3.5 Water Resource Sector

3.5.1 Preconditions for the sector

In the Water Resource Sector, GHG emission reduction activities can be classified into the following two activities;

1) Reduction of the amount of water supply
2) Improvement of energy consumption efficiency in waterworks facilities

3.5.2 Summary of quantification methods

The summary of quantification methods in the Water Resource sector is as follows;

Table 3.5.1 Summary of quantification methods in Water Resources sector

Item	Component	Quantification methods
Common item	GHG emission from electricity consumption	Electricity consumption × CO_2 emission factor of electricity generation
Reduction of water purification, transmission, and distribution	Leakage control Installation of water – saving devices	Reduction of electricity consumption through reduction of water delivered
Improvement of energy consumption efficiency in waterworks facilities	Improvement of water distribution system (e.g. application of gravity distribution)	Reduction of energy consumption through improvement of energy consumption in the water utility

3.5.3 GHG emission reduction activities of JICA projects

Project examples listed in Table 3.5.2 consist of the projects that were recognized to be effective for mitigation of climate change in the research called "JICA's Assistance for Mitigation to Climate Change - The Co-Benefits Approach to Climate Change". And they also include the projects that JICA specified as the mitigation projects from JICA projects of year 2008.

Therefore, these project examples do not contain all of JICA projects. In other words, there are other JICA projects with other GHG reduction components shown in Table 3.5.2.

Table 3.5.2 GHG emission reduction activities of JICA projects

Project example	**Reduction of water purification, transmission and distribution**			**Improvement of energy consumption efficiency in waterworks facility**
	Leakage control	**Installation of water saving devices**	**Technical cooperation and training regarding water saving and leakage control**	**Improvement of water distribution system (e.g. application of gravity distribution)**
Leakage control <u>Representative project</u> Capacity Development Project for Non-Revenue Water Reduction in Jordan	○			
Policy of waterworks <u>Representative project</u> Water Supply Policy Adviser in Indonesia			○	
Maintenance of waterworks facilities <u>Representative project</u> Capacity Building of Water Maintenance in Jamaica	○	○	○	○
Establishment of water saving society <u>Representative project</u> Model Planning Project for Water Saving Society in China			○	
Enhancement of water supply system <u>Representative project</u> Study on Augmentation of Water supply and Sanitation for the Goa State in the Republic of India	○			○
Study on water supply system <u>Representative project</u> Study on the Sustainable, Automatic Drinking Water Supply Program in the South region of Madagascar	○			

3.5.4 Summary of GHG emission reduction scenarios and quantification sheet by activity

GHG emission reduction components are categorized as shown in the chart below.

The sector consists of two types of activities; 1) Reduction of the amount of water supply and 2) Improvement of energy consumption efficiency in water works facilities.

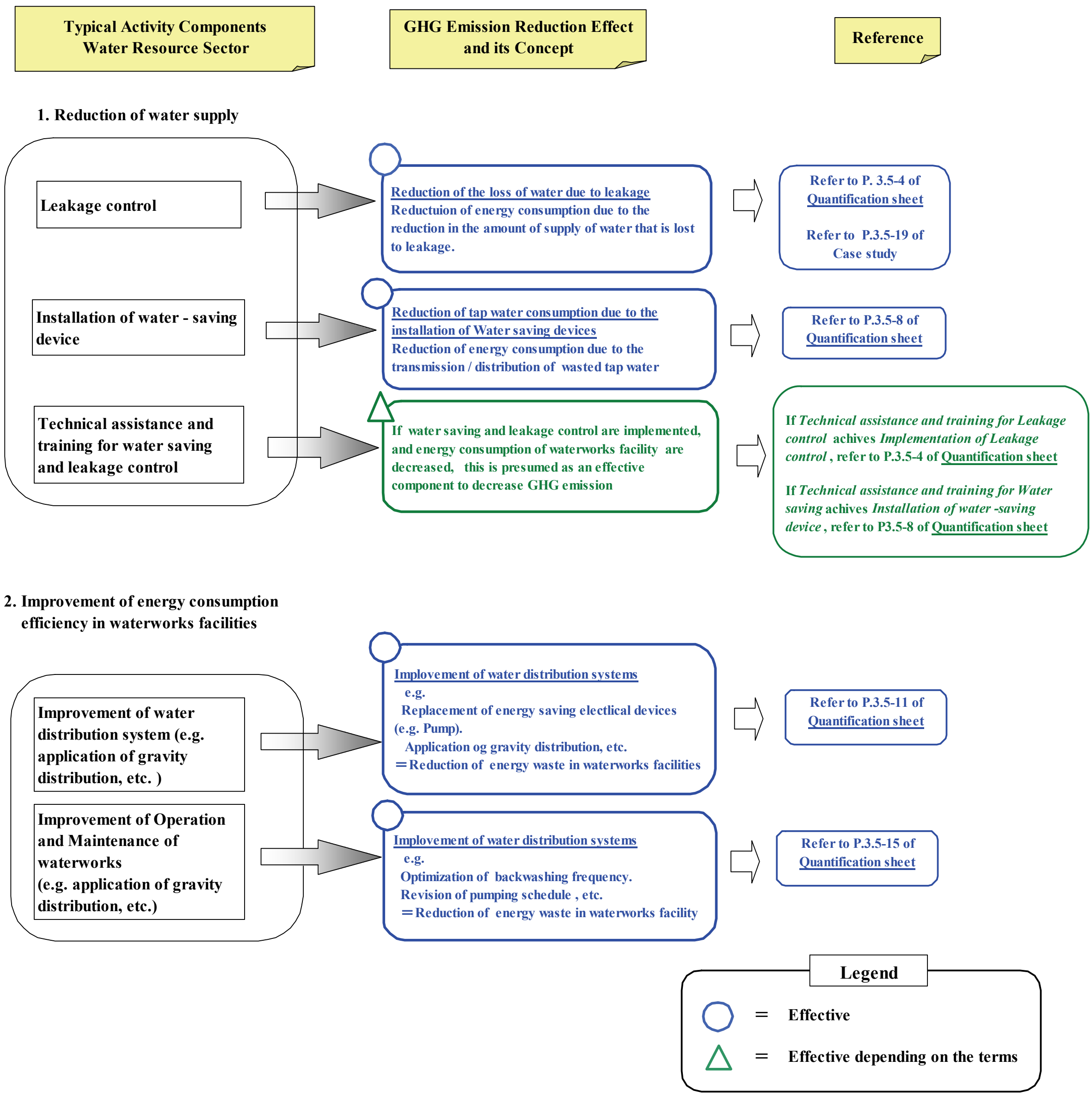


Figure 3.5.1 Quantification possibility of each component

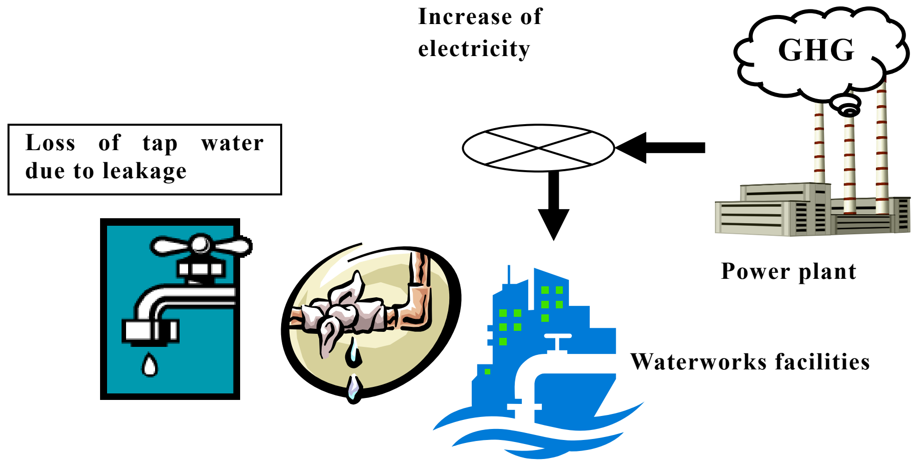
Quantification Sheet

Activity: Leakage control

<table>
<tr><td>Sector</td><td>Water resource</td></tr>
<tr><td>Sub-sector</td><td>Energy saving</td></tr>
<tr><td>GHG emission reduction activity</td><td>Leakage control</td></tr>
<tr><td>GHG emission reduction impact</td><td><u>1: Activity will lead to GHG emission reduction</u>
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

＜Without the activity＞

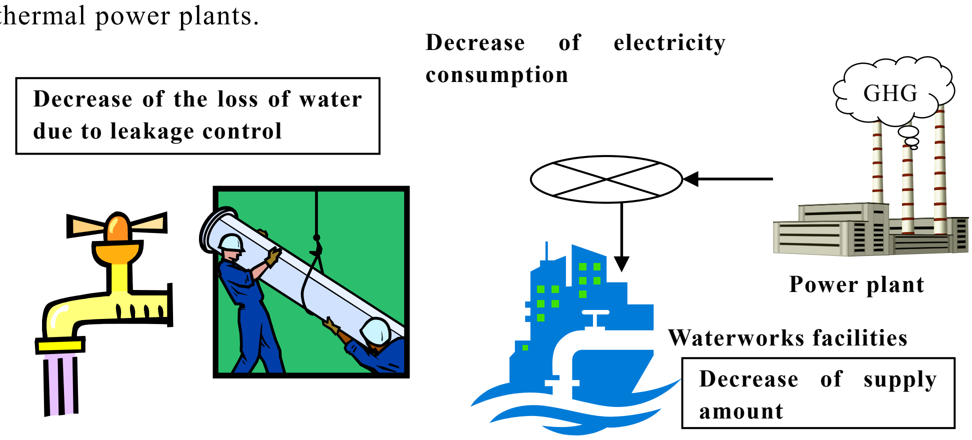
The loss of water due to leakage causes an increase in the water supply amount. This increase of supply amount causes the increase of electricity consumption in waterworks facilities, and then causes an increase in the GHG emissions from the power plant due to the commensurate increase in the production of electric energy.



＜With the activity＞

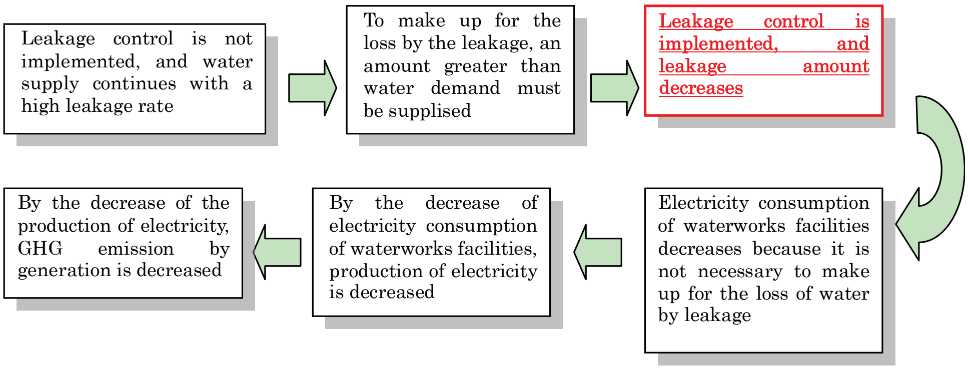
The loss of water supply due to leakage is decreased by the implementation of leakage control.

Decrease in water supply leads to the decrease of electricity consumption in the water works facility, as well as the decrease of GHG emissions from the thermal power plants.



</td></tr>
</table>

[Schematics of GHG emission reduction process]



Calculation of GHG emission reduction

[Calculation method]

The calculation method refers to the CDM approved methodology AM0020 “Baseline methodology for water pumping efficiency improvements.”

[Equations]

Without the activity

Calculation of GHG emission of electricity consumption in waterworks facilities without leakage control.

$BE_{Without} = EC_{BL,EL} \times FE_{EL}$

$EC_{BL,EL} = \{RW_{With} / (1- NRW_{Without})\} \times$ Electricity consumption per supply amount (kWh/ m^3)

RW_{With} = Supply amount (With) (m^3/yr)×(1-NRW_{With})

With the activity

Calculation of GHG emission from electricity consumption in waterworks facilities with leakage control.

$PE_{With} = EC_{PJ,EL} \times FE_{EL}$

$EC_{PJ,EL}$ = Supply amount (With) (m^3/yr) ×Electricity consumption per supply amount (kWh/ m^3)

GHG emission reductions

ER ($kgCO_2$/yr) = $BE_{Without} - PE_{With}$

	Abbreviation $EC_{BL,EL}$: Electricity consumption without leakage control (kWh/yr) $EC_{PJ,EL}$: Electricity consumption with leakage control (kWh/yr) EF_{EL}: CO_2 emission factor of electricity ($kgCO_2$/kWh) $NRW_{Without}$: Non-revenue water without leakage control (m^3/yr) NRW_{With}: Non-revenue water with leakage control (m^3/yr) $RW_{Without}$: Revenue water without leakage control (m^3/yr) RW_{With}: Revenue water with leakage control (m^3/yr)
Required data and data source	$NRW_{Without}$ and NRW_{With} - Use the result of pilot project - Interview the personnel of the waterworks utility Supply amount (With) and Supply amount (Without) - Use the result of pilot project - Interview the personnel of the waterworks utility Electricity consumption per supply amount - Use published data - Interview the personnel of the waterworks utility CO_2 emission factor of electricity (EF_{EL}) - See ***Annex 1***
Preconditions	Relationship between Supply amount, RW, NRW and NRW rate (%) are as follows; - Supply amount = RW + NRW - NRW = Supply amount × NRW rate (%) (i.e. NRW rate = NRW / Supply amount × 100 (%)) - RW = Supply amount × RW rate (%) (i.e. RW rate = RW / Supply amount × 100 (%)) However, the NRW contains physical loss (Leakage) and commercial loss (illegal connections, inadequate water meters, etc). Leakage control is implemented mainly to reduce physical loss. Moreover, the NRW rate can be obtained easily in field study. But it is difficult to estimate the physical loss from the NRW rate. Therefore, it is assumed that this calculation does not distinguish between leakage and NRW. Conditions regarding electric energy are as follows; - Energy source in waterworks facilities is electric energy - Electricity is produced by thermal power plants - Electricity consumption per supply amount is constant without / with

	leakage control
Special notes	Following data are necessary; - Supply amount after leakage control is implemented - NRW rate before and after leakage control is implemented

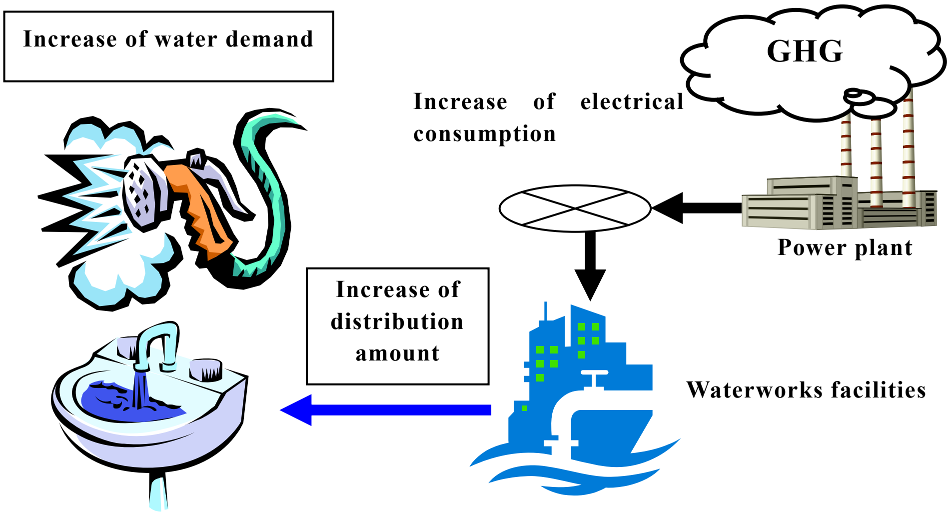
Quantification Sheet

Activity: Installation of water saving device

<table>
<tr><td>Sector</td><td>Water resource</td></tr>
<tr><td>Sub-sector</td><td>Energy saving</td></tr>
<tr><td>GHG emission reduction activity</td><td>Installation of water saving device</td></tr>
<tr><td>GHG emission reduction impact</td><td>1: Activity will lead to GHG emission reduction
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

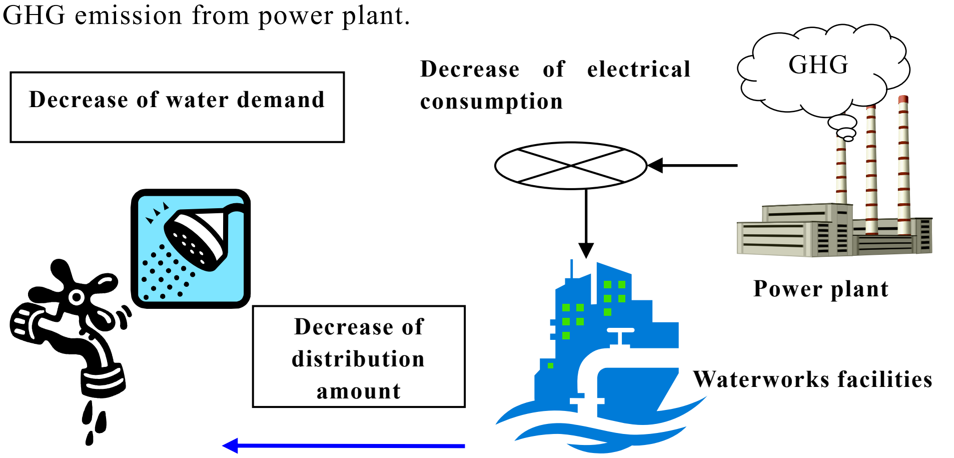
<Without the activity>

Water demand is greater because there are no acts of water saving (e.g. installation of water saving device). Therefore, electricity consumption in the waterworks facilities is increased, and GHG emission from the power plant is increased.

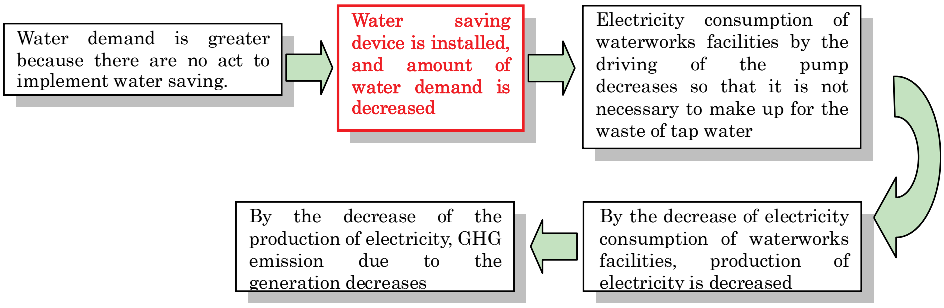


<With the activity>

The installation of water saving device has an effect to reduce water demand. This reduction of water demand causes the reduction of electricity consumption in the waterworks facilities, and this produces a decrease of GHG emission from power plant.



</td></tr>
</table>

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculation method refers to the CDM methodology AM0020 “Baseline methodology for water pumping efficiency improvements” **[Equations]** **<u>Without the activity</u>** Calculation of GHG emission of electricity consumption without installation of water saving device. $BE_{Without} = EC_{BL,EL} \times EF_{EL}$ $EC_{BL,EL}$(kWh/yr) = {Supply amount (Without) / supply population (Without)} × Supply population (With) × Electricity consumption per supply amount (kWh/ m^3) **<u>With the activity</u>** Calculation of GHG emission of electricity consumption with installation of water saving device. $PE_{With} = EC_{PJ,EL} \times EF_{EL}$ $EC_{PJ,EL}$ = {Supply amount (With) / Supply population (With)} × Supply population (With) × Electricity consumption per supply amount (kWh/ m^3) **<u>GHG emission reductions</u>** ER ($kgCO_2$/yr) $= BE_{Without} - PE_{With}$ **<u>Abbreviation</u>** $EC_{BL,EL}$: Electricity consumption without leakage control (kWh/yr) $EC_{PJ,EL}$: Electricity consumption with leakage control (kWh/yr) EF_{EL}: CO_2 emission factor of electricity ($kgCO_2$/kWh)

Required data and data source	Supply amount with or without installation of water saving device Supply population with or without installation of water saving device - Use the result of pilot project - Interview the personnel of the waterworks utility - Use published database CO_2 emission factor of electricity (EF_{EL}) - See ***Annex 1***
Preconditions	- Energy source in water works facilities is electric energy - Electric energy is produced by thermal power plant - The supply amount data and the supply population data must be the same tome period.
Special notes	- This calculation method concerns only electricity consumption of pumps or electric motors in the waterworks facilities which relate directly to purification, transmission and distribution (i.e. electric energy for lighting, air conditioning, etc is not included in this calculation) - This calculation method cannot evaluate separately the effects of the installation of water saving device and the effects of the change of the form of the domestic water consumption (e.g. decrease of the frequency of washing, bathing, etc) due to the spread of the water saving philosophy.

