6.

Data / Parameter:	**$EC_{BL,y}$**
Data unit:	MWh
Description:	Electricity consumed by improved storage facility in year y
Source of data:	Electricity meter connected to the electricity generation facility/grid
Measurement procedures (if any):	Meter readings
Monitoring frequency:	yearly
QA/QC procedures:	Meter shall be calibrated according to national standards
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	$L_{SB,y}$ $L_{DB,y}$
Data unit:	%
Description:	Refrigerant refilled during service of cooling system/ equipment in year y expressed as fraction of initial charge
Source of data:	Operator of improved storage facility / service technician
Measurement procedures (if any):	Service book of improved storage facility operator
Monitoring frequency:	yearly
QA/QC procedures:	
Any comment:	-

Document information

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1.0	12/02/2021	Draft methodology
1.0	18/02/2022	Revised methodology
1.0	14/09/2022	Revised methodology