Quantification Sheet

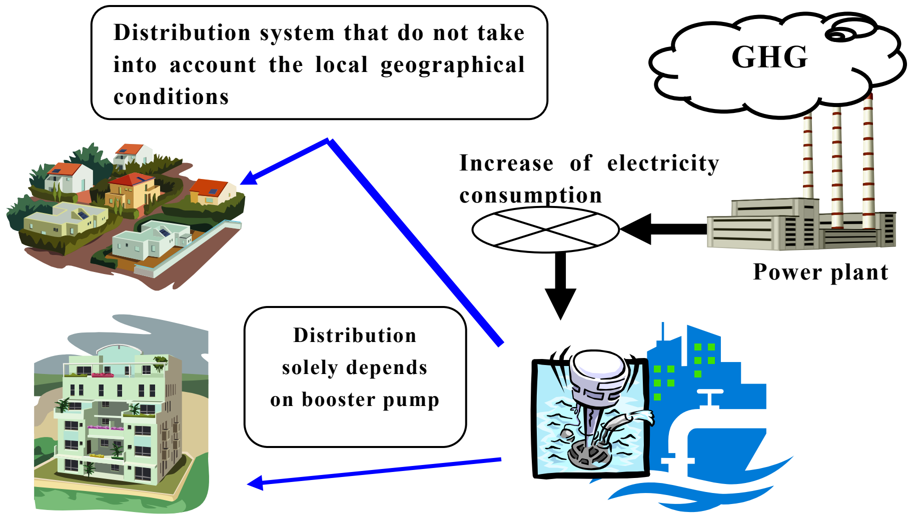
Activity: Improvement of water distribution system (e.g. application of gravity distribution)

<table>
<tr><td>Sector</td><td>Water resource</td></tr>
<tr><td>Sub-sector</td><td>Energy saving</td></tr>
<tr><td>GHG emission reduction activity</td><td>Improvement of energy efficiency</td></tr>
<tr><td>GHG emission reduction impact</td><td>1: Activity will lead to GHG emission reduction
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

Improvement of water distribution system

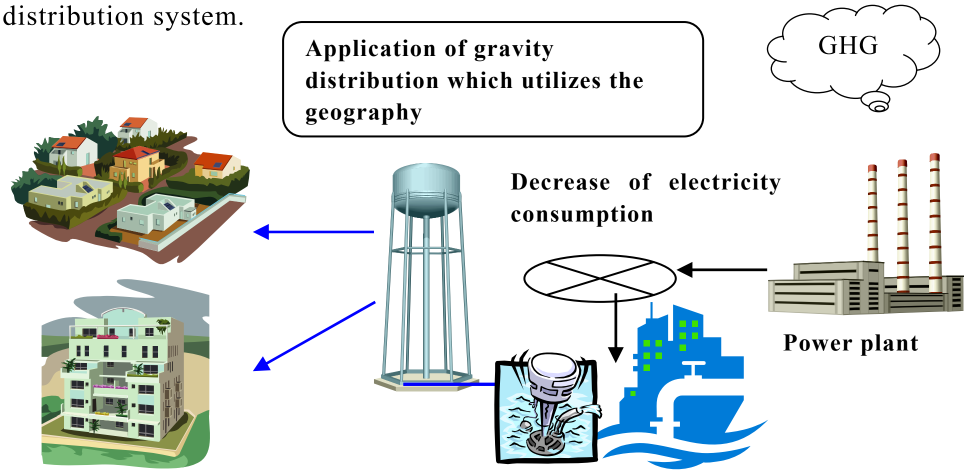
＜Without the activity＞

Losses of electrical energy due to distribution system that do not take into account the geographical conditions, etc.



＜With the activity＞

Reduction of energy consumption through the improvement of water distribution system.



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</table>

[Schematics of GHG emission reduction process]

Electrical energy is wasted in waterworks facilities because of the low efficiency of electricity consumption (e.g. use of inefficient pumps or electric motors or distribution / transmission network that does not utilize the topography) or waste of water and electrical energy (e.g. Backwashing operation with excess frequency).

→ The electricity use efficiency of waterworks facilities is improved, and the electricity consumption of waterworks facilities are decreased

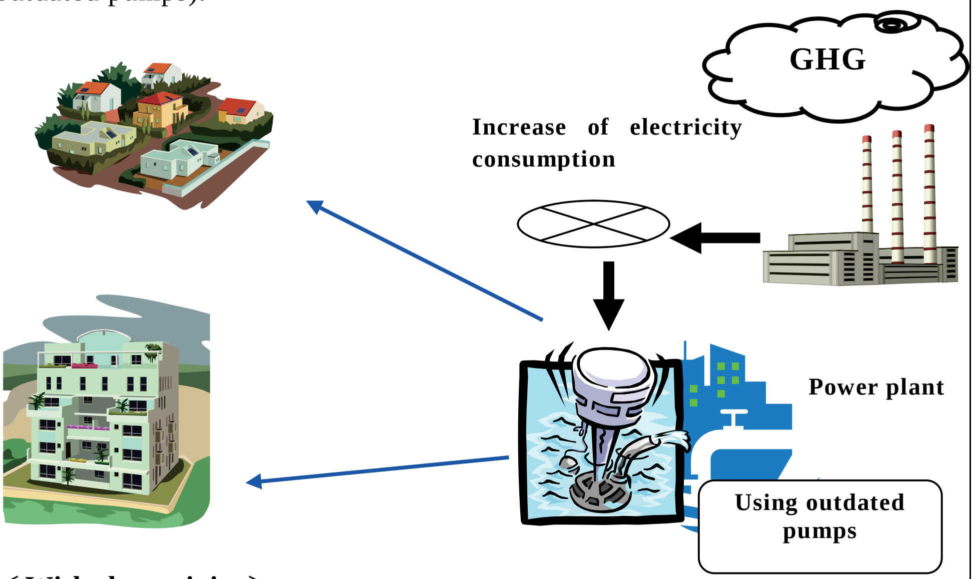
→ By the decrease of electricity consumption of waterworks facilities, production of electricity is decreased

→ By the decrease of the production of electricity, GHG emission due to generation decreases

Renovation of electrical devices

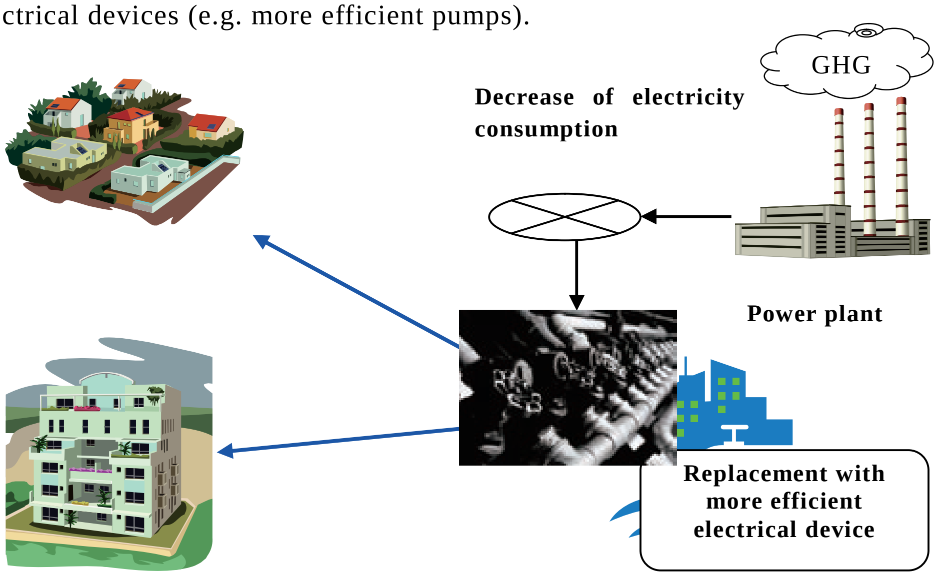
＜Without the activity＞

Losses of electrical energy due to inefficient electrical devices (e.g. an outdated pumps).



＜With the activity＞

Reduction of energy consumption through the replacement with more efficient electrical devices (e.g. more efficient pumps).



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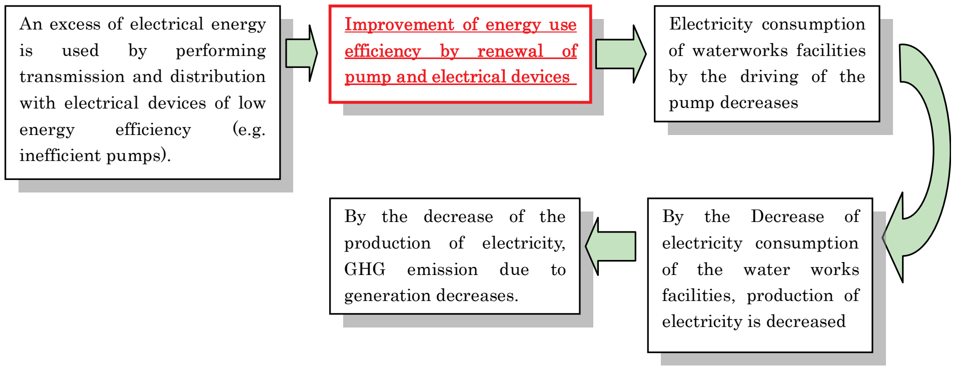
<td>

[Schematics of GHG emission reduction process]



</td>
</tr>
<tr>
<td>Calculation of GHG emission reduction</td>
<td>

[Calculation method]

The calculation method refers to the CDM approved methodology AM0020 "Baseline methodology for water pumping efficiency improvements."

[Equations]

<u>Without the activity</u>

Calculation of GHG emission of electricity consumption without implementation of energy consumption efficiency.

$BE_{Without} = EC_{BL,EL} \times EF_{EL}$

$EC_{BL,EL}$ = Supply amount (Without) × Electricity consumption per supply amount (Without)

<u>With the activity</u>

Calculation of GHG emission of electricity consumption with implementation of energy consumption efficiency.

$PE_{With} = EC_{PJ,EL} \times EF_{EL}$

$EC_{PJ,EL}$ = Supply amount (With) × Electricity consumption per supply amount (With)

<u>GHG emission reductions</u>

ER $(kgCO_2/yr) = BE_{Without} - PE_{With}$

<u>Abbreviation</u>

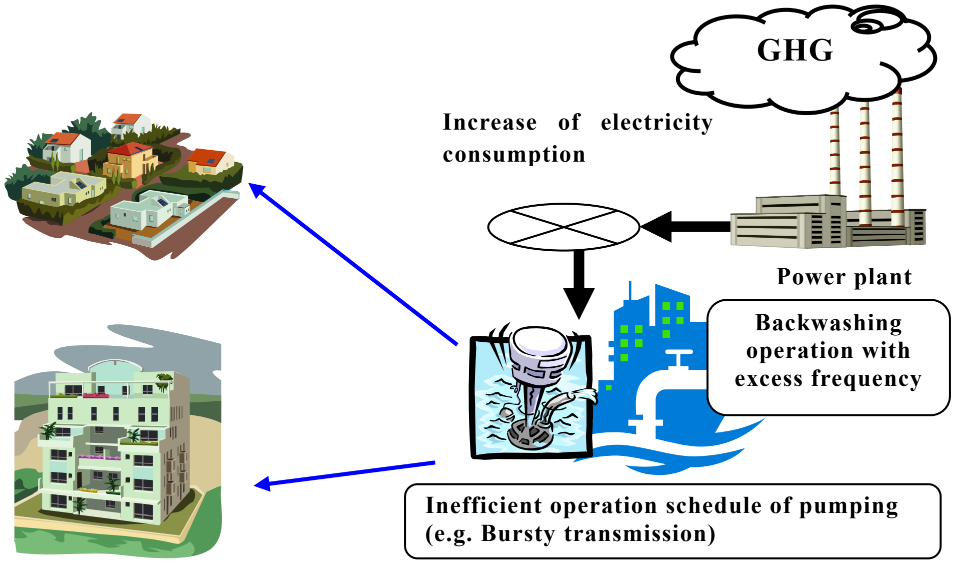
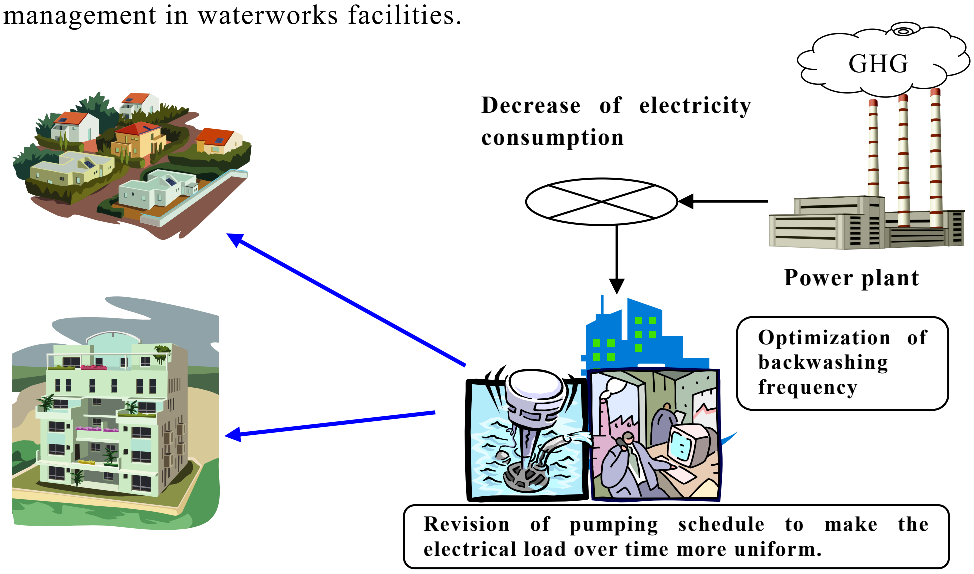
$EC_{BL,\ EL}$: Electricity consumption without energy efficient improvement (kWh/yr)

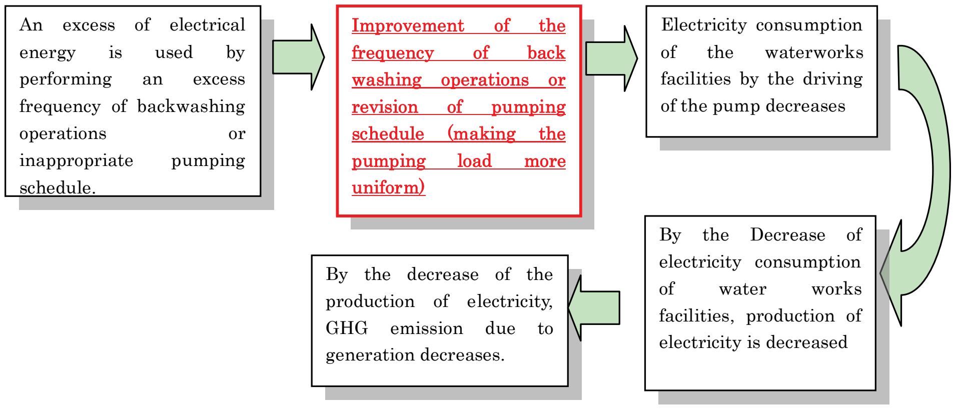
</td>
</tr>
</table>

	$EC_{PJ,\ EL}$: Electricity consumption with energy efficient improvement (kWh/yr) EF_{EL}: Electricity CO_2 emission coefficient ($kgCO_2$/kWh)
Required data and data source	1) Electricity consumption per supply amount with or without energy efficient improvement (kWh/ m^3) 2) Supply amount (m^3/yr) with or without energy efficient improvement - Use results of pilot project - Interview with waterworks utility - Use published database 3) CO_2 emission factor of electricity (EF_{EL}) - See ***Annex 1*** for detail
Preconditions	- Energy source in water works facilities is electric energy - Electric energy is produced by thermal power plants - Distribution amount is constant with or without improvement - The supply amount data and the supply population data must be from the same time period.
Special notes	- This calculation method concerns only electricity consumption of pumps or electric motors in water works facilities that are related directly to purification, transmission and distribution (i.e. the electric energy for lighting, air conditioning, etc, is not included in this calculation)

Quantification Sheet

Activity: Improvement of operation management of waterworks facilities (e.g. Optimization of backwashing frequency)

Sector	Water resource
Sub-sector	Energy saving
GHG emission reduction activity	Improvement of energy efficiency
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** Loss of energy due to excess energy consumption in water works facilities.  **＜With the activity＞** Reduction of energy consumption through the improvement of operation management in waterworks facilities. 

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** The calculation method refers to the CDM approved methodology AM0020 "Baseline methodology for water pumping efficiency improvements." **[Equations]** **<u>Without the activity</u>** Calculation of GHG emission of electricity consumption without implementation of the energy consumption efficiency. $BE_{Without} = EC_{BL,EL} \times EF_{EL}$ $EC_{BL,EL}$ = Supply amount (Without) × Electricity consumption per supply amount (Without) **<u>With the activity</u>** Calculation of GHG emission of electricity consumption with implementation of the energy consumption efficiency improvements. $PE_{With} = EC_{PJ,EL} \times EF_{EL}$ $EC_{PJ,EL}$ = Supply amount (With) × Electricity consumption per supply amount (With) **<u>GHG emission reductions</u>** ER ($kgCO_2/yr$) $= BE_{Without} - PE_{With}$

	Abbreviation $EC_{BL,\ EL}$: Electricity consumption without energy efficient improvement (kWh/yr) $EC_{PJ,\ EL}$: Electricity consumption with energy efficient improvement (kWh/yr) EF_{EL}: Electricity CO_2 emission coefficient ($kgCO_2$/kWh)
Required data and data source	1) Electricity consumption per supply amount with or without energy efficient improvement (kWh/ m^3) 2) Supply amount (m^3/yr) with or without energy efficient improvements - Use result of pilot project - Interview with waterworks utility - Use published database 3) CO_2 emission factor of electricity (EF_{EL}) - See ***Annex 1*** for detail
Preconditions	- Energy source in water works facilities is electric energy. - Electric energy is produced by thermal power plants. - Distribution amount is constant with or without improvements. - The supply amount data and the supply population data must be from the same time period.
Special notes	- This calculation method concerns only the electricity consumption of the pumps or electric motors in water works facilities that are related directly to purification, transmission and distribution (i.e. the electric energy for lighting, air conditioning, etc, is not included in this calculation)

3.5.5 Example of case study

№	Project Title	Sector
9	Capacity Development Project for Non-Revenue Water Reduction in Jordan	Water resource

Case study No.	9
Project title	Capacity Development Project for Non-Revenue Water Reduction in Jordan
Sector	Water resource
Sub-sector	Energy saving
Project summary	**[Background]** Water shortage is a critical issue in Jordan, which is attributed to rapid growth in water demand due to continuous population increase and the acceptance of refugees from the neighbouring countries. In spite of such a chronic shortage of water, the non-revenue water (NRW) rate of the country shows a high value of about 50% in the early 2000's. **[Objectives]** Purpose of this project is to enhance the capacity of personnel in the WAJ (Water authority of Jordan) who are involved in leakage control. For that purpose, technical training was provided to the Jordanian side concerning leakage investigation, maintenance and repair of pipelines, installation of water meters, and operation and improvement of network systems. **[Condition after project implementation]** As a result of this project, the NRW rate in the pilot area that covers 6 provinces and 9 districts has decreased to almost half that of the pre-project condition, or from 20 – 60% NRW to 18 – 28%, This project is currently underway, and the Phase 2 project was started in 2009. The NRW reduction measures have been undertaken nationwide owing to Jordan side's further efforts. It is considered such effects are attributable to the JICA project to a great extent.
GHG emission reduction scenarios	**<u>Without the activity</u>** Leakage control was not undertaken and water is supplied but with a high leakage rate. To make up for the loss through leakage, an amount of water greater than the amount of water demand must be supplied. As electricity consumption at water works facilities increases to supply more water, production of electricity increases to meet the electricity demand of the waterworks facilities. This will lead to the increase of GHG emissions in line with the increase of the production of electricity. **<u>With the activity</u>** By undertaking the water leakage control, the amount of leakage is decreased which meant that the amount of water supplied is decreased. This will reduce the electricity consumption at the waterworks facilities. As the electricity generation decreases, the amount of GHG emissions due to power generation decreases.
Equations to calculate GHG	**[Calculation method]** The calculation is performed in accordance with the "Quantification Sheet Leakage control".

emissions	**[Equations]** **<u>Without the activity</u>** Calculation of GHG emissions by the electricity consumption of waterworks facilities where the leakage control measures are not taken. $BE_{Without} = EC_{BL,EL} \times FE_{EL}$ $EC_{BL,EL}$ = {RW_{With} / (1- $NRW_{Without}$)} × Electricity consumption per supply water amount (kWh/ m^3) **<u>With the activity</u>** Calculation of GHG emissions by the electricity consumption at waterworks facilities where the leakage control measures are taken. PE_{With}= $EC_{PJ,EL}$ (kWh/yr) × FE_{EL} (kgCO_2/kWh) $EC_{PJ,EL}$ (kWh/yr) = Supply amount (With) (m^3/yr) × Electricity consumption per supply amount (kWh/ m^3) **<u>GHG emission reductions</u>** ER(kg-CO_2/yr) = $BE_{Without} - PE_{With}$ **<u>Abbreviation</u>** $EC_{BL,EL}$: Electricity consumption without leakage control (kWh/yr) $EC_{PJ,EL}$: Electricity consumption with leakage control (kWh/yr) EF_{EL}: Electricity CO_2 emission coefficient (kgCO_2/kWh) $NRW_{Without}$: Amount of non-revenue water without leakage control (m^3/yr) NRW_{With}: Amount of non-revenue water with leakage control (m^3/yr) $RW_{Without}$: Amount of revenue water without leakage control (m^3/yr) RW_{With}: Amount of revenue water with leakage control (m^3/yr)
Applied data	Data used for quantification is obtained by employing one of the following three options according to the level of difficulty in obtaining data. a) If a field study is not carried out - Make the calculations using the data of the planned supply amount in the target year of evaluation and the NRW rate before and after leakage control is undertaken b) If a field study is carried out - Make the calculations using the data of the identified NRW rate before and after leakage control and identified supply amount after leakage control c) If the planned supply amount in the target year of evaluation cannot be obtained

- Make the calculations using the data of identified supply amount before leakage control and the NRW rate before and after leakage control

Since the data of the observed supply amount before leakage control and observed NRW rate before and after leakage control were obtained in this case study, the above mentioned option c) was applied to the calculation.

Field data and calculated results are shown in Table 1.

- Values in columns I, II and III in Table 1 are observed values. Column I is the annual supply amount before leakage control, Column II is the NRW rate before leakage control, and Column III is the NRW rate after leakage control.
- Column IV is the NRW before leakage control that is calculated using data in columns I and II.
- Column V is the RW before leakage control that is calculated using data in columns I and IV. In the case of this case study, because the period of leakage control implementation is short (only a few months), it was presumed that the RW amount was constant before and after leakage control.
- Column VI is the NRW after leakage control that is calculated using data in columns III and V.
- Column VII is supply amount after leakage control that is calculated using data in columns V and VI.

Table 1 Field data (supply amount and NRW rate) and calculated result

Pilot Area		I	II	III	IV	V	VI
		Water supply amount before countermeasures (m^3/yr)	NRW Baseline ratio (%)	NRW Completed ratio (%)	NRW Basaline (m^3/yr)	RW Baseline (m^3/yr)	Estimated water supply amount after countermeasure (m^3/yr)
					I×II	I-IV	V/(1-III)
Balqa	Al-Salalim	565750	45	20	254588	311163	388953
	Fuhais	171915	44	19	75643	96272	118855
Zarqa	Wadi Al-Hajar	76024	47	25	35731	40293	53724
	Hashimiah	319949	58	25	185570	134378	179171
Madaba	Faisalea	329021	57	28	187542	141479	196499
Karak	Smakeyeh & Hmound	114297	44	23	50291	64006	83125
Tafalah	Mansurah	132182	28	18	37011	95171	116062
Ma'an	Odruh 1	133277	55	17	73302	59975	72259
	Total	1842416					1208648

To calculate GHG emission with the data in Table 1, the following conversion factors were used;

- Electricity consumption per supply amount in Jordan (national average):3.88 kWh/m^3
- Electricity CO_2 emission factor in Jordan (national average in 2007):0.62 $kgCO_2$/kWh

Calculation of GHG emissions

Calculation result of GHG reduction for all 8 pilot projects are shown in Table 2.

- GHG emission before leakage control (BE) (Column II) was calculated by multiplying the electricity consumption per supply amount in Jordan (3.88 kWh/m^3) and the electricity CO_2 emission factor in Jordan (0.62 kg-CO_2/kWh) by the Supply amount before leakage control (Column I).
- GHG emission after leakage control (PE) (Column IV) was calculated the same way as GHG emission before leakage control (BE) (Column II) using the estimated supply amount after leakage control (Column III).
- GHG reduction (Column V) was calculated as the difference between $BE_{Without}$(Column II) and PE_{With}(Column IV)
- As a result, GHG reduction by leakage control is 38,778 to 425,303 kgCO_2/yr, and the total GHG reduction of all 8 pilot projects was 1,524,591 kgCO_2/yr.

Table 2 Calculation result of GHG reduction by implementation of leakage control

Pilot Area		I	II	III	IV	V
		Water supply amount before countermeasures (m^3/yr)	GHG emission before countermeasure BE (kg-CO_2/yr)	Estimated water supply amount after countermeasure (m^3/yr)	GHG emission after countermeasure PE (kg-CO_2/yr)	GHG reduction:BE-PE (kg-CO_2/yr)
			Ix3.88(kWh/m^3)x0.62(kg-CO_2/kWh)		IIIx3.88(kWh/m^3) x0.62(kg-	II-IV
Balqa	Al-Salalim	565750	1360968	388953	935666	425303
	Fuhais	171915	413559	118855	285917	127642
Zarqa	Wadi Al-Hajar	76024	182884	53724	129238	53646
	Hashimiah	319949	769668	179171	431014	338654
Madaba	Faisalea	329021	791494	196499	472698	318796
Karak	Smakeyeh & Hmound	114297	274953	83125	199966	74987
Tafalah	Mansurah	132182	317977	116062	279200	38778
Ma'an	Odruh 1	133277	320611	72259	173826	146786
	Total	**1842416**	**4432115**	**1208648**	**2907524**	**1524591**

GHG reduction by leakage control in 2020 and 2022 was estimated. In this calculation, the supply amount and NRW rate are the national average of the whole Jordan (2007's data is observed value, 2020 and 2022's data are target value).

Data and calculation results are shown in Table 3.

Table 3 Prediction of GHG reduction in 2020 and 2022

Data			Year			Note
			2007 (Without)	2020 (With)	2022 (With)	
I	Water supply amount	(m^3/yr)		421,000,000	456,000,000	
II	NRW	(%)	42.6	28	25	
III	NRW (With)	(m^3/yr)		117,880,000	114,000,000	IxII
IV	RW (With)	(m^3/yr)		303,120,000	342,000,000	I-III
V	GHG emission:BE	(kg−CO^2/yr)		1,270,546,110	1,433,514,020	Ix3.88x0.62
VI	GHG emission:PE	(kg−CO^2/yr)		1,012,757,600	1,096,953,600	IV/(1-0.426) x3.88x0.62
IV	GHG reduction (kg-CO_2)	(kg−CO^2/yr)	・・・	**257,788,510**	**336,560,420**	V-VI

	In the whole of Jordan, the NRW rate of 2007 was 42.6%, but Jordan aims at decreasing it to 28% by 2020 and to 25% by 2022. The calculation result is derived using these target NRW rates for 2020 and 2022, It was estimated that GHG reduction in 2020 would be 336,560,420 kgCO_2/yr and in 2022 would be 257,788,510 kgCO_2/yr.
Preconditions	- NRW rate = leakage rate - In the pilot project in this case study, the supply amount after leakage control was not obtained. Therefore, this case study established the presumption that the RW amount was constant because the period of leakage control implementation was short (about few months). - Electricity consumption per supply amount used a national mean value in Jordan because there is no data for any of the local waterworks facilities that carried out a pilot project.
Lessons learned from case study	The following data are necessary to perform a quantitative assessment - NRW rate before and after leakage control (observed value or target value) - Supply amount after leakage control (observed value or target value)

3.6 Rural Development Sector

3.6.1 Preconditions for the sector

In Rural Development Sector, GHG reduction activities can be classified into the following 5 activities:

1) Forest conservation
2) Improvement of energy efficiency of agricultural facilities
3) Composting of unused agricultural waste and biogas
4) Application of renewable energy
5) Development of human resources, publication of technology and assistance with creating instructional manuals

GHG emission reductions are expected to be achieved when the concrete GHG reduction activities are carried out in 4 actions: **1) Forest conservation**, **2) Improvement of the energy efficiency of agricultural facilities**, **3) Composting of unused waste and biogas**, and **4) Application of renewable energy**. Therefore, quantification methods for these 4 activities are considered.

Activity **5) Development of human resources, publication of technology and assistance with creating instructual manuals** is expected to be able to achieve GHG reduction when additional technical cooperation or financial assistance are implemented and they lead to the implementation of concrete GHG reduction activities finally.

Therefore, the quantification method for this activity will refer to one of other additional activity which is finally carried out as a result of this activity.

3.6.2 Summary of quantification methods

Summary of quantification methods in the Rural Development sector are as follows:

Table3.6.1 Summary of quantification methods in Rural Development sector

Component	Item	Quantification methods
GHG emission from electricity consumption	Common item	Electricity consumption ×CO_2 emission factor of electricity
GHG emission from fossil fuel combustion	Common item	Fuel consumption × CO_2 emission factor of fossil fuel
CO_2 emission reduction due to reduction of fuel wood consumption[1)]	Forest conservation	Reduction of CO_2 emission due to reduction of quantity of deforestion[2)]
CO_2 absorption due to afforestation[1)]		Increase of CO_2 absorption due to new growth of the forest
CO_2 absorption result from forest conservation[1)]		CO_2 discharge prevention due to forest conservation + Increase of CO_2 absorption due to growth of the forest
Repair of waterways, improvement of irrigation methods and introduction of drought-resistant plants	Improvement of energy efficiency of agricultural facilities	Irrigation quantity of water×Energy consumption per irrigation quantity of water×CO_2 emission factor
Repair of wells (cleaning, pump replacement, etc.)		Energy consumption×CO_2 emission factor of electricity or fossil fuel
Improvement of energy efficiency of agricultural facilities (e.g. farm products processing facilities)		Energy consumption×CO_2 emission factor of electricity or fossil fuel
Composting of agricultural waste[3)]	Composting of agricultural waste and biogas	CH_4 emission due to decay of agricultural waste – GHG emission due to operation of composting facilities
Biogas[3)]		CH_4 emission due to decay of unused agricultural waste – Physical leakage from CH_4 generator
Application of renewable energy	Application of renewable energy	GHG emission reduction when electricity generated with renewable energy replaces fossil fuel combustion or grid electricity[4)]

1) Quantification method for forest conservation is shown in this guidebook, quantification method of forest conservation refers to the report. "Contribution of JICA in the global warming countermeasure (Forest sector) – On quantification of CO_2 absorption".

2) Regarding CO_2 emission result from deforestation, this guidebook refers to the following article:

Trees accumulate carbon, but carbon accumulation does not continue when they are harvested. In many cases, harvested wood is burnt or decays over a long time, but it is impossible to forecast how the harvested wood will be used.

Reference: IPCC Guideline for National Greenhouse Gas Inventories, Vol.3, Chapter5, p.5.17, Box5.

Therefore, to be conservative, this guidebook presupposes that carbon is discharged at the same time that the wood is harvested.

3) This guidebook assumes that the GHG reduction activity is done with small facilities in a farm village. Therefore, the quantification method in this guidebook mainly refers to small scale CDM methodology.

4) GHG emission from the renewable energy (e.g. solar power, wind power, etc.) is assumed to be 0 (Zero)

3.6.3 GHG emission reduction activities of JICA projects

GHG emission reduction components in 5 GHG reduction activities (see P.3.6-1) and typical JICA projects for each GHG reduction component are shown in Tables 3.6.2(1) to 3.6.2 (3).

"Forest conservation" includes Improved kitchen stoves, Afforestation, Agro forestry (Afforestation) and Agro forestry (Forest conservation).
"Improvement of energy use efficiency of agricultural facilities" includes Repair of irrigation canals, Rehabilitation of irrigation wells, Water saving agriculture (Improvement of irrigation methods), Water saving agriculture (Introduction of drought-resistant plants) and Improvement of energy use efficiency of agricultural facilities.
"Composting of waste and biogas" includes Composting of unused agricultural waste and Biogas.
"Application of renewable energy" includes Application of renewable energy to agricultural facilities.
"Development of human resources, publication of technology and assistance with the preparation of instructional manuals" includes Development of human resources and publication of technology about composting or biogas technology and Assistance with the preparation of instructional manuals about energy use improvement in farm products processing facilities.

Project examples listed in Table 3.6.2(1) to Table 3.6.2(3) consist of the projects that were recognized to be effective for mitigation of climate change in the research called "JICA's Assistance for Mitigation to Climate Change - The Co-Benefits Approach to Climate Change". And they also include the projects that JICA specified as the mitigation projects from JICA projects of year 2008.
Therefore, these project examples do not contain all of JICA projects. In other words, there are other JICA projects with other GHG reduction components shown in Table 3.6.2(1) to Table 3.6.2(3).

Table 3.6.2 (1) GHG emission reduction activities of JICA projects (Forest conservation)

Project example	**Improved kitchen furnace**	**Afforestation**	**Agro forestry (Afforestation)**	**Agro forestry (Forest conservation)**
Improvement of living conditions and poverty alleviation that considered gender	○			
Improvement of livelihood and better living conditions	○			
Reduction of fire wood consumption	○			
Environmental conservation in rural areas		○	○	○

Table 3.6.2 (2) GHG emission reduction activities of JICA projects (Improvement of energy use efficiency of agricultural facilities)

Project example	**Repair of irrigation canals (Leakage control, etc.)**	**Rehabilitation of irrigation wells (cleaning, pump replacement, etc.)**	**Water–saving agriculture (Improvement of irrigation methods)**	**Water–saving agriculture (introduction of drought-resistant plants)**	**Improvement of energy efficiency of agricultural facilities (e.g. farm products processing facility)**
Improvement of living conditions and poverty alleviation that considered gender	○		○		
Irrigated agriculture policy				○	
Improvement of livelihood and better living conditions	○				
Effective utilization of cattle manure and agricultural waste					○
Improvement of processing of agricultural and fishery products					○
Water resource development and effective water use	○	○			

Table 3.6.2 (3) GHG emission reduction activities of JICA projects
(Composting of waste, biogas, application of renewable energy, development of human resources, publication of technology and assistance in creation of instructional manuals)

Project example	**Composting of unused agricultural waste**	**Biogas**	**Application of renewable energy (e.g. solar power, wind power, .etc.) to agricultural facilities**	**Development of human resources and publication of technology about composting or biogas technology**	**Assistance of manual making about energy use improvement in farm products processing facility**
Biogas		○		○	
Improvement of living conditions and poverty alleviation that considered gender	○				
Effective utilization of cattle manure and agricultural waste	○				○
Improvement of rural environment	○				
Environmental conservation in rural areas			○	○	

3.6.4 Summary of GHG emission reduction scenarios and qualification sheet by activity

The following figure shows the schema of GHG reduction and mechanism of each GHG reduction activity (See Table 3.6.2 (1) to Table 3.6.2 (3)).

In this figure, reference information about "Quantification Sheet" for each GHG reduction activity and results of case study are referenced.

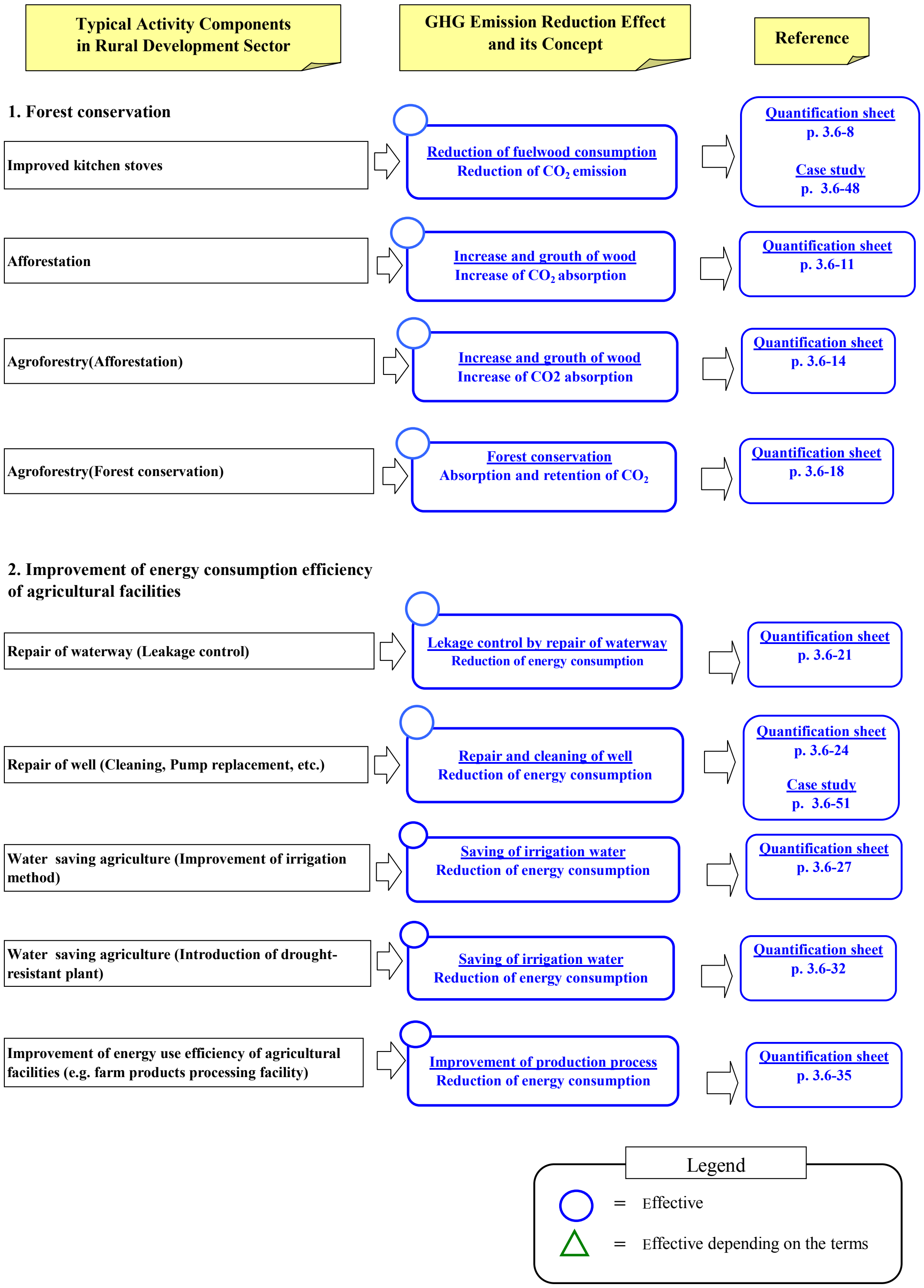


Figure 3.6.1 Quantification possibility of each component
(Forest conservation and Improvement of energy efficiency of agricultural facilities)

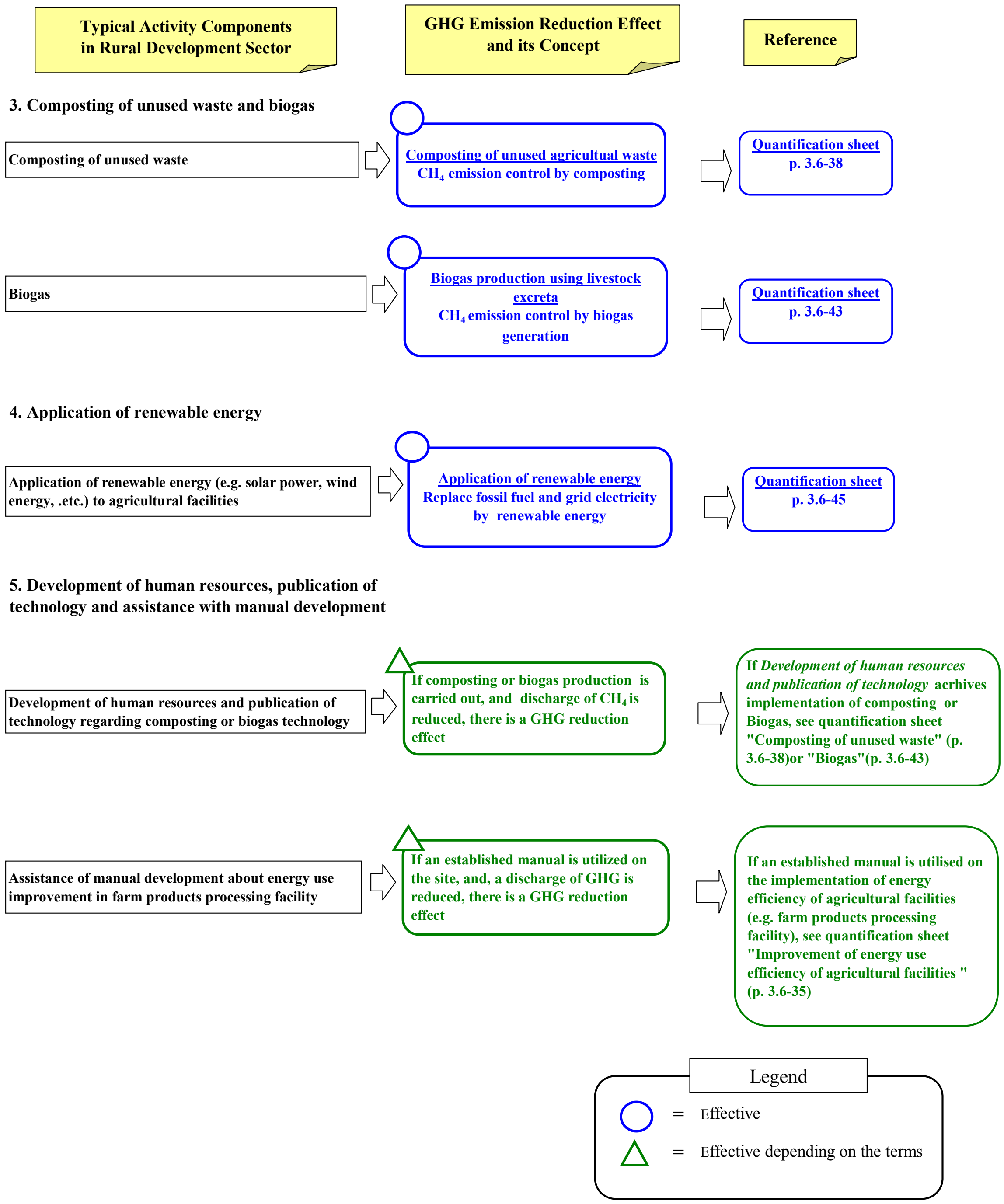
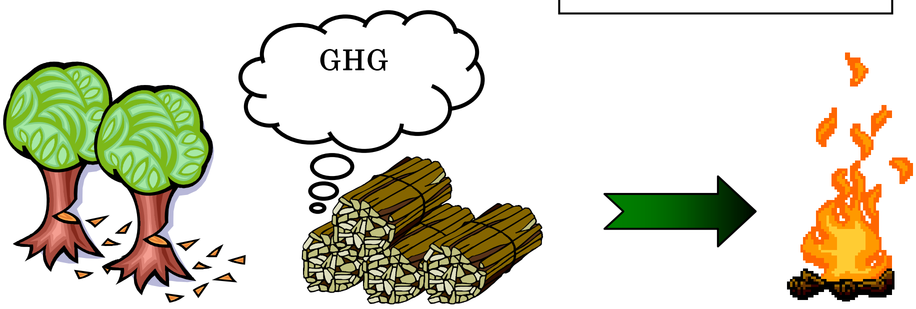


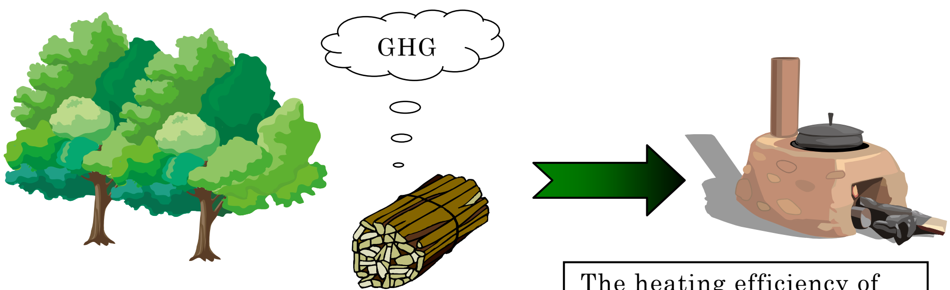
Figure 3.6.2 Quantification possibility of each component

(Composting of unused waste and biogas, Development of human resources / publication of technology and Assistance with manual development)

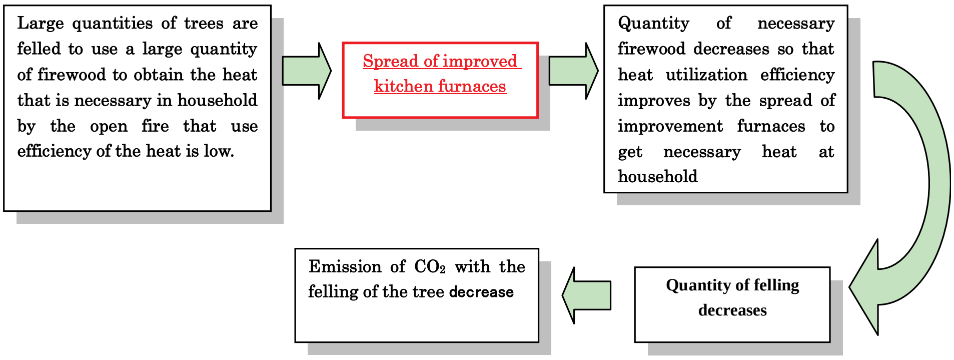
Quantification Sheet

Activity: Improved kitchen stoves

<table>
<tr><td>Sector</td><td>Rural development</td></tr>
<tr><td>Sub-sector</td><td>Forest conservation</td></tr>
<tr><td>GHG emission reduction activity</td><td>Forest conservation</td></tr>
<tr><td>GHG emission reduction impact</td><td><u>1: Activity will lead to GHG emission reduction</u>
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>
<Without the activity>
Many trees are cut down to get a lot of fuel wood
Open fire needs much fuel wood because its heat efficiency is low


<With the activity>
Owing to the application of improved kitchen stoves, the consumption of fuel wood is decreased. Therefore, the amount of timber cut is decreased.
It is supposed that carbon (CO_2) stored in trees is discharged at the time of the cutting of the trees. Therefore, it is considered that a decrease in the cutting of timber will mean a decrease in the discharge of CO_2 from the decomposition of the trees.


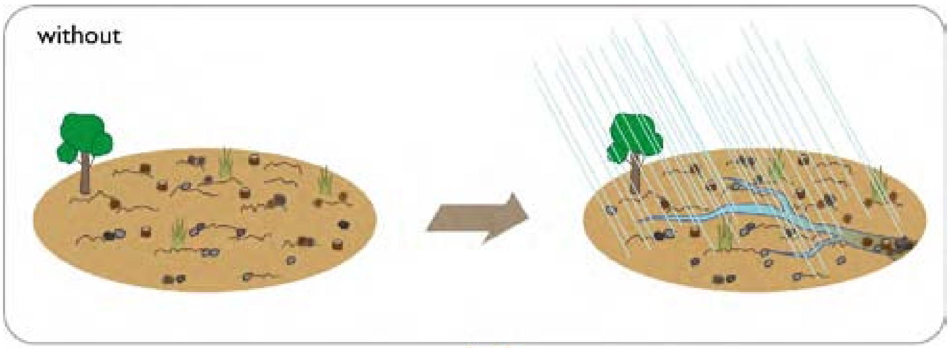
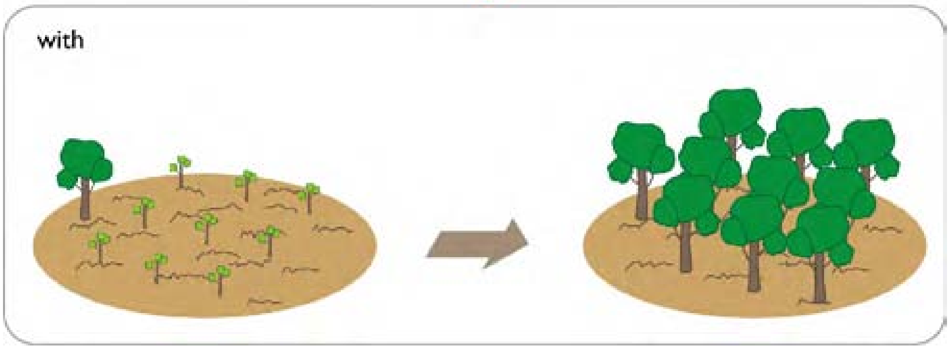
The heating efficiency of improved kitchen stoves is better than open fires. Therefore, the consumption of fuel wood is decreased.
</td></tr>
</table>

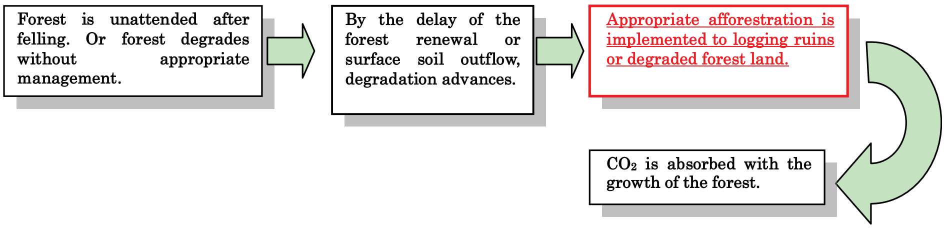
	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculate CO_2 emission reduction owing to the reduction of timber that is cut. Calculation of CO_2 emission of felling refers to the “Contribution of JICA in the global warming countermeasure (Forest sector) – On quantification of CO_2 absorption” **[Equations]** **<u>Without the activity</u>** Calculation of CO_2 emission of felling of trees without introduction of improved kitchen stoves. $BE_{Without}$=Fuel wood consumption without improved kitchen stoves (t-dry matter)×1.2 (1＋root to shoot ratio: 0.2)×0.5 (carbon fraction of dry matter, default value :0.5) ×44/12 (conversion factor from C to CO_2) **<u>With the activity</u>** Calculation of CO_2 emission of cutting of trees with improved kitchen stoves introduction. BE_{With}=Fuel wood consumption with modified furnace (t-dry weight)×1.2×0.5×44/12 **<u>GHG emission reductions</u>** $ER(tCO_2) = BE_{Without} - PE_{With}$
Required data and data source	1) Fuel wood consumption with or without adoption of improved kitchen stoves. - Data is obtained by the implementation of pilot project or interview in field study - It is possible that the consumption of fuel wood will have a seasonal change. Therefore, the investigation about the consumption of fuel wood

	should be implemented over the course of an entire year to obtain any seasonal changes. - When the consumption of fuel wood is obtained in volume (m^3), that data has to be converted into weight (t-dry matter). The calculation formula is as follows; Weight of fuel wood(t-dry matter)＝Volume of fuel wood (m^3) × Basic wood density D Basic wood density D is decided according to IPCC Good Practice Guidance (GPG) for LULUCF, Annex 3A.1 Biomass Default Tables for Section 3.2 Forest Land, Tables 3A.1.9-1 and 3A.1.9-2. 2) Tree species of fuel wood - This information is necessary when the volume of the fuel wood is converted into weight using IPCC GPG for LULUCF, Annex 3A.1, Tables 3A.1.9-1 and 3A.1.9-2. - Data is obtained by the implementation of pilot project or interview in field study
Preconditions	The heat capacity from combustion of fire wood with improved kitchen stoves is the same as with the open-fire
Special notes	- There are various ways of gathering fuel wood such as gathering dead wood, cutting down only branches, cutting down entire trees, etc. From the conservative side, this guidebook assumes that the way of gathering fuel wood is performed by the felling of the whole tree (above ground part + root part), because this way has the biggest influence on forests and increase of GHG emission amount. - Fuel wood consumption should be calculated as weight (t-dry matter) to avoid the trouble of having to convert from volume (m^3) to weight (t-dry weight).

Quantification Sheet

Activity: Afforestation

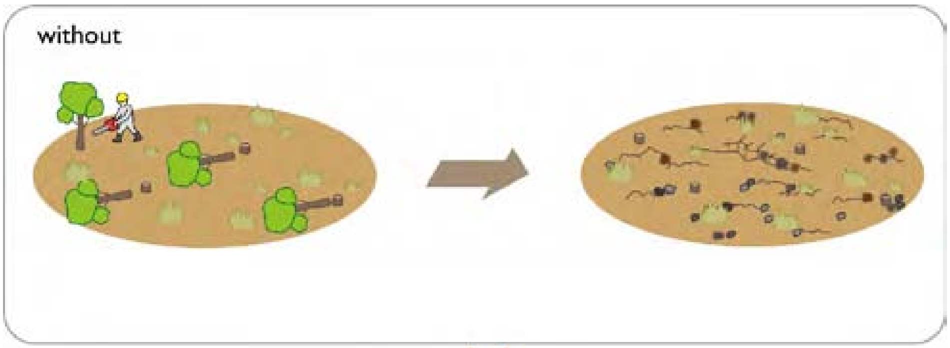
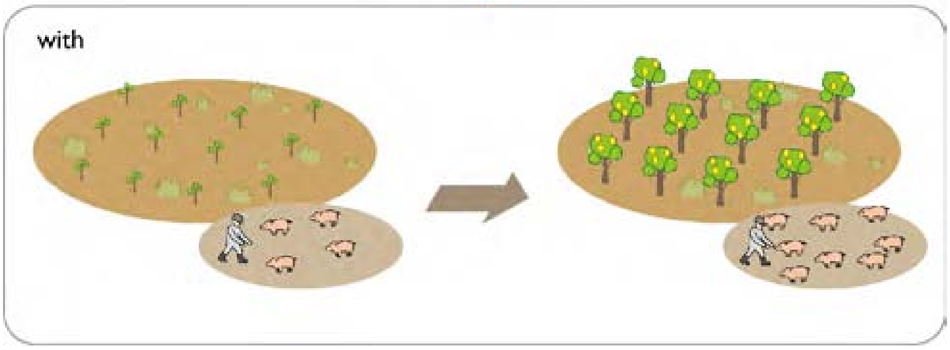
Sector	Rural development
Sub-sector	Forest conservation
GHG emission reduction activity	Afforestation
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	＜**Without the activity**＞ Forest is left unattended after felling of trees. Or forest degrades without appropriate management. By the delay of the forest renewal or surface soil outflow, degradation advances.  ＜**With the activity**＞  Appropriate afforestation is implemented on logging ruined area or degraded forest land. CO_2 is absorbed in proportion to the growth of the forest.

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculation of CO_2 absorption by the growth of afforested trees. Calculation of CO_2 absorption refers to the "Contribution of JICA in the global warming countermeasure (Forest sector) – On quantification of CO_2 absorption" **[Equations]** CO_2 absorption(t-CO_2/yr)= above-ground biomass (t-dry matter / ha / yr)× Forested area (ha)×1.2 (1＋root to shoot ratio: 0.2)×0.5 (carbon fraction of dry matter, default value :0.5) ×44/12 (conversion factor from C to CO_2)
Required data and data source	1) Forested area - Record of forested area - Data is obtained by field study, interpretation of an aerial photo or satellite photo - When many kinds of trees are afforested, forested area for each tree species should be recorded 2) Metrological conditions - Record of Geographical division, type of forest and rainfall condition - This data is used to calculate above-ground biomass 3) Tree species - Record of tree species which is afforested - This data is used to calculate above-ground biomass 4) Above-ground biomass - Above-ground biomass is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.6. - When 20 years passes after afforesting, use values for more than 20 years old in Table 3A.1.6.
Preconditions	- GHG reduction assumes that there is CO_2 absorption by the growth of afforested trees
Special notes	- It is necessary to wait for several years till CO_2 absorption by afforested trees is advanced enough. Therefore, it is necessary to implement maintenance of the forest until then. - Follow up monitoring should be implemented after the quantification of

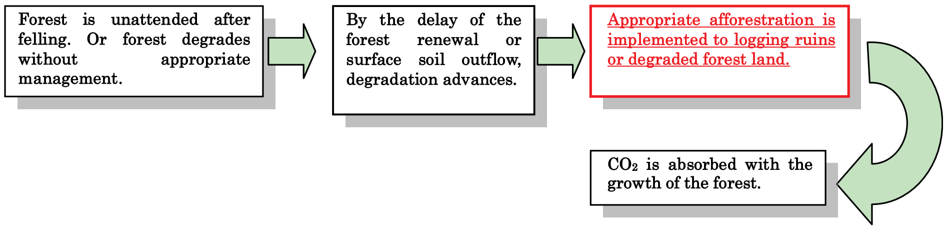
	GHG absorption is feasible (about few years after afforestation). Quantification of afforestation will be done using follow up monitoring data. - Monitoring items in the follow up monitoring are afforesting tree species, tree age and forested area

Quantification sheet

Activity: Agro forestry (afforestation)

Sector	Rural development
Sub-sector	Forest conservation
GHG emission reduction activity	Forest conservation and afforestation
GHG amission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** In an area where the forest is hard to form (e.g. Sahel), the trees are felled for fuel wood forest or pasturage. Forest is unattended without the forest recovering, and degradation of the forest continues.  **＜With the activity＞**  The forest recovers by implementation of appropriate agroforestry (afforestation) suitable for local conditions. The appropriate means of living are secured by implementation of appropriate agroforestry (afforestation). Therefore the forest which recovers is kept in good condition, and CO_2 is absorbed with the growth of the forest.

[Schematics of GHG emission reduction process]



Calculation of GHG emission reduction

[Calculation method]

Calculation of CO_2 absorption by the growth of afforested trees and CO_2 absorption due to forest maintenance.

Calculation of CO_2 absorption refers to the “Contribution of JICA in the global warming countermeasure (Forest sector) – On quantification of CO_2 absorption”

[Equations]

When the total area subject to afforestation that has been carried out as a part of the agroforestry can be determined.

CO_2 absorption by afforestation (tCO_2/yr) = aboveground biomass (t-dry matter/ ha / yr) × forested area (ha) × 1.2(1 + root to shoot ratio :0.2) × 0.5(carbon fraction of dry matter, default value :0.5) × 44/12(conversion factor from C to CO_2)

When the total area subject to forest conservation that has been carried out as a part of the agroforestry can be determined.

CO_2 absorption by forest conservation (tCO_2/yr)= amount of CO_2 retained by the forest (tCO_2/yr) + absorption amount by forest (tCO_2/yr)

Where

The amount of CO_2 retained by the forest= CO_2 accumulative amount × forest area change rate (%)

CO_2 accumulative amount (tCO_2/yr) = Aboveground biomass$_{\text{Biomass stock}}$ (t-dry matter/ ha / yr) × conservation area (ha) × 1.2(1 + root to shoot ratio :0.2) × 0.5(carbon fraction of dry matter, default value :0.5) × 44/12(conversion factor from C to CO_2)

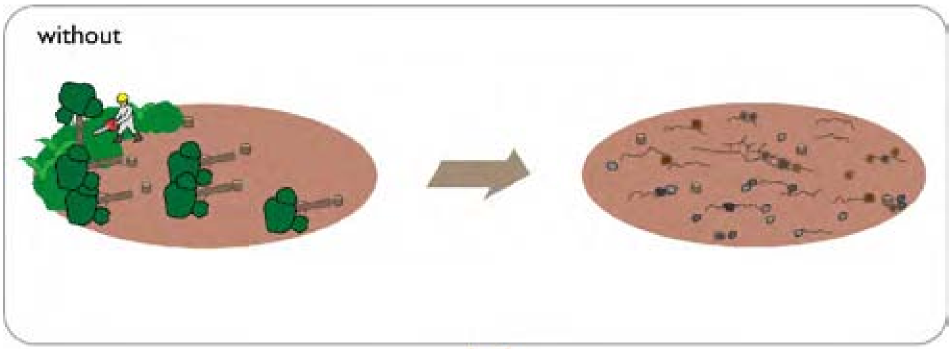
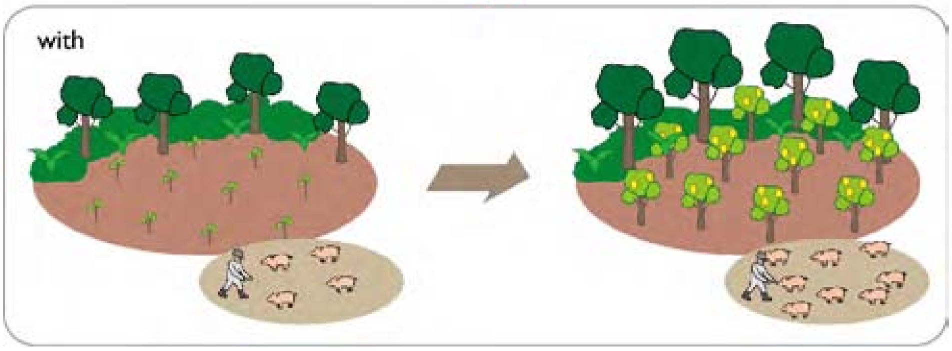
Forest area change rate(%) :Refer to “IPCC good practice guideline for LULUCF Annex 3A.1, Table 3A.1.1

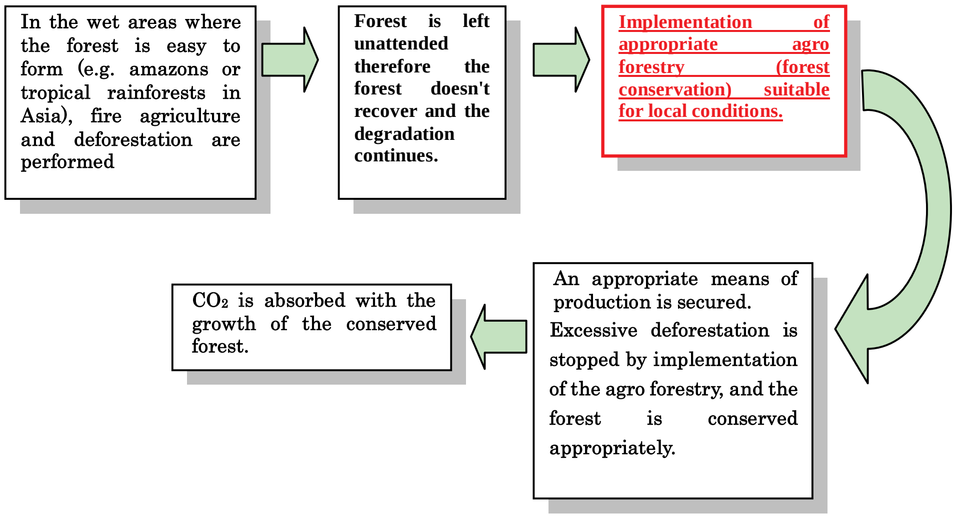
	Absorption amount by forest (tCO_2/yr)＝Aboveground biomass$_{Increment}$ (t-dry matter/ ha / yr)×conservation area (ha)×1.2(1＋root to shoot ratio :0.2)×0.5(carbon fraction of dry matter, default value :0.5)×44/12(conversion factor from C to CO_2)
Required data and data source	**<u>Data regarding afforestation</u>** 1) Forested area - Record of forested area - Data is obtained by field study, interpretation of aerial photo or satellite photo - When many kinds of trees are afforested, forested area for each tree species should be recorded 2) Metrological conditions - Record of Geographical division, type of forest and rainfall condition - This data is used to calculate above-ground biomass 3) Tree species - Record of tree species which is afforested - This data is used to calculate above-ground biomass 4) Above-ground biomass - Above-ground biomass is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.6. - When 20 years passes after afforesting, use values more than 20 years old in Table 3A.1.6. **<u>Data regarding forest conservation</u>** 1) Conservation area - Record of conservation area - Data is obtained by field study, interpretation of aerial photo or satellite photos - When many kinds of trees are afforested, forested area for each tree species should be recorded 2) Forest area change rate - Forest area change rate is decided according to "IPCC good practice guideline for LULUCF Annex 3A.1, Table 3A.1.1 3) Above-ground biomass$_{Biomass\ stock}$ - Above-ground biomass$_{Biomass\ stock}$ is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.2. 4) Above-ground biomass$_{Increment}$ - Above-ground biomass$_{Increment}$ is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.2.
Preconditions	- GHG reduction assumes that there is CO_2 absorption due to the growth of afforested trees

	- It is necessary to perform quantification for the forested area and conservation area
Special notes	- It is necessary to wait for several years until CO_2 absorption by afforested trees is advanced enough. Therefore, it is necessary to implement maintenance of the forest till then. - Follow up monitoring should be implemented after the quantification of GHG absorption is feasible (about few years after afforestation). Quantification of afforestation will be done using follow up monitoring data. - Monitoring items in the follow up monitoring are afforesting tree species, tree age and forested area

Quantification sheet

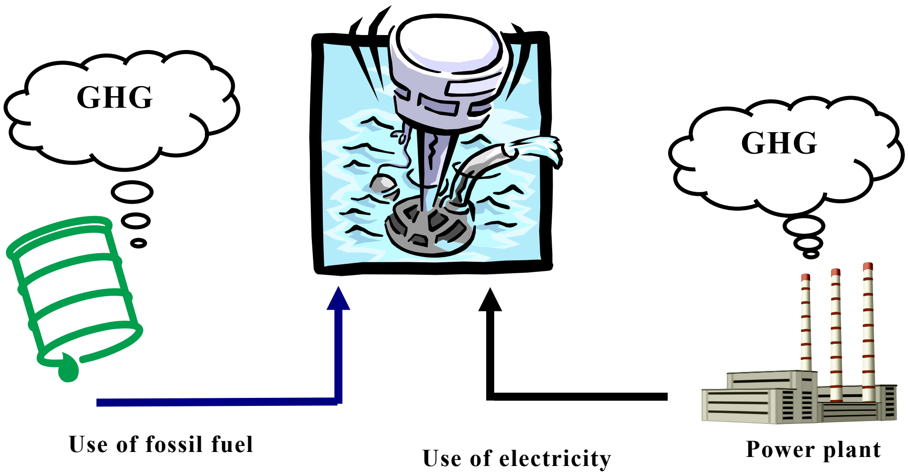
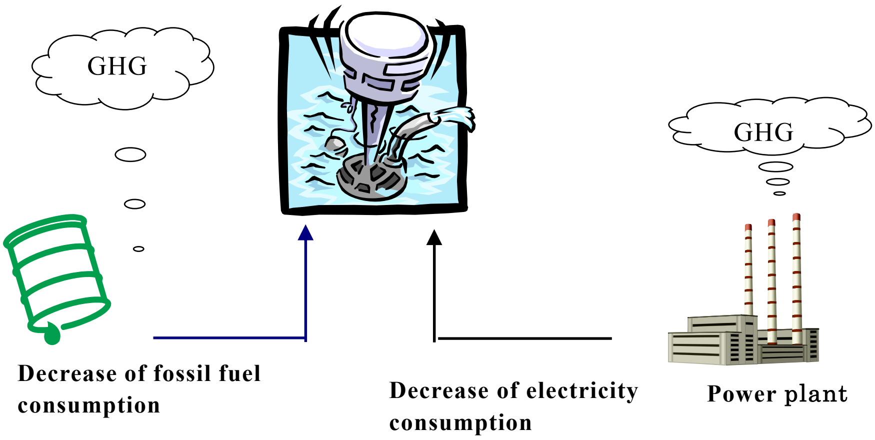
Activity: Agro forestry (forest conservation)

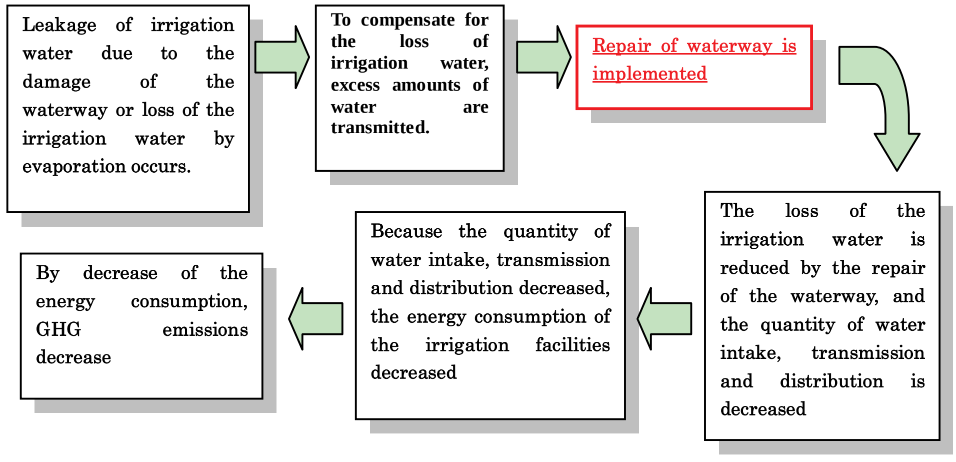
Sector	Rural development
Sub-sector	Forest conservation
GHG emission reduction activity	Forest conservation and afforestation
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** Slash & burn agriculture and deforestation are performed in the area where the forest is easy to reform (e.g. tropical rainforests). Leaving the forest untended after that causes degradation of the forest.  **＜With the activity＞**  Agroforestry (forest conservation) is implemented. The forest is conserved and CO_2 is absorbed by the growth of the trees.

	[Schematics of GHG emissions reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculate absorption and amount of CO_2 retained due to forest conservation. Calculation of CO_2 absorption refers to "Contribution of JICA in the global warming countermeasure (Forest sector) – On quantification of CO_2 absorption" **[Equations]** CO_2 absorption by forest conservation (tCO_2/yr)= amount of CO_2 retained by forest (tCO_2/yr)＋absorption amount by forest (tCO_2/yr) Where amount of CO_2 retained amount by forest= CO_2 accumulative amount×forest area change rate (%) CO_2 accumulative amount (tCO_2/yr)＝Aboveground $biomass_{Biomass\ stock}$ (t-dry matter/ ha / yr)×conservation area (ha)×1.2(1＋root to shoot ratio :0.2)×0.5(carbon fraction of dry matter, default value :0.5)×44/12(conversion factor from C to CO_2) Forest area change rate(%) :Refer to "IPCC good practice guideline for LULUCF Annex 3A.1, Table 3A.1.1 Absorption amount by forest (tCO_2/yr)＝Aboveground $biomass_{Increment}$ (t-dry matter/ ha / yr)×conservation area (ha)×1.2(1＋root to shoot ratio :0.2)×0.5(carbon fraction of dry matter, default value :0.5)×44/12(conversion factor from C to CO_2)

Required data and data source	1) Conservation area - Record of conservation area - Data is obtained by field study, interpretation of aerial photo or satellite photo - When many kinds of trees are afforested, forested area for each tree species should be recorded 2) Metrological condition - Record of Geographical division, type of forest and rainfall condition - This data is used to calculate above-ground biomass 3) Tree species - Record of tree species which is afforested - This data is used to calculate above-ground biomass 4) Forest area change rate - Forest area change rate is decided according to "IPCC good practice guideline for LULUCF Annex 3A.1, Table 3A.1.1 5) Above-ground $biomass_{Biomass\ stock}$ - Above-ground $biomass_{Biomass\ stock}$ is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.2. 6) Above-ground $biomass_{Increment}$ - Above-ground $biomass_{Increment}$ is decided according to IPCC GPG for LULUCF Annex 3A.1, Table 3A.1.2.
Preconditions	- GHG reduction assumes the sum total of CO_2 retained by forest conservation and CO_2 absorption by the growth of afforested tree - It is necessary to perform quantification for the forested area and conservation area
Special notes	- Follow up monitoring should be implemented after the quantification of GHG absorption is feasible (about few years after afforestation). Quantification of afforestation will be done using follow up monitoring data. - Monitoring items in the follow up monitoring are afforested tree species, tree age and forested area

Quantification sheet
Activity: Repair of waterway (Leakage control, .etc.)

Sector	Rural development
Sub-sector	Energy saving
GHG emission reduction activity	Improvement of energy consumption efficiency
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** To compensate for loss of water due to leakage of irrigation canals or evaporation, etc., it is necessary to convey water more than the amount of demand. This excess water conveyance causes excess consumption of energy in irrigation facilities and GHG emissions since energy consumption is increased.  **＜With the activity＞** Loss of irrigation water is decreased due to leakage control. These implementations bring about a decrease in energy consumption and decrease of GHG emissions due to reduced energy consumption. 

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculate GHG reduction due to the reduction of energy consumption in irrigation facilities. Calculation method refers to CDM methodology AM 0020, "Baseline methodology for water pumping efficiency improvements" **[Equations]** **<u>Without the activity</u>** Calculation of GHG emission without the improvement of the irrigation canals $BE_{Without}$=Pump flow volume (Without)×energy consumption per irrigation water unit ($1m^3$)×CO_2 emission factor of electricity or fossil fuel **<u>With the activity</u>** Calculation of GHG emission with the improvement of the irrigation canal PE_{With}= Pump flow volume (With) ×energy consumption per irrigation water unit ($1m^3$)×CO_2 emission factor of electricity or fossil fuel **<u>GHG emission reductions</u>** $ER(kgCO_2) = BE_{Without} - PE_{With}$ **<u>Abbreviations</u>** Pump flow volume (Without): Flow volume without canal improvement (m^3) Pump flow volume (With): Flow volume with canal improvement (m^3)
Required data and data source	1) Pump flow volume of irrigation water with and without irrigation canal improvement - Interview of superintendent of irrigation facilities - Flow volume at the inlet of agricultural field is required. - If it is difficult to obtain a flow volume at the inlet of agricultural field,

	transmission / distribution volume of irrigation pump is applied. 2)Change of irrigation area with and without irrigation canal improvement (see Special notes) - Interview superintendent of irrigation facilities - Both flow volume of irrigation water and irrigation area should be obtained at the same time 3) Energy consumption per irrigation water unit ($1m^3$) - Grid electricity: electricity consumption per irrigation water unit (kWh/m^3) - Fossil fuel (e.g. diesel-powered pump): fuel consumption per irrigation water unit (L/m^3) 4) CO_2 emission factor - Grid electricity: CO_2 emission factor of electricity($kgCO_2/kWh$) ***See Annex 1*** - Fossil fuel: CO_2 emission factor of fossil fuel ($kgCO_2/L$) ***See Annex 2 and 4***
Preconditions	It is assumed that the no increase of irrigation area or change of crop planting is implemented with the improvement of the irrigation canal.
Special notes	However, if the improvement of the canal and an increase of irrigation area is implemented at the same time and flow volume of irrigation water is increased by the increase of irrigation area, Flow volume (Without) should be converted into Converted flow volume (Without) corresponding to an increase in the irrigation area. Conversion formula is as follows: *Conversion flow volume (Without)＝Flow volume (Without) / Irrigation area after increase (m^2 or ha)×Irrigation area before increase (m^2 or ha)*

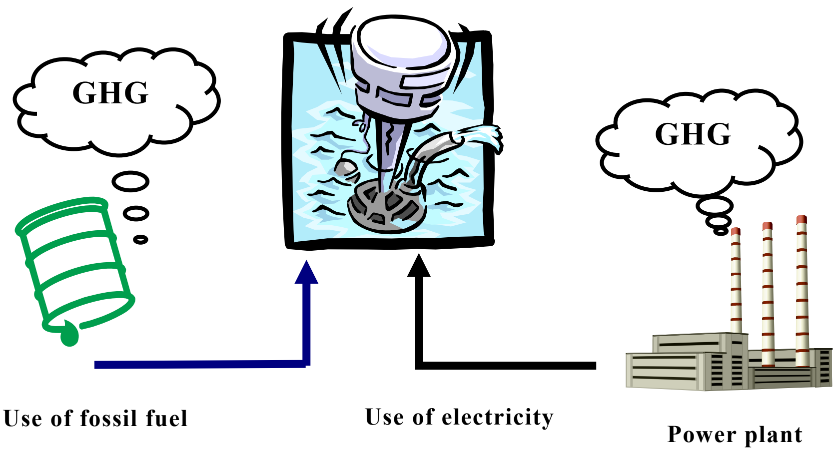
Quantification sheet

Activity: Repair of irrigation wells (Cleaning, replacement of pumps, etc.)

<table>
<tr><td>Sector</td><td>Rural development</td></tr>
<tr><td>Sub-sector</td><td>Energy saving</td></tr>
<tr><td>GHG emission reduction activity</td><td>Improvement of energy consumption efficient</td></tr>
<tr><td>GHG emission reduction impact</td><td>1: Activity will lead to GHG emission reduction
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

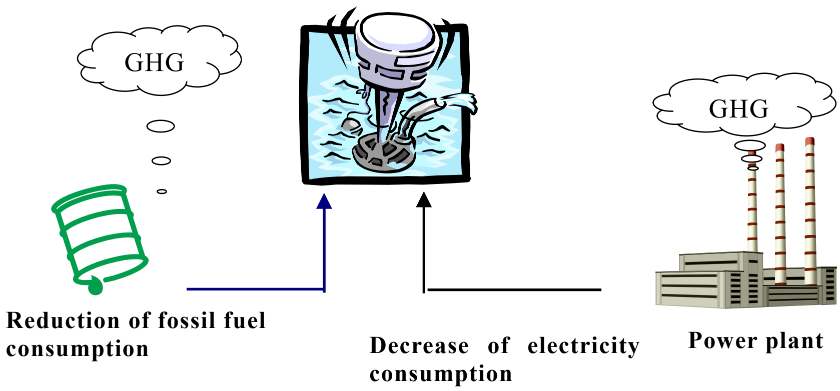
＜Without the activity＞

Energy consumption of pumping is increased by continuing use of wells that have a clogged strainer or deteriorated pump. GHG emission is increased by the increase of energy consumption in the irrigation facilities.

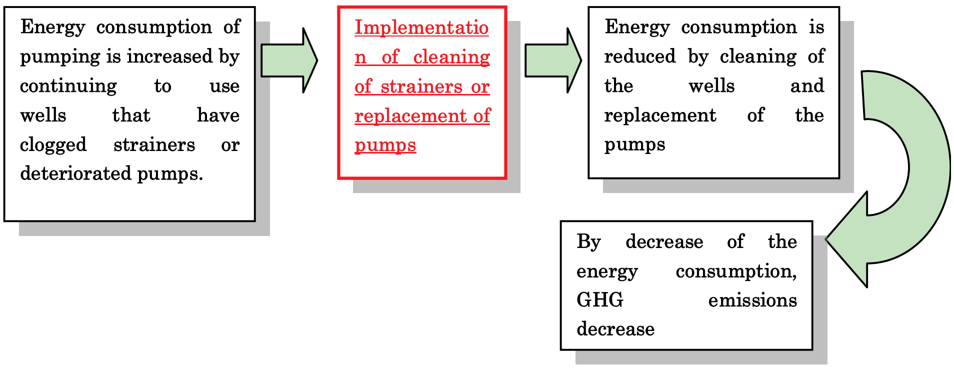


＜With the activity＞

Energy consumption is reduced by cleaning of the wells and replacing the pump, and then GHG emissions decrease.



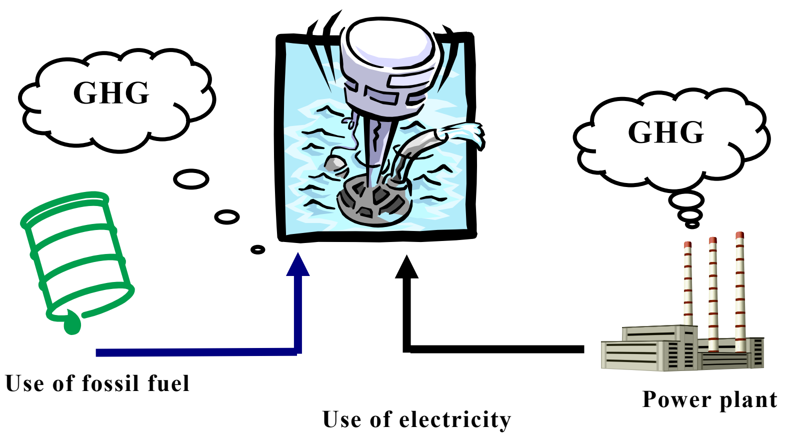
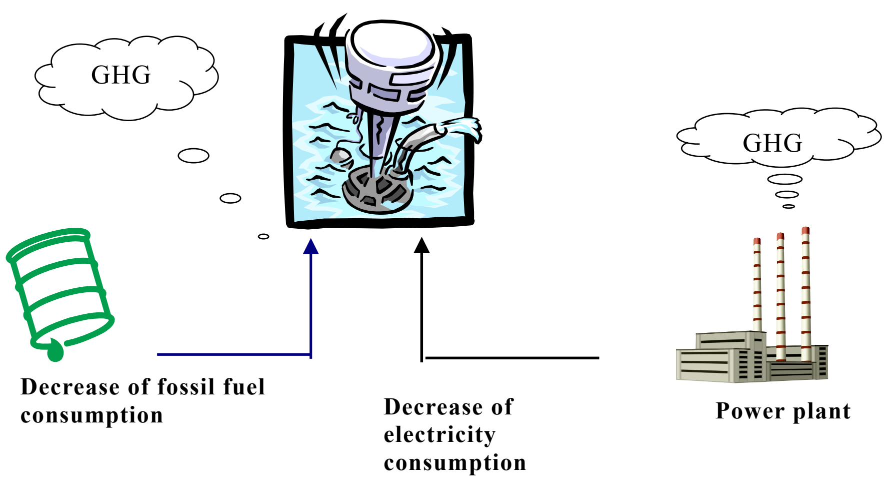
</td></tr>
</table>

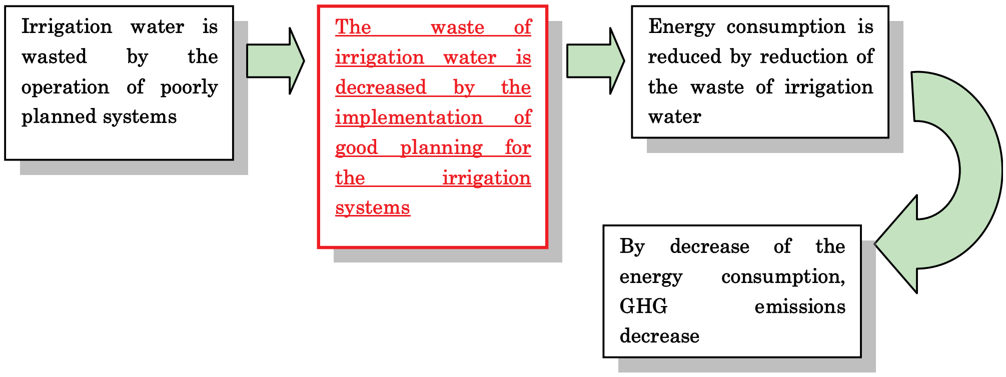
	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Caluculation method]** Calculate GHG reduction due to the reduction of energy consumption in irrigation well system by the repair of irrigation well. Calculation method refers to CDM methodology AM 0020, "Baseline methodology for water pumping efficiency improvements" **[Equations]** **<u>Without the activity</u>** Calculate GHG emission without repair of irrigation well $BE_{Without}$=Energy consumption without repair of irrigation well × CO_2 emission factor of electricity or fossil fuel **<u>With the activity</u>** Calculate GHG emission with repair of irrigation well $BE_{Without}$=*Energy consumption (With)*×CO_2 emission factor of electricity or fossil fuel **<u>GHG emission reductions</u>** ER(kg-CO_2)＝$BE_{Without}$ – PE_{With}
Required data and data source	1) Capacity of pump with and without repair ▪ Interview of administrator of irrigation facilities ▪ Implementation of pilot project 2) *Energy consumption (With)* and *Energy consumption (Without)* ▪ Grid electricity: electricity consumption per irrigation water unit (kWh/m^3) ▪ Fossil fuel (e.g. diesel-powered pump): fuel consumption per irrigation water unit (L/m^3) 3) CO_2 emission factor ▪ Grid electricity: CO_2 emission factor of electricity (kg-CO_2/kWh) ***See***

	Annex 1 ▪ Fossil fuel: CO_2 emission factor of fossil fuel (kg-CO_2/L) ***See Annex 2 and 4***
Preconditions	It is assumed that no increase in the irrigation area or change of crop planting is implemented concurrent with the repair of irrigation well.
Special notes	If capacity of pumping is increased by the repair of the irrigation well, E*nergy consumption (Without)* should be converted into *Converted flow volume (Without)* corresponding to the increase of the irrigation area. Conversion formula is as follows: *Converted energy consumption (Without)*＝*Energy consumption (Without)* / *Capacity of pumping (Without)* ×*Capacity of pumping (With)*

Quantification sheet

Activity: Water saving agriculture (Improvement of irrigation method)

Sector	Rural development
Sub-sector	Energy saving
GHG emission reduction activity	Improvement of energy consumption efficiency
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the ativity＞** Irrigation water is wasted by the operation without proper irrigation method (e.g. occurrence of waste of water). The waste of water causes waste of energy in irrigation facilities, and then increase in the emission of GHG.  **＜With the activity＞** The amount of wasted irrigation water is decreased by the implementation of irrigation with proper irrigation method. The water-saving results decrease energy consumption and decrease of GHG emission. 

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculate GHG reduction due to the implementation of improvement of irrigation method. Calculation method refers to CDM methodology AM 0020, "Baseline methodology for water pumping efficiency improvements" **[Equations]** **<u>Without the activity</u>** Calculation of GHG emission without the improvement of irrigation canal $BE_{Without}$=Pump flow volume (Without)×energy consumption per irrigation water ($1m^3$)×CO_2 emission factor **<u>With the activity</u>** Calculation of GHG emission with the improvement of irrigation canal PE_{With}= Pump flow volume (With) ×energy consumption per irrigation water ($1m^3$)×CO_2 emission factor **<u>Abbreviations</u>** Pump flow volume (Without): Flow volume without improvement of irrigation method (m^3) Pump flow volume (With): Flow volume with improvement of irrigation method (m^3) **<u>GHG emission reductions</u>** $ER(kgCO_2) = BE_{Without} - PE_{With}$
Required data and data source	1) Irrigation water amount with and without improvement of irrigation method - Interview of superintendent of irrigation facilities - Flow volume at the inlet of agricultural field is required. - If it is difficult to obtain a flow volume at the inlet of agricultural field, transmission / distribution volume of irrigation pump is applied. 2)Change of irrigation area with and without improvement of irrigation method - Interview of superintendent of irrigation facilities - Both the flow volume of irrigation water and the irrigation area should be

	obtained at the same time 3) Energy consumption per irrigation water unit (1m^3) - Grid electricity: electricity consumption per irrigation water unit (kWh/m^3) - Fossil fuel (e.g. diesel-powered pump): fuel consumption per irrigation water amount unit (L/m^3) 4) CO_2 emission factor - Grid electricity : electrical CO_2 emission factor (kgCO_2/kWh):***See Annex1*** - Fossil fuel : fuel CO_2 emission factor (kgCO_2/L) : ***See Annex 2 and 4***
Preconditions	- It is assumed that no increase in the irrigation area or change of crop planting is implemented concurrent with the repair of the irrigation well. - The following are proposed as an appropriate irrigation method ✓ Irrigation enforcement of an appropriate time equal to the growth of the crops (e.g. Water-saving rice cropping) ✓ Appropriate operation of irrigation channel network (e.g. control of excess distribution or non-homogeneous distribution, reduction of waste of water)
Special notes	However, if irrigation area is expanded with the improvement of irrigation method, Irrigation water amount (Without) should be converted into Converted irrigation water amount (Without) corresponding to the expanded irrigation area. Conversion formula is as follows: *Converted irrigation water amount (Without) = Irrigation water amount (Without) / Irrigation area (Without) ×Irrigation area (With)*
Calculation example	**1. Summary of project** **<u>Project name</u>** Islamic Republic of Mauritania, The oasis zone development focused on promotion of women, Pilot project 2 **<u>Outline of irrigation method</u>** Irrigation method: Pumping from a shallow well using an engine powered pump. Irrigation water is conveyed to farms with hose or soil waterway. Transportation efficiency of irrigation water: 10～50％ **2. Result of pilot project** Pilot project was implemented for each farm product (tomatoes and carrots). By the improvement of the irrigation method, 36％～80％ of irrigation water was saved. **<u>2.1 Case1 Tomato</u>** **[Information about irrigation water]** **Without the activity** Amount of irrigation water (Without): 40.8 m^3 Amount of production per irrigation water unit (Without): 0.21 kg/m^3

With the activity
Amount of irrigation water (With): 40.8 m^3
Amount of production per irrigation water (With): 1.05 kg/m^3
In this case, *The amount of irrigation water (Without)* and *Amount of irrigation water (with)* was same; therefore *Amount of irrigation water (without)* was converted into *Converted Amount of irrigation water (without)* with *Amount of production per irrigation water (Without)* and *Amount of production per irrigation water (With).*

Converted Amount of irrigation water (without) = Amount of irrigation water (without)×(*Amount of production per irrigation water (With) / Amount of production per irrigation water(Without)*)

i.e. *Converted Amount of irrigation water (without)*=40.8×1.05／0.21＝204 m^3

Therefore, the reduction of irrigation water by the improvement of irrigation methods is as follows:

Reduction of irrigation water (tomato)

Converted Amount of irrigation water (without)	204 m^3
Amount of irrigation water (With)	40.8 m^3
Irrigation water reduction ratio due to improvement of irrigation method	80%

[Fossil fuel consumption of engine powered pump]
There was no information about the specifications of the pump in the pilot project. Therefore, this examination supposes that a small portable pump was used in the pilot project. Assumed specifications of the “small portable pump” are as follows:

<u>Pump</u>
Maximum discharge volume 140 L/min

<u>Engine</u>
Gasoline-powered engine
Capacity of tank: 0.47 L
Run time: 60 min

Calculation of fuel consumption per discharged water volume:

Fuel consumption rate: Capacity of tank / Run time = 0.47 L/60 min=0.0078 L/min

Necessary time to discharge 1m^3: 1m^3/Maximum discharge volume = 1000/140 ＝7.14 min

Therefore, fuel consumption per discharged water volume:

Necessary time to discharge 1 m^3 × Fuel consumption rate = 0.056 L/m^3

CO_2 emission factor of gasoline

CO_2 emission factor of gasoline = 69.25kgCO_2/GJ × 0.0344GJ/L = 2.3822kgCO_2/L ***: See Annex 5***

[GHG reduction by improvement of irrigation method]

Without the activity

$BE_{Without}$=*Corrected amount of irrigation water(Without)*×*Fuel consumption per discharged volume*×*CO_2 emission factor of gasoline*＝204×0.056×2.3822 ＝27.2 $kgCO_2/m^3$

With the activity

PE_{With}= *Amount of irrigation water(With)*×*Fuel consumption per discharged volume* × *CO_2 emission factor of gasoline* = 40.8 × 0.056 × 2.3822 = 5.4$kgCO_2/m^3$

i.e.

ER(tomato) = $BE_{Without}$ − PE_{With} = 27.2$kgCO_2/m^3$ − 5.4$kgCO_2/m^3$ = 21.8 $kgCO_2/m^3$

2.2 Case2 (carrot)

Without the activity

Amount of irrigation water (Without): 47.7 m^3

Amount of production per irrigation water (Without): 0.18 kg/m^3

With the activity

Amount of irrigation water (With): 47.7 m^3

Amount of production per irrigation water (With): 0.28 kg/m^3

The same as Case1 (tomatoes), *Amount of irrigation water (without)* is converted into *Corrected Amount of irrigation water (without).*

Corrected Amount of irrigation water (without)=47.7×0.28／0.18＝74.2 m^3

Therefore, the reduction of irrigation water by the improvement of irrigation methods is shown as follows:

Reduction of irrigation water (carrot)

Converted Amount of irrigation water (Without)	74.2 m^3
Amount of irrigation water (With)	47.7 m^3
Irrigation water reduction ratio due to improvement of irrigation method	36%

Fuel consumption per discharged water volume: 0.056 L/m^3 unit (See Case 1)

CO_2 emission factor of gasoline = 2.3822 $kgCO_2/L$ (See Case 2)

[GHG reduction by improvement of irrigation method]

Without the activity

$BE_{Without}$= *Converted Amount of irrigation water (Without)*×Fuel consumption per discharged water volume×*CO_2 emission factor of gasoline*＝74.2×0.056×2.3822＝9.9$kgCO_2/m^3$

With the activity

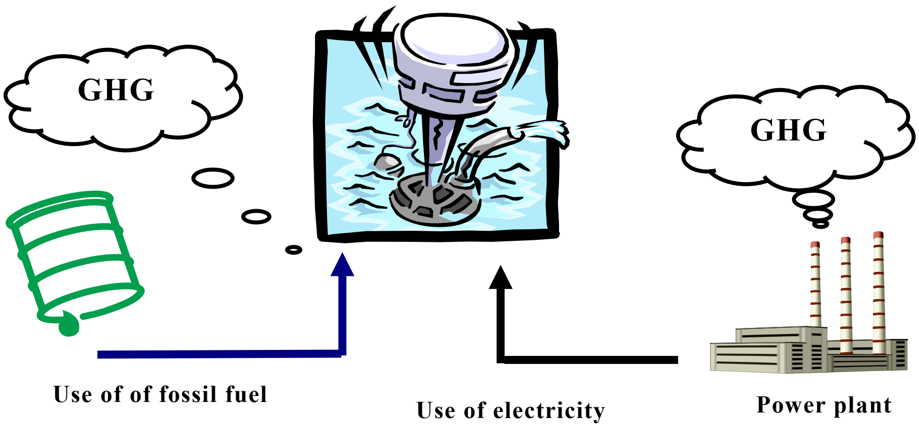
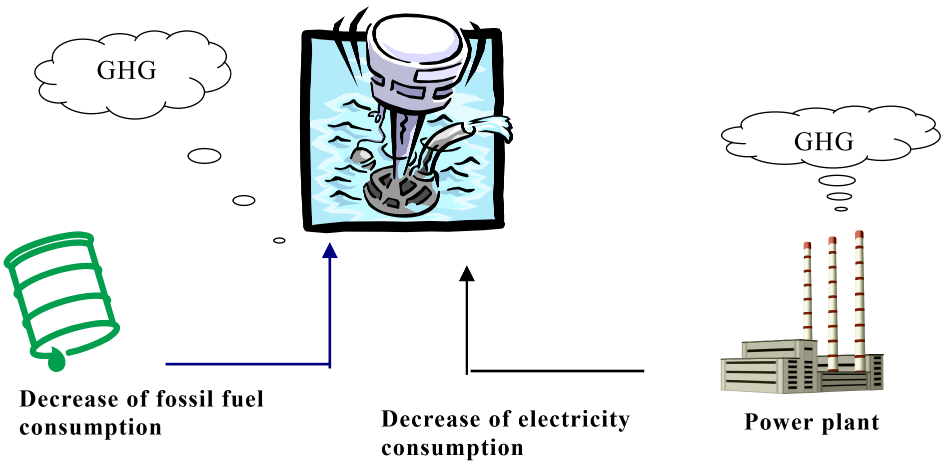
PE_{With}=*Amount of irrigation water (With)*×Fuel consumption per discharged water volume×*CO_2 emission factor of gasoline*＝47.7×0.056×2.3822＝6.4$kgCO_2/m^3$

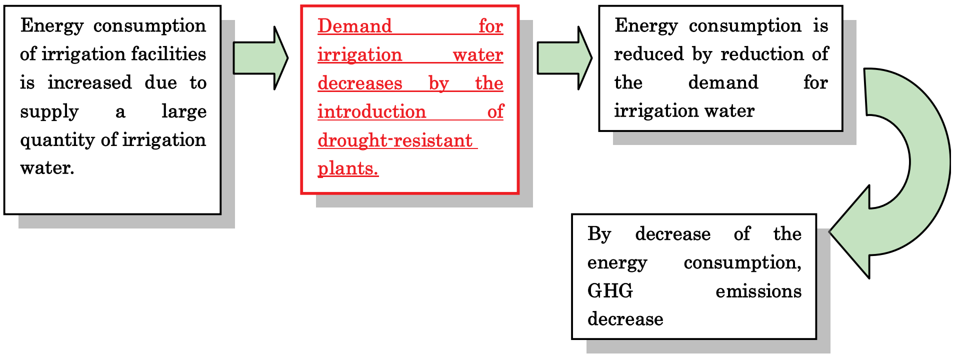
i.e.

ER(carrot)=$BE_{Without}$－PE_{With}＝9.9$kgCO_2g/m^3$－6.4$kgCO_2/m^3$＝3.5$kgCO_2/m^3$

Quantification sheet

Activity: Water saving agriculture (Introduction of drought-resistant plants)

Sector	Rural development
Sub-sector	Energy saving
GHG emission reduction activity	Improvement of energy consumption efficiency
GHG emission reduction impact	<u>1: Activity will lead to GHG emission reduction</u> 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** Energy consumption of irrigation facilities is increased due to supply of a large quantity of irrigation water, and this causes the increase of GHG emissions.  **＜With the activity＞** Demand for irrigation water decreases by the introduction of drought-resistant plants. Therefore, energy consumption of irrigation facilities is decreased, and then GHG emission is decreased. 

	[Schematics of GHG emission reduction process]  **Reference:** There are drought-resistant plant such as watermelon and date palms.
Calculation of GHG emission reduction	**[Calculation method]** Calculation of GHG reduction due to the introduction of drought-resistant plants. Calculation method refers to CDM methodology AM 0020, "Baseline methodology for water pumping efficiency improvements" **[Equations]** **Without the activity** Calculation of GHG emission from irrigation facilities without introduction of drought-resistant plants. $BE_{Without}$=Amount of irrigation water (Without)×energy consumption per irrigation water×CO_2 emission factor **With the activity** Calculation of GHG emission from irrigation facilities with introduction of drought-resistant plants. $BE_{Without}$=Amount of irrigation water (With)×energy consumption per irrigation water×CO_2 emission factor Amount of irrigation water (Without): amount of irrigation water without introduction of drought-resistant plants (m^3) Amount of irrigation water (With): amount of irrigation water with introduction of drought-resistant plants (m^3) **GHG emission reductions** $ER(kgCO_2) = BE_{Without} - PE_{With}$
Required data and data source	1) Amount of irrigation water with and without introduction of drought-resistant plants 2) Change of irrigation area with or without improvement of introduction of

	drought-resistant crops ▪ Interview with superintendent of irrigation facilities ▪ Both the flow volume of irrigation water and the irrigation area should be obtained at the same time 3) Energy consumption per irrigation water unit (1 m^3) ▪ Grid electricity: electricity consumption per irrigation water unit (kWh/m^3) ▪ Fossil fuel (e.g. diesel-powered pump): fuel consumption per irrigation water unit (L/m^3) 4) CO_2 emission factor ▪ Grid electricity : electrical CO_2 emission factor ($kgCO_2/kWh$) : ***See Annex 1*** ▪ Fossil fuel : fuel CO_2 emission factor ($kgCO_2/L$) : ***See Annex 5***
Preconditions	▪ This calculation assumes that the switch to drought-resistant crops is implemented in the area where irrigation agriculture is already performed. ▪ It is assumed that no expansion of irrigation area is implemented concurrent with the introduction of drought-resistant crops.
Special notes	However, if irrigation area is expanded with the introduction of drought-resistant crops, and *Irrigation water amount (With)* becomes larger the *Irrigation water amount (without)*, *Irrigation water amount (Without)* should be converted into *Converted irrigation water amount (Without)* corresponding to the expanded irrigation area. Conversion formula is as follows: *Converted irrigation water amount (Without)* = *Irrigation water amount (Without) / Irrigation area (Without) ×Irrigation area (With)*

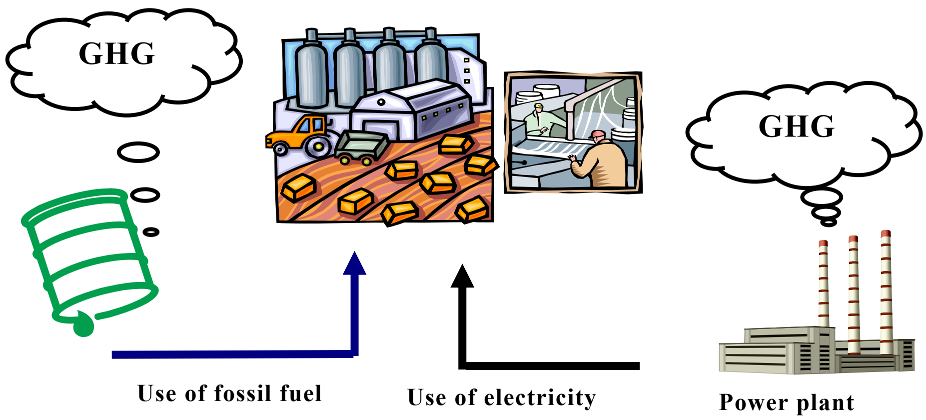
Quantification sheet

Activity: Improvement of energy use efficiency of agricultural facilities (e.g. farm products processing facility)

<table>
<tr><td>Sector</td><td>Rural development</td></tr>
<tr><td>Sub-sector</td><td>Energy saving</td></tr>
<tr><td>GHG emission reduction activity</td><td>Improvement oc energy consumption efficiency.</td></tr>
<tr><td>GHG emission reduction impact</td><td><u>1: Activity will lead to GHG emission reduction</u>
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

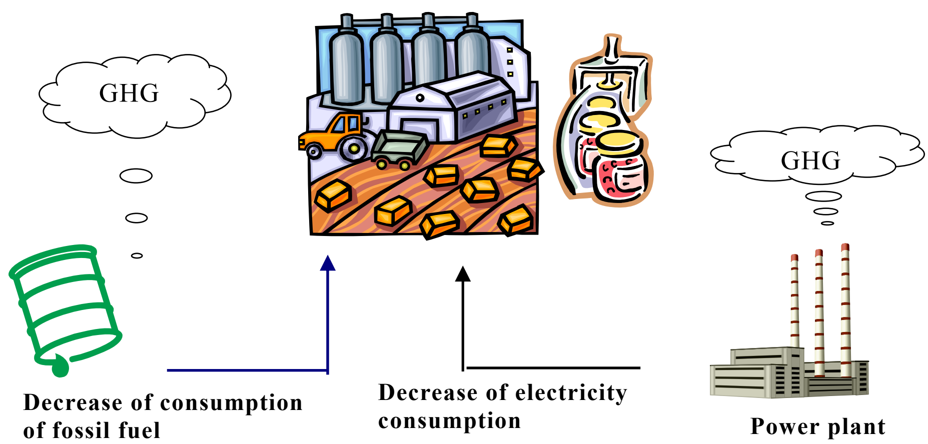
＜Without the activity＞

Energy consumption increases because of the continued operation of agricultural facilities with low energy efficiency. This increase of energy consumption causes increase of GHG emissions.



＜With the activity＞

Energy consumption of agricultural facilities is decreased due to the improvement of energy efficiency. This decrease of energy consumption causes a decrease of GHG emissions.



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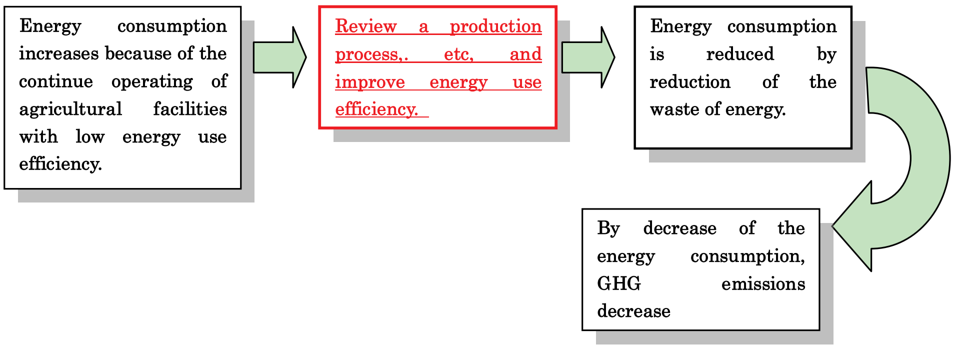
<table>
<tr><td></td><td>
[Schematics of GHG emission reduction process]



</td></tr>
<tr><td>Calculation of GHG emission reduction</td><td>
[Calculation method]
Calculation of GHG reduction by the reduction of energy consumption due to improvement of energy efficiency.

[Equations]
<u>Without the activity</u>
Calculation of GHG emission without improvement of energy use efficiency.
$BE_{Without} = $ Energy efficiency (Without) $\times CO_2$ emission factor

<u>With the activity</u>
Calculation of GHG emission with improvement of energy use efficiency.
$BE_{With} = $ Energy efficiency (With) $\times CO_2$ emission factor

<u>GHG emission reductions</u>
$ER(kgCO_2) = BE_{Wihout} - PE_{With}$
</td></tr>
<tr><td>Required data and data source</td><td>
1) Energy consumption with or without improvement of energy efficiency
- Interview with superintendent of agricultural facilities
- Energy source of agricultural facilities is grid electricity: Electricity consumption (kWh)
- Energy source of agricultural facilities is fossil fuel: Fossil fuel consumption (L)

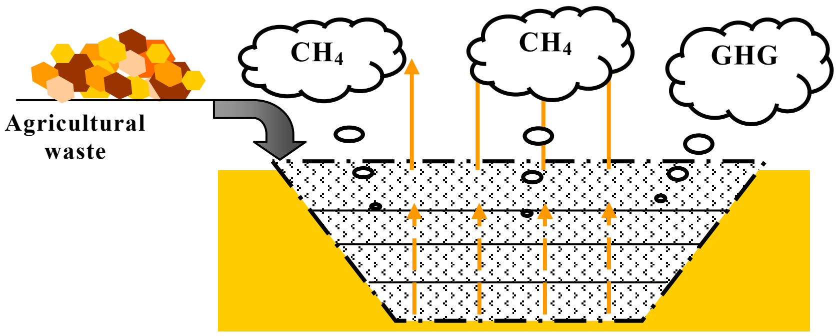
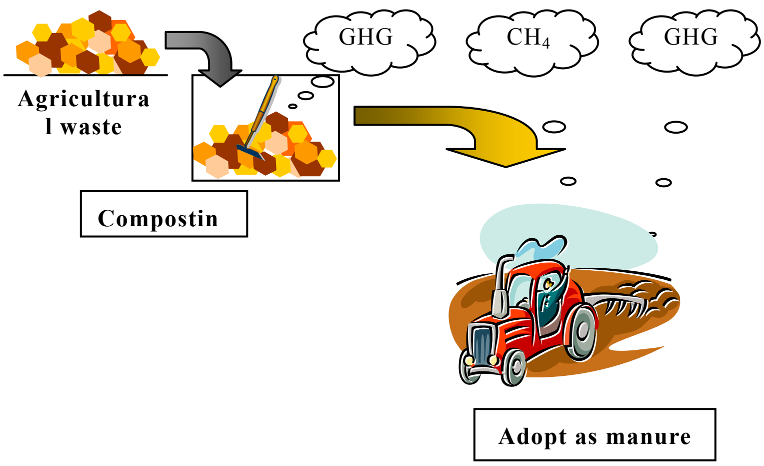
2) CO_2 emission factor
- Grid electricity : electrical CO_2 emission factor ($kgCO_2$/kWh) : See Annex 1
- Fossil fuel : fuel CO_2 emission factor ($kgCO_2$/L) : See Annex 5

3) Amount of production with and without improvement of energy efficiency
- Interview superintendent of agricultural facilities
- Amounts of production energy consumption data should be obtained at the same time.
</td></tr>
</table>

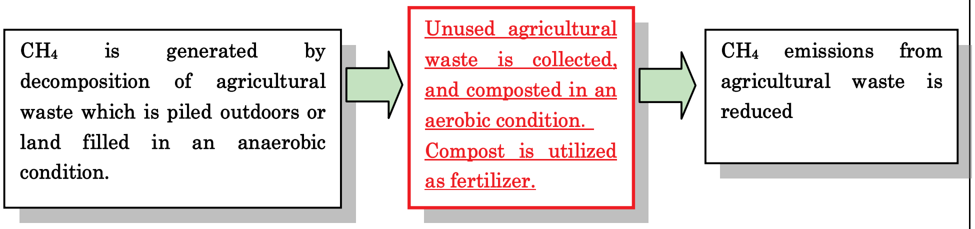
Preconditions	It is supposed that the amount of production does not change with or without improvement of energy efficiency
Special notes	However, if the amount of production is increased with the improvement of energy efficient, *Energy efficiency (Without)* should be converted into *Converted energy efficiency (Without)* corresponding to the increased production. Conversion formula is as follows: *Converted energy efficiency (Without)* = *Energy efficiency (Without)* / *Production amount (Without)* ×*Production amount (With)* The following matters are expected as spin-offs of improvement of energy efficiency: ▪ The extension of life of the installed facility (Because running is with load uniformity) ▪ Improvement of profit (Because energy expense is reduced)

Quantification sheet

Activity: Composting of unused agricultural waste

Sector	Rural development
Sub-sector	Unutilized energy
GHG emission reduction activity	Composting of unused agricultural waste Reduction of CH_4 emission
GHG emission reduction impact	1: Activity will lead to GHG emission reduction 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** CH_4 is generated by decomposition of agricultural waste which is piled outdoors or in a landfill space. Generated CH_4 diffuses directly into the air.  **＜With the activity＞** Reduction of CH_4 generation by collection and composting of agricultural waste. 

[Schematics of GHG emission reduction process]



Calculation of GHG emission reduction

[Calculation method]

Calculation method refers to CDM methodology "AMS III-F Avoidance of methane production from decay of biomass through composting"

[Equations]

1. In case the composting facility is newly constructed

Without the activity

Calculation of amount of CH_4 generation from agricultural waste which was disposed of in piles outdoors or in a landfill space.

$BE_{Without} = BE_{CH4,SWDS,y} - MD_{y,reg} \times GWP_{CH4}$

$MD_{y,reg}$: Annual amount of CH_4 that would have to be captured and combusted to the comply with the prevailing regulations

GWP_{CH4}: Global warming potential of methane (=21)

$BE_{CH4,SWDS,y}$:Annual amount of CH_4 generation without composting. Calculation of $BE_{CH4,SWDS,y}$ is as follows;

$$BE_{CH4,SWDS,y} = \varphi \times (1-f) \times GWP_{CH4} \times \frac{16}{12} \times F \times DOC_f \times (1\text{-}OX) \times MCF \times \sum_{x=1}^{y} \sum_{j}^{n} W_{j,x} \times DOC_j \times e^{-k_j(y-x)} \times \left(1-e^{-k_j}\right)$$

φ : Model correction factor to account for model uncertainties (default: 0.9)

f : Fraction of methane captured at the solid waste disposal site (SWDS) and flared, combusted or used in another manner

F: Fraction of methane in the SWDS gas (volume fraction, default: 0.5)

DOC_f: Fraction of degradable organic carbon (DOC) that can be decomposed (measured data or default value, default value: 2006 IPCC Guideline, Vol.3, Chapter3, p.3.27, Table3.5)

MCF: CH_4correction factor (default value: 2006 IPCC Guideline, Vol.3, Chapter3, p.3.14, Table3.1)

OX: Oxidation factor (reflecting the amount of CH_4 from SWDS that is

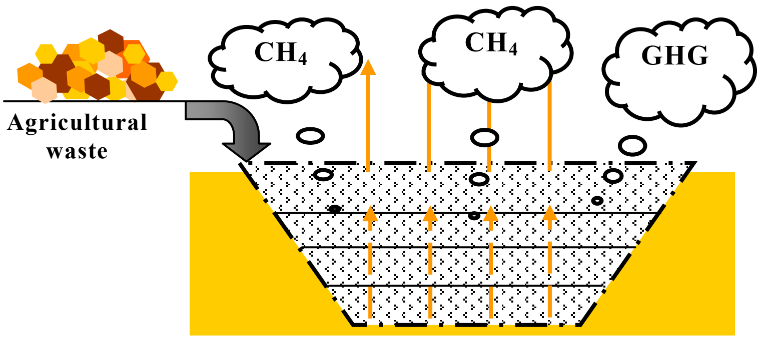
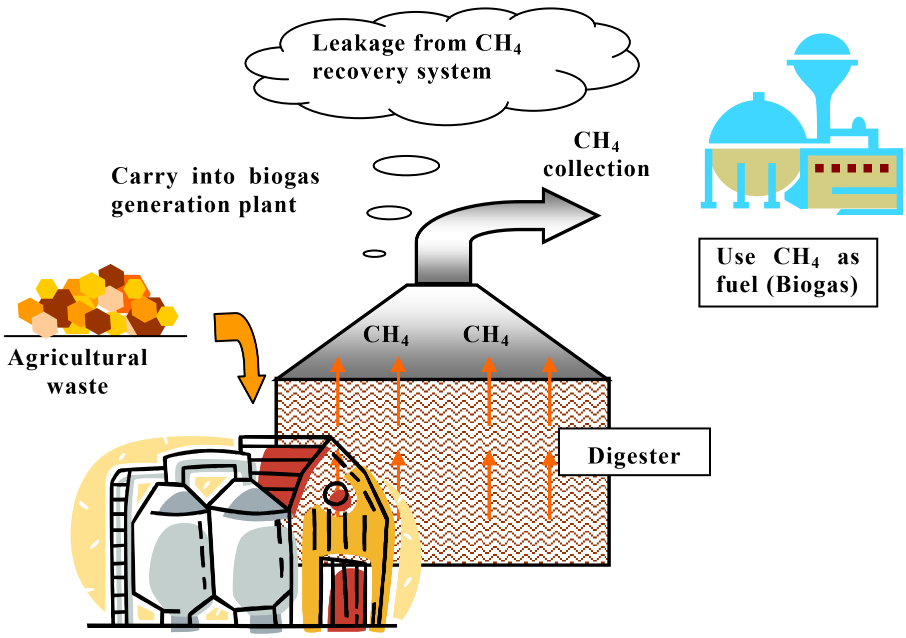
	oxidized in the soil or other material covering the waste) (Default value: controlled landfill site＝0.1、 others＝0.0) W*j*, *x*: Amount of organic waste type *j* prevented from disposal in the SWDS in the year *x* (t) k*j*: Decay rate for the waste type *j* (default value: 2006IPCC Guideline, Vol.3, Chapter3, p.3.17, Table3.3) *x*: A year containing the GHG reduction quantification period *y*: Year for which CH_4 emissions are calculated **With the activity** Calculation of amount of CO_2 emission by the operation of composting facility $PE_{With} = PE_{y,transp} + PE_{y,power}$ $PE_{y,transp}$: Emissions from incremental transportation $PE_{y,transp} = (Q_y/CT_y) \times DAF_w \times EF_{CO2} + (Q_{y,comp}/CT_{y,comp}) \times DAF_{comp} \times EF_{CO2}$ Where Q_y : Quantity of waste composted (t / yr) CT_y : Average truck capacity for waste transportation (t / truck) DAF_w : Average increase in distance for solid waste (km / truck) EF_{CO2} : CO_2 emission factor from fuel use due to transportation (kg-CO_2/km) $Q_{y,comp}$: Quantity of final compost product (t /yr) $CT_{y,comp}$: Average truck capacity for final compost product transportation (t / truck) DAF_{comp} : Average distance for final compost product transportation (km / truck) $PE_{y,power}$: GHG emission from electricity or fossil fuel due to operation of composting facility $PE_{y,power}$ = energy consumption due to operation of composting facility × CO_2 emission factor **GHG emission reductions** $ER(tCO_2e) = BE_{Without} - PE_{With}$

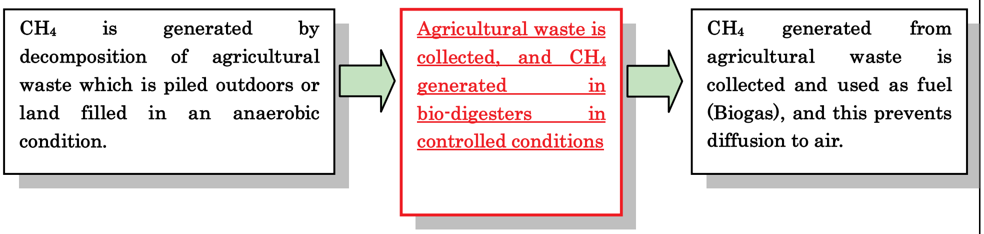
	2. In the case of increase of capacity utilization of existing facilities **GHG emission reductions** $ER(tCO_2e) = (BE_{Without} - PE_{With}) \times (1-r)$ Where ✓ BE and PE: as described above ✓ $r = WCOM_{BAU}/TWCOM_y$ Where - $WCOM_{BAU}$: Registered annual amount of waste composted (t) at the facility on a BAU (Business as usual) basis calculated as the highest amount of annual compost production in the last 5 years prior to the project implementation - $TWCOM_y$: Total quantity of waste composted in the year at the facility (t)
Required data and data source	1) Quantity of agricultural waste - Measured data in the field 2) Quality of waste composted (Q_y) 3) Quantity of final compost product ($Q_{y,comp}$) 4) Average truck capacity for waste transportation (CT_y) and average increase in distance for solid waste transport (DAF_w) 5) Average truck capacity for final compost product transportation ($CT_{y,comp}$) and Average distance for final compost product transportation (DAF_{comp}) 6) Energy consumption of composting facility - Design data of facility 7) CO_2 emission factor - Grid electricity : electrical CO_2 emission factor (kg-CO_2/kWh) : ***See Annex 1*** - Fossil fuel : fuel CO_2 emission factor (kg-CO_2/L) : ***See Annex 2 and 4***
Preconditions	- This guidebook is for GHG reduction quantification of the unused agricultural waste from a farm village by a small composting business. Therefore, this guidebook refers to small scale CDM methodology "AMS III-F Avoidance of methane production from decay of biomass through composting" - The purpose of this methodology is to collect agricultural waste and compost them in aerobic conditions, and prevent the CH_4 emissions that result in an uncontrollable state from dumped agricultural waste. Therefore, the baseline of this methodology is the quantity of CH_4 which occurs when agricultural wastes were dumped and decayed. - This methodology is only for the process of composting. GHG occurring

	from disposed compost or compost used as manure is not considered.
Special notes	- In the implementation of composting project, the decrease of GHG emission from the operation of composting facility (PE in calculating formula) is important.

Quantification sheet

Activity: Biogas

Sector	Rural development
Sub-sector	Unutilized energy
GHG emission reduction activity	Use of agricultural waste to produce energy Reduction of CH_4 emission
GHG emission reduction impact	<u>1: Activity will lead to GHG emission reduction</u> 2: Activity will lead to GHG emission reduction subject to condition(s) 3: Activity will not lead to GHG emission reduction
GHG emission reduction scenarios (description of how GHG is reduced)	**＜Without the activity＞** CH_4 is generated by decomposition of agricultural waste which is piled outdoors or in a landfill space. Generated CH_4 is diffused directly into the air.  **＜With the activity＞** Collect agricultural waste and generate CH_4 within a managed facility. CH_4 which is generated in the facility is collected and atmosphere release is prevented. 

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** Calculation method refers to CDM methodology "AMS Ⅲ .R. Methane recovery in agricultural activities at household /small farm level" **[Equations]** **<u>Without the activity</u>** The same as the "Without" Case in the "Quantification sheet Composting of unused agricultural waste" **<u>With the activity</u>** Calculation of GHG emission from use of fossil fuels or electricity for the operation of the system and the physical leakage of CH_4 from the recovery system. $PE_{With}=LF_{AD}\times(CH_4GWP\times D_{CH4}\times Bo\times VS_{m.y.})/1000$ LF_{AD}: CH_4 leakages from anaerobic digesters; Default value 0.10(IPCC guideline 2006, Vol.4, Chapter10, Table10A-8) CH_4GWP: Global warming potential of CH_4; 21 D_{CH4}: Conversion factor of m^3 CH_4 to kg CH_4 (IPCC guideline 2006, Vol.4, Chapter10, p10.42) Bo: Maximum methane producing potential of the manure type treated in the biogas digesters (m^3-CH_4/kg, depends on specie of livestock) (IPCC guideline 2006, Vol.4, Chapter10, Table 10A.4 to Table 10A.9) $VS_{m.y.}$: Annual amount of volatile solids treated in the biogas digesters on dry matter weight (kg dry-matter/y) (IPCC guideline 2006, Vol.4, Chapter10, Table 10A.4 to Table 10A.9) **<u>GHG emission reductions</u>** $ER(tCO_2e)=BE_{Without}-PE_{With}$
Required data and data source	1) The data which is necessary for the calculation of the "Without Case" - Refer to "Quantification sheet Composting of unused agricultural waste" 2) Kind of livestock and livestock excreta - Design data of facility
Preconditions	This guidebook is for a small biogas facility in a farm village.
Special notes	The consumption of firewood or fossil fuel is reduced, and reduction of the additional GHG emission with it is expected by the spread of biogas technology.

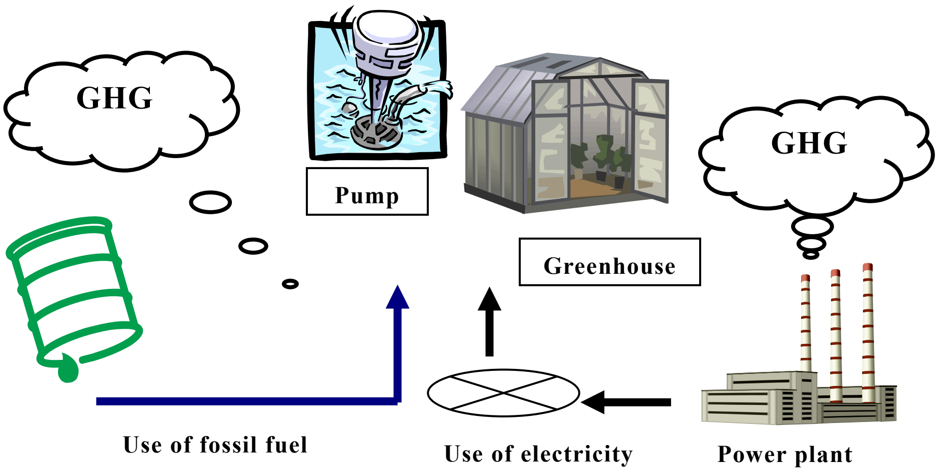
Quantification sheet

Activity: Application of renewable energy

<table>
<tr><td>Sector</td><td>Rural development</td></tr>
<tr><td>Sub-sector</td><td>Unutilized energy</td></tr>
<tr><td>GHG emission reduction activity</td><td>Application of renewable energy to agricultural facilities</td></tr>
<tr><td>GHG emission reduction impact</td><td><u>1: Activity will lead to GHG emission reduction</u>
2: Activity will lead to GHG emission reduction subject to condition(s)
3: Activity will not lead to GHG emission reduction</td></tr>
<tr><td>GHG emission reduction scenarios (description of how GHG is reduced)</td><td>

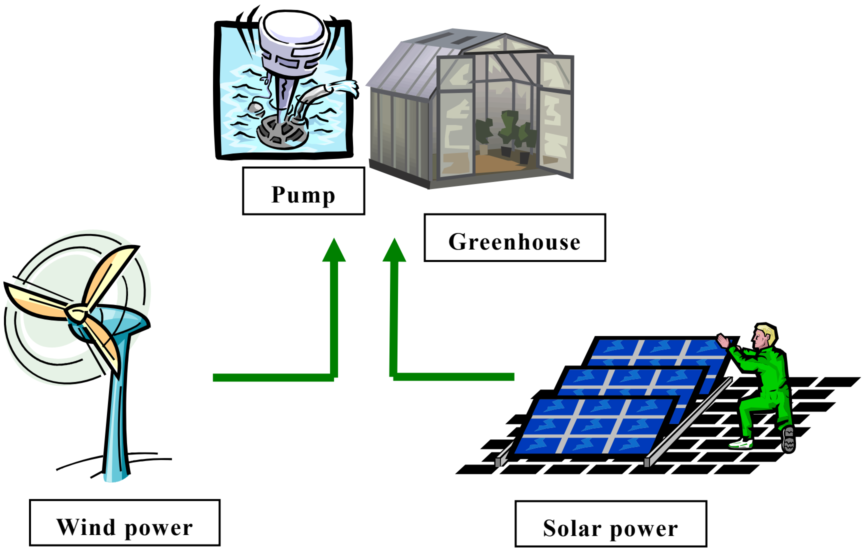
＜**Without the activity**＞

Agricultural facilities are operated with grid electricity or fossil fuel. Use of grid electricity or fossil fuel causes GHG emission.

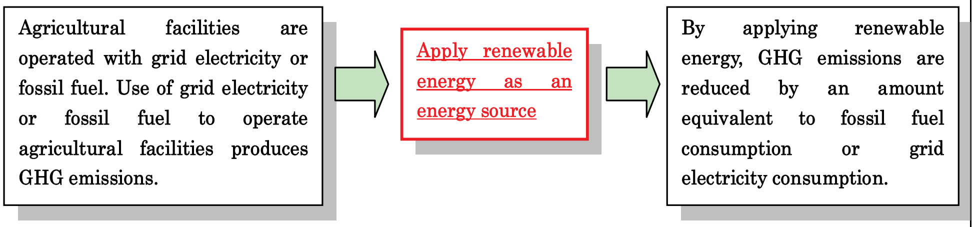


＜**With the activity**＞

Agricultural facilities are operated with renewable energy (solar power, wind power,.etc). GHG is not emitted by using renewable energy.



</td></tr>
</table>

	[Schematics of GHG emission reduction process] 
Calculation of GHG emission reduction	**[Calculation method]** GHG emission becomes 0 (Zero) by grid electricity or fossil fuel being replaced with renewable energy. **[Equations]** **<u>Without the activity</u>** Calculation of GHG emission amount from grid electricity or fossil fuel consumption. GHG emission amount due to grid electricity consumption $BE_{Without}$ = Electricity consumption (kWh/yr) × CO_2 emission factor of electricity GHG emission amount by fossil fuel consumption $BE_{Without}$ = Fossil fuel consumption (L / yr) × CO_2 emission factor of fossil fuel **<u>With the activity</u>** GHG emission by renewable energy PE_{With} = 0(Zero) **<u>GHG emission reductions</u>** ER(tCO_2/y) = $BE_{Without}$
Required data and data source	1) Electricity consumption and Fossil fuel consumption ▪ Replace grid electricity or fossil fuel with renewable energy: Obtain observed value by an interview with the institution manager ▪ Newly adopted renewable energy: Design data of facility (predicted value of grid electricity or fossil fuel reduction) 2) CO_2 emission factor ▪ Grid electricity : CO_2 emission factor of electricity (kgCO_2/kWh) : ***See Annex 1*** ▪ Fossil fuel : CO_2 emission factor of fossil fuel (kgCO_2/L) : ***See Annex 2 and 4***
Preconditions	▪ GHG emission of renewable energy is presumed to be 0 (Zero) ▪ In this guidebook, GHG emission at the time of production and construction of renewable energy device is not considered
Special notes	When it is expected that there is much use of a backup energy source using fossil fuel or grid electricity, it is desirable to consider GHG emission by the backup energy source.

3.6.5 Appended Case Studies

№	Project Title	Sector
10	Sustainable rural development in Soconusco, Chiapas state in Mexico	Rural development
11	The feasibility study on water resources development and management in Jordan River rift valley	Rural development

Case study No.	10
Project title	Sustainable rural development in Soconusco, Chiapas state in Mexico
Sector	Rural development
Sub-sector	Forest conservation
Project summary	**[Background]** Mexico recognizes the importance of equal development of the whole farm village, but this is not being realized due to lack of ability of the local government for rural development and the weakness of the benefiting organization. The implementation area of the project in Chiapas is behind in development, farmer's income is falling, and social inequity fuels a lay guerrilla organization. **[Objectives]** Purpose of this project is that a voluntary rural development project by the local government (city or village) is performed in Soconusco area of Chiapas state. Furthermore, this project aims at an improvement of living conditions in the Soconusco area. **[Condition after project implementation]** In this project, several mini projects were carried out. In the project regarding the GHG reduction, introduction of improved kitchen stoves was implemented. In the families that introduced improved kitchen stoves, consumption of fuel wood was decreased by about 30%. Also, reduction of CO_2 emission per household per month was 0.92 (t-CO_2 / household/month). The spread of improved kitchen stoves in this pilot project and decrease of the fuel wood consumption due to it were contributions by JICA which carried out this project.
GHG emission reduction Scenarios	**<u>Without the activity</u>** Open fire needs much fuel wood because its heat efficiency is low. ↓ Many trees are cut down to get a lot of fuel wood. ↓ Carbon (CO_2) kept in tree is emitted after cutting of the trees. Therefore, the felling of a large quantity of trees means a large quantity of CO_2 emission. **<u>With the activity</u>** By the spread of improved kitchen stoves, consumption of fuel wood decreases ↓ The felling of trees is decreased ↓ CO_2 emissions from the felling of trees decreases
Equations to calculate GHG emissions	**[Equations]** **<u>Without the activity</u>** Calculation of CO_2 emission of felling of trees without introduction of improved kitchen furnace. $BE_{Without}$=Fuel wood consumption without improved kitchen furnace (t-dry matter)×1.2 (1＋root to shoot ratio: 0.2)×0.5 (carbon fraction of dry matter, default value :0.5) ×44/12 (conversion factor from C to CO_2)

<table>
<tr><td></td><td><u>With the activity</u>
Calculation of CO_2 emission of cutting of trees with improved kitchen furnace introduction.

BE_{With}=Fuel wood consumption with improved kitchen furnace (t-dry weight) × 1.2 × 0.5 × 44/12

<u>GHG emission reductions</u>
$ER(tCO_2) = BE_{Without} - PE_{With}$</td></tr>
<tr><td>Applied data</td><td>- Data about fuel wood consumption (the result of pilot project)
Monthly average fuel wood consumption of beneficial household (Before improved furnace is applied): 3.26 (m^3)

Effect of reduction of fuel wood consumption: 30 (%)

- Citation data
Basic wood density: 0.42 (t-dry matter)</td></tr>
<tr><td>Calculation of GHG emissions</td><td>(1) Calculation of fuel wood consumption

Reduction of fuel wood consumption (m^3/ household / month) is calculated as follows:

$3.26m^3 \times 0.3\% = 0.98\ m^3$

Henceforth, amount of fuel wood is handled as t-dry matter. Conversion from cubic measure to t-dry matter is performed as follows:

Basic wood density: 0.42(t-dry matter/ m^3)
Reference: IPCC Good Practice Guidance for LULUCF, Table3A.1.9-1, apply the value of Tsuga

Therefore, fuel wood consumption (m^3/ household / month) is converted as follows:
$0.98 \times 0.42 = 0.41$ (t-dry matter/ household /month)

(2) Calculation of reduction of CO_2 emission

$ER(tCO_2) = BE_{Without} - PE_{With}$ = (Furl wood consumption without modified furnace - Furl wood consumption with modified furnace)×1.2×0.5×44/12

Herein, (Fuel wood consumption without modified furnace - Fuel wood consumption with modified furnace) means reduction in amount of fuel wood by the application of improved kitchen furnace.

Therefore;

$$\mathbf{ER(tCO_2) = BE_{Without} - PE_{With} = 0.42 \times 1.2 \times 0.5 \times 44/12 = 0.92(tCO_2/household/month)}$$</td></tr>
<tr><td>Preconditions</td><td>- The heat capacity to get by combustion of fire wood with improved kitchen furnace is the same as with the open-fire.

- Basic wood density is different by wood species. IPCC Good Practice Guidance for LULUCF, Tables 3A.1.9-1 and 3A.1.9-2 contain many kinds of woods in tropical zone, temperate zone and cold zone. To perform an appropriate estimate, it is important to research a wood species of fuel woods, and select an appropriate basic wood density according to Tables 3A.1.9-1 and 3A.1.9-2.

- However, in the interest of saving time, it is desirable to acquire the fuel wood consumption data by weight (t-dry matter).</td></tr>
</table>

Lessons learned from case study	▪ It was indicated that the consumption of firewood has seasonal change. Therefore, the research period about the consumption of fuel wood should contain at least summer and winter or dry-season and rainy-season. ▪ The consumption of the fuel wood may be different by household. Therefore, it is necessary to obtain data from at least four or five households about the consumption of the fire wood.

Case study No.	11
Project title	The feasibility study on water resources development and management in Jordan River rift valley
Sector	Rural development
Sub-sector	Improvement of energy use efficiency of agricultural facilities
Project summary	**[Background]** A key industry of the Jordan Valley area is agriculture, and the source of irrigation water is a spring or well. However, it can be said that limited water resources are not used effectively because of their poor irrigation facilities and the trouble of pumping facility, and inappropriate irrigation water distribution. In addition, strong water demand is expected in the future in the area. Therefore, in this area, the beneficial use of agricultural water and existing water source, and practical use of unused water source are needed. **[Ovjectives]** There were three objectives of this project: (1) Effective use of agricultural water: To clarify the policy of effective use of agricultural water in Jordan Valley area. (2) Development of new water source: To clarify the policy of application of unused water source in Jordan Valley area. (3) Technical transfer: To promote the improvement of technologies about improvement of use efficiency of agricultural water and application of unused water source. And enhancement of planning counterparts. **[Condition after project implementation]** Rehabilitation of well was performed as a case study. As for the result about four wells, fuel consumption decreased 30% - 50%. In addition, GHG emission reduction averaged 30.3 kgCO_2/hr and 121.1 kgCO_2/hr in total. Decrease of the fossil fuel consumption of the pump in this pilot project was a contribution by JICA which carried out this project.
GHG emission reduction scenarios	**<u>Without the activity</u>** Energy consumption of pumping is increased by continuous use of wells that have a clogged strainer or deteriorated pump. ↓ GHG emission is increased by the increase of energy consumption of irrigation facilities.

	With the activity Cleaning of well and replacement of pump is implemented. ↓ Energy consumption of pumping is decreased. ↓ GHG emission is decreased by the decrease of energy consumption.
Equations to calculate GHG emissions	**[Equations]** **Without the activity** Calculate GHG emission without repair of irrigation well $BE_{Without}$=Energy consumption without repair of irrigation well × CO_2 emission factor of fossil fuel **With the activity** Calculate GHG emission with repair of irrigation well $BE_{Without}$=*Energy consumption (With)* × CO_2 emission factor of fossil fuel **GHG emission reductions** $ER(kgCO_2) = BE_{Without} - PE_{With}$
Applied data	**Pumping discharge and fuel consumption** Measured data in pilot project is shown in Table 1.

Table 1 Pumping discharge and fuel consumption in pilot project

Well No.	Before rehabilitation (Without) (December 2007)			After rehabilitation (With) (August 2008)	
	Pumping discharge (m^3/hr)	Fuel consumption (L/hr)	Fuel consumption / Fuel discharge (L/m^3)	Pumping discharge (m^3/hr)	Fuel consumption (L/hr)
19-17/055	85	22	0.26	118	14
19-17/027	50	18	0.36	50	9
19-17/034	55	18	0.33	55	9
18-18/036	80	18	0.23	90	9

Reference data

CO_2 emission factor of fossil fuel

In the pilot project area, engine-powered pump (diesel engine) is used.

Therefore, this case study uses CO_2 emission as factor of diesel fuel.

CO_2 emission factor of diesel fuel: 2.746kg-CO_2/L

(***See Annex 5:*** Factor of diesel oil: 74.01kgCO_2/GJ × 0.0371GJ/L)

Calculation of GHG emissions

[Correction of fuel consumption]

By the rehabilitation of wells, the pumping discharges of well No.19-17/055 and No.18-18/036 increase.

Therefore, the fuel consumption of these two wells (No.19-17/055 and No.18-18/036) is collected. For the calculation, please refer Special notes of p.3.6-25.

Results of calculation are as follows:

Well No.19-17/055

Collected fuel consumption (Without)＝0.26×118＝30.5 L/hr

Well No.18-18/036

Collected fuel consumption (Without)＝0.23×90＝20.3 L/hr

However, the pumping discharge of No. 19-17/027 and No.19-17/034 was not changed and fuel consumption decreased.

Therefore, collection of fuel consumption for No. 19-17/027 and No.19-17/034 were not done.

[Calculation of GHG emission reduction]

Data for calculation of GHG emission reduction and the result of the calculation are shown in Table 2.

As the result of the rehabilitation of four wells, GHG emission was reduced 24.7 to 45.4 ($kgCO_2$/hr).

Table 2 GHG emission reduction due to the rehabilitation of wells

Well No.	Before rehabilitation (Without)		After rehabilitation (With)		GHG emission reduction BE－PE (kg-CO_2/hr)
	Fuel consumption (L/hr)	GHG emission (BE)	Fuel consumption (L/hr)	GHG emission (PE)	
19-17/055	30.5(Without)	83.87	14	38.44	45.4
19-17/027	18.0	49.43	9	24.71	24.7
19-17/034	18.0	49.43	9	24.71	24.7
18-18/036	20.3(Without)	55.61	9	24.71	30.9

Preconditions

- In this case study, it was assumed that pumping discharge was constant even through the implementation of rehabilitation.
- This pilot project implemented both cleaning of well and pump replacement at the same time. Therefore, in this case study, it was not able to estimate the effect of each well cleaning and pump replacement.

Lessons learned from

- When similar calculation is carried out, it is desirable to acquire data items like this case study, i.e. 1) Pumping discharge with and without rehabilitation, 2)

case study	Energy consumption with and without rehabilitation, and 3) Energy source of irrigation pump and its energy consumption.

CHAPTER 4 Recommendations

Recommendations for application of GHG quantification to JICA's GHG emission mitigation activities are described below.

(1) Enhance Mitigation Activities in JICA Project

In implementing cooperation activities in developing countries, it is important that JICA encourages the aid recipient country to analyze the sustainability of the cooperation activity from the climate change perspective, and to bring mitigation measures into the cooperation activity. It is also recommended that mitigation measures should be considered at each stage of the project cycle from planning, through implementation, and evaluation of a JICA project activity.

It is expected that JICA officials from the headquarters offices and overseas offices, JICA experts as well as consultants involved in the JICA project and counterparts of developing countries will make further efforts to improve the GHG mitigation effects achieved by the JICA project activities, once such stakeholders are able to quantitatively identify and objectively assess the climate change mitigation effects of the JICA project, and to acknowledge such positive mitigation effects in actual numbers by using this GHG Quantification Guidebook.

(2) Enhance Follow-up to achieve JICA Project Objectives

In order to quantify the GHG emission reduction effects from JICA projects, it is essential to quantitatively identify the achievement level of the project goal, or more specifically, achievement level of the overall goal of a technical cooperation project or the realization level of a master plan.

And therefore, it is important to regularly monitor the level of impact from a technical cooperation project or the realized contents proposed in a development study, and if that monitored level and/or realized contents are found to be different than expected, it is essential to examine the causes and barriers and properly give feedback to the JICA project planners.

In this sense, this GHG Quantification Guidebook can act as a useful tool to not only identify GHG emission reduction effects, but also to ensure follow-up of a JICA project activity.

(3) Internalization of Collection of GHG Quantification Data

This Guidebook limits the required data for quantification to the minimum and simplest possible so that users can obtain and use the existing data from the JICA project. However, in some cases the required data are not contained in the report of the project; and therefore, it is recommended such required data for GHG quantification is collected and stored in all relevant projects.

(4) Monitoring after Project Implementation

This Guidebook allows users to calculate the expected GHG emission reductions in such future years as when a technical cooperation project or a master plan is in the implementation stage.

However, to order to compare the actual GHG emissions reduction to the reduction amount expected during the planning stage, users need to calculate GHG emissions using the monitored data from the project activity.

In other words, GHG mitigation impacts from a JICA project activity cannot be assessed without proper monitoring of that project activity[1].

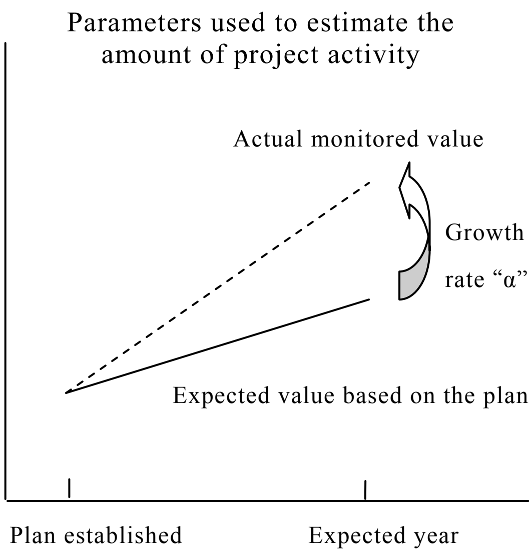
[1] For technical cooperation projects such as training and dissemination activities, various conditions must be fulfilled after completion of the project such as continuous financing or technical cooperation before finally GHG reductions are achieved. Therefore, monitoring of project activities may be not easy. In this case, it is possible to show that the project complies with the MRV requirements by using performance indicators of EGTT technology transfer such as (1) the number of organizations established or supported by technology transfer, (2) the number of participants in a cooperation program, (3) the number of participants in seminars held, and (4) the number of successful capacity development activities, etc.

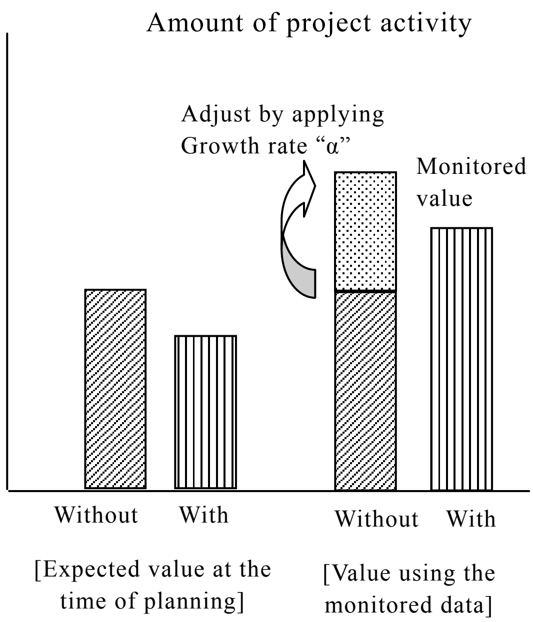
[Notes]

In a case where the projected amount of project activity will largely increase due to the unexpectedly high economic growth, the amount of GHG emissions from the project activity ("***With***" project case) using the actually monitored data may be larger than the amount of GHG emissions from the project activity that was estimated during the planning phase as a "***Without***" case.

In such case, the amount of project activity in the "***Without***" case should be adjusted. Users can monitor parameters used for the estimation of the amount of project activity (e.g. population, number of households, shipment value of a product, etc.), and compare those parameters and yield the growth rate (α), which can then be applied to the amount of project activity in the "***Without***" case (see figures below).

For example, for a project that involves an energy conservation measure, the amount of project activity is expressed as energy consumption and the parameters used to estimate this energy consumption value are the shipment value and volume of a product.





***Annex 1:* Calculation Method of CO_2 Emission Factor of Electricity ($kgCO_2/kWh$)**

CO_2 emission factor of electricity is calculated using the current data of grid electricity system such as electricity generation and fuel consumption by power plant(s), and CO_2 emission factor by fuel type(s) (IPCC 2006 default value)

CO_2 Emission of fossil fuel, PE_{FC} ($kgCO_2/y$) is calculated as follows.

$PE_{FC} = \sum FC_i \text{ x } COEF_i$

PE_{FC}: CO_2 emission by combustion of fossil fuel ($kgCO_2/y$)

FC_i: Consumption of Fuel i (mass or volume/y)

$COEF_i$: CO_2 Emission Factor ($kgCO_2$/mass or volume) (IPCC 2006 default value)

i: Fuel Type

CO_2 Emission Factor, $COEF_i$ ($kgCO_2$/mass or volume) is calculated by using 2 options of calculation method depending on the available data.

Reference) CDM Methodology Tool: "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion" (Version 2)

Option A:

When unit of FC_i is weight, $COEF_i = w_{C,i} \text{ x } 44/12$

When unit of FC_i is volume, $COEF_i = w_{C,i} \text{ x } \rho_i \text{ x } 44/12$

$w_{C,i}$: Weighted average of carbon contents per mass by fuel type i (kgC/mass)

ρ_i: Weighted average of mass density by fuel type i (mass/volume of fuel)

Option B:

CO_2 Emission Factor, $COEF_i$ ($kgCO_2$/mass or volume) is calculated using net calorific value, NCV_i and CO_2 Emission Factor by fuel type *i*.

$COEF_i = NCV_i \text{ x } EF_{CO2,i}$

NCV_i: Weighted average of net calorific value by fuel type *i* (kJ/mass or volume)

$EF_{CO2,i}$: Weighted average of CO_2 Emission Factor by fuel type *i* ($kgCO_2/kJ$)

Finally, CO_2 emission factor of electricity ($kgCO_2/kWh$) is calculated by dividing CO_2 Emission of fossil fuel, PE_{FC} by total amount of electricity generation (kWh/y). Net calorific value by fuel type *i* (kJ/mass or volume) is referred to ***Annex 4.***

CO_2 emission factor of electricity ($kgCO_2/kWh$) = PE_{FC} / EG

EG: total amount of electricity generation (kWh/y)

Reference) CDM Methodology Tool: "Tool to calculate the emission factor for an electricity system" (Version 1)

Annex 2: CO_2 Emission Factor by Fuel Type ($kgCO_2/kJ$)

CO_2 emission factor by fuel type ($kgCO_2/kJ$)

= CO_2 emission factor(tC/TJ)$\times 44/12 \times 10^{-6}$

= CO_2 emission factor($kgCO_2/TJ$)$\times 10^{-9}$

CO_2 emission factor by fuel type is calculated using the default value of "2006 IPCC Guideline for National Greenhouse Gas Inventories" shown below.

Fuel Type	Default Carbon Content (tC/TJ)	Default CO_2 Emission Factor ($kgCO_2/TJ$)
Crude Oil	20.0	73,300
Natural Gas Liquids	17.5	64,200
Motor Gasoline	18.9	69,300
Other Kerosene	19.6	71,900
Gas/Diesel Oil	20.2	74,100
Residual Fuel Oil	21.1	77,400
Liquefied Petroleum Gases	17.2	63,100
Anthracite	26.8	98,300
Lignite	27.6	101,000
Natural Gas	15.3	56,100
Waste Oil	20.0	73,300
Municipal Wastes (non-biomass fraction)	25.0	91,700
Municipal Wastes (biomass fraction)	27.3	100,000
Industrial Wastes	39.0	143,000
Wood / Wood Waste	30.5	112,000

Source: 2006 IPCC Guideline for National Greenhouse Gas Inventories Volume 2 Energy p-1.23~1.24 TABLE 1.4 **DEFAULT CO_2 EMISSION FACTORS FOR COMBUSTION**

(Other fuel type is referred to the same table of source mentioned above.)

Annex 3: **Calculation Method of CO_2 Emission from Vehicle**

CO_2 emission from Vehicle is calculated using the equation 3.2.1（page 3.12）and the equation 3.2.6（page 3.26）in “2006 IPCC Guideline for National Greenhouse Gas Inventories Volume 2 Energy, Chapter 3 Mobile Combustion”

$E_{vehicle} = \sum[V_{i,j} \times D_{i,j} \times C_{i,j} \times NCV_j \times EF_j] = VD_{i,j} \times EF^*_{i,j}$

Where,

$E_{vehicle}$:	CO_2 emission amount(kg CO_2)
$V_{i,j}$:	Number of vehicles by vehicle type-i, fuel-j
$D_{i,j}$:	Travel distance by vehicle type-i, fuel-j (km)
$C_{i,j}$:	Average fuel consumption by vehicle type-i, fuel-j (Gg/km)
i :	Vehicle type (Sedan, bus, etc.)
j :	Fuel (petrol, diesel, etc.)
EF_j :	Emission factor of fuel-j (kgCO_2/TJ)
NCV_j :	Calorific value of fuel-j (TJ/Gg)
$VD_{i,j}$:	VKT(vehicle kilometers travelled) by vehicle type-i, fuel-j (number of vehicles x travel distance)
$EF^*_{i,j}$:	Emission factor by vehicle type-i, fuel-j (kgCO_2/VKT)

Which means,

CO_2 emission from Vehicle

＝VKT(vehicle kilometers travelled) ×Emission factor per VKT

＝VKT×Fuel efficiency×Emission factor per unit of fuel

＝Fuel Consumption×Emission factor per unit of fuel

For example of fuel economy of Japan, the values of ”Annual Automobile transportation Statistical Report” (2007, Ministry of Land, Infrastructure, Transport and Tourism: http://toukei.mlit.go.jp/jidousya/jidousya.html）are shown in next page.

Vehicle Type		Fuel Type	Fuel Efficiency （Liters/km）
Business Use	Standard-size Car	Gasoline	0.2
		Diesel	0.25
	Small-size Car	Gasoline	0.12
		Diesel	0.12
	Special Purpose Car	Gasoline	0.11
		Diesel	0.22
	Light Car	Gasoline	0.09
		Diesel	-
Personal use	Standard-size Car	Gasoline	0.15
		Diesel	0.19
	Small-size Car	Gasoline	0.11
		Diesel	0.11
	Special Purpose Car	Gasoline	0.14
		Diesel	0.18
	Light Car	Gasoline	0.09
		Diesel	-

For example of fuel economy internationally, the values of “Calculating CO2 Emissions from Mobile Sources Table 4. Default Fuel economy factors for different types of mobile sources and activity data” (GHG Protocol - Mobile Guide (03/21/05) v1.3） are shown below.

Vehicle Type	Fuel Efficiency	CO_2/km traveled
	Liters/100km	gCO_2 / km
New small gas/electric hybrid	4.2	100.1
Small gas auto, highway	7.3	175.1
Small gas auto, city	9.0	215.5
Medium gas auto, highway	7.8	186.8
Medium gas auto, city	10.7	254.7
Large gas automobile, highway	9.4	224.1
Large gas automobile, city	13.1	311.3
Medium Station wagon, highway	8.7	207.5
Med Station wagon, city	11.8	280.1
Mini Van, highway	9.8	233.5
Mini Van, city	13.1	311.3
Large Van, highway	13.1	311.3
Large Van, city	16.8	400.2
Mid size. Pick-up Trucks, highway	10.7	254.7
Pick-up Trucks, city	13.8	329.6
Large Pick-up Trucks, highway	13.1	311.3
Large Pick-up Trucks, city	15.7	373.5
LPG automobile	11.2	266
Diesel automobile	9.8	233
Gasoline light truck	16.8	400
Gasoline heavy truck	39.2	924
Diesel light truck	15.7	374
Diesel heavy truck	33.6	870
Light motorcycle	3.9	93
Diesel bus	35.1	1034.6

Source: Miles per gallon for typical vehicles based on averages from **US - EPA 2001 Guide**.
（www.epa.gov/autoemissions）

Annex 4: **Net Calorific Value by Fuel Type**

Net calorific value by fuel type is referred to the default value of "2006 IPCC Guideline for National Greenhouse Gas Inventories" shown below.

Fuel Type	Net Calorific Value (TJ/Gg)	Net Calorific Value (GJ/Litters)
Crude Oil	42.3	0.0391
Natural Gas Liquids	44.2	-
Motor Gasoline	44.3	0.0346
Other Kerosene	43.8	0.0367
Gas/Diesel Oil	43.0	0.0382
Residual Fuel Oil	40.4	-
Liquefied Petroleum Gases	47.3	-
Anthracite	26.7	-
Lignite	11.9	-
Natural Gas	48.0	
Waste Oil	40.2	
Municipal Wastes (non-biomass fraction)	10	-
Municipal Wastes (biomass fraction)	11.6	-
Wood / Wood Waste	15.6	-

Source 1) Net calorific value (TJ/Gg) : 2006 IPCC Guideline for National Greenhouse Gas Inventories Volume 2 Energy p-1.18~1.19 TABLE 1.2 DEFAULT NET CALORIFIC VALUES (NCVS) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS

(Other fuel type is referred to the same table of source mentioned above.)

2) Net calorific value (GJ/Litters): "GHG Calculation Method and Emission Factor in Estimation, Report and Public Announcement System"（Ministry of Environment, Ministry of Economy, Trade and Industry）

***Reference:* Conversion Factors**

1) Basic Energy Units

1 J (joule) = 0.2388 cal

1 cal (calorie) = 4.1868 J

1 Btu (British thermal unit) = 1.055 kJ = 0.252 kcal

2) Standard Energy Units

1 toe (ton of oil equivalent) = 42 GJ = 10.034 Mcal

1 tce (ton of coal equivalent) = 7,000 Mcal = 29.3 GJ

1 barrel = 42 US gallons ≒ 159 Liters

1 m^3 = 35.315 cubic feet = 6.2898 barrels

1 kWh = 3.6 MJ ≒ 860 kcal

Source: "Clean Coal Technology (CCT) in Japan" (March, 2006, New Energy and Industrial Technology Development Organization (NEDO), Japan Coal Energy Centre)

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Chapter 1. Background

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- The GHG Indicator: UNEP Guidelines for Calculating Greehouse Gas Emissions for Business and Non-commercial Organisations, UNEP, 2000

Chapter 3 GHG Quantification Guidebook by Sector

3.2 Forestry and Natural Resource Conservation Sector

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Website

- Approved A/R Methodorogies
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  http://cdm.unfccc.int/methodologies/SSCAR/approved.html

3.3 Environmental Management Sector

Literature

- IPCC Guidelines for National Greenhouse Gas Inventories 2006, Volume 5 Waste
  http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
- Tool to determine project emissions from flaring gases containing methane
  http://cdm.unfccc.int/methodologies/Tools/eb28_repan13.pdf
- Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion
  http://cdm.unfccc.int/methodologies/Tools/meth_tool03_v02.pdf
- Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion
  http://cdm.unfccc.int/methodologies/Tools/meth_tool03_v02.pdf
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- AMS-III.B：Switching fossil fuels
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3.4 Transport Sector

Literature

- IPCC Guidelines for National Greenhouse Gas Inventories 2006, Volume 2 Energy, Chapter 3 Mobile Combustion
  http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf
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- AMSⅢ.R：Methane recovery in agricultural activities at household /small farm level
  http://cdm.unfccc.int/methodologies/DB/QE20VV8BRNGZ42MYWO1RP1THASXS8L/view.html