

# Fuel Switch & Energy Efficiency CDM Project Case Study

Prepared for 2<sup>nd</sup> Training Program Session  
May 20, 2011

JICA CDM Expert Team



## Objective & Content

Content:

- Scale of Energy Saving & Fuel Change
- What is Fuel Change project?
- What is Energy Saving project?
- Case Study

Objective:

**? & !**



# 0. Before Step Into CDM

Be familiar with the unit of energy to have a scale.  
How much energy do they consume/generate??



発電出力: 312kW ~ 2,700kW

	Fukushima 1	Hydro Power	Gas Engine	Household
Capacity	460,000 kW	25,000 kW	312 kW	0.48 kW
Runtime	6,000 hours	4,800 hours	4,000 hours	8,760 hours
Power	MWh	MWh	MWh	MWh
Heat (MJ)	$\times 10^6$ MJ	$\times 10^6$ MJ	$\times 10^6$ MJ	$\times 10^6$ MJ
Energy(TOE)	$\times 10^3$ TOE	$\times 10^3$ TOE	$\times 10^3$ TOE	$\times 10^3$ TOE

Calculate and fill the table.  
1kWh = 3.6 MJ  
1 TOE = 41.686 GJ  
1kcal = 4,166J

kilo	mega	giga	tera	peta
k	M	G	T	P
$10^3$	$10^6$	$10^9$	$10^{12}$	$10^{15}$

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## Fukushima 1

$$\begin{aligned}
 & 460,000\text{kW} \times 6,000 \text{ hours} \\
 &= 276 \times 10^7 \text{ kWh} \\
 &= 276 \times 10^4 \text{ MWh} \\
 & (1\text{MWh} = 1,000\text{kWh} = 10^3\text{kWh}) \\
 &= 2,760,000 \text{ MWh} \\
 & 276 \times 10^7 \text{ kWh} \times 3.6 \text{ MJ/kWh} \\
 &= 993.6 \times 10^7 \text{ MJ} \\
 &= 9,936 \times 10^6 \text{ MJ} \\
 & 9,936 \times 10^6 \text{ MJ} \div 41.686\text{GJ/TOE} \\
 &= (9,936,000 \times 10^3 \text{ GJ}) \div \\
 & 41.686\text{GJ/TOE} \\
 &= 238.353 \times 10^3 \text{ TOE}
 \end{aligned}$$

## Hydro Power Station

$$\begin{aligned}
 & 25,000\text{kW} \times 4,800\text{hours} \\
 &= 1,200 \times 10^5 \text{ kWh} \\
 &= 120 \times 10^3 \text{ MWh} \\
 & 1,200 \times 10^5 \text{ kWh} \times 3.6\text{MJ/kWh} \\
 &= 4,320 \times 10^5 \text{ MJ} \\
 &= 432 \times 10^6 \text{ MJ} \\
 & 432 \times 10^6\text{MJ} \div 41.686\text{GJ/TOE} \\
 &= (432 \times 10^3 \text{ GJ}) \div 41.686\text{GJ/TOE} \\
 &= 10.36 \times 10^3 \text{ TOE}
 \end{aligned}$$

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### Gas Engine

$$312\text{kW} \times 4,000\text{hours}$$

$$= 1,248 \times 10^3 \text{ kWh}$$

$$= 1,248 \text{ MWh}$$

$$1,248 \times 10^3 \text{ kWh} \times 3.6 \text{ MJ/kWh}$$

$$= 4,492 \times 10^3 \text{ MJ}$$

$$4,492 \times 10^3 \text{ MJ} \div 41.686 \text{ GJ/TOE}$$

$$= (4.492 \times 10^3 \text{ GJ}) \div 41.686 \text{ GJ/TOE}$$

$$= 107.9 \text{ TOE}$$

$$= 0.108 \times 10^3 \text{ TOE}$$

### Household

$$0.48 \text{ kW} \times 8,760 \text{ hours}$$

$$= 4,204.8 \text{ kWh}$$

$$= 4.20 \text{ MWh}$$

$$4.200\text{kWh} \times 3.6 \text{ MJ/kWh}$$

$$= 15,120 \text{ MJ}$$

$$= 0.015 \times 10^6 \text{ GJ}$$

$$= 15 \times 10^3 \text{ GJ}$$

$$15 \times 10^3 \text{ GJ} \div 41.686 \text{ GJ/TOE}$$

$$= 0.0032 \times 10^3 \text{ TOE}$$

1kcal = 4,166J



## 0. Before Step Into CDM

Be familiar with the unit of energy to have a scale.  
How much energy do they consume/generate??



発電出力: 312kW ~ 2,700kW



	Fukushima 1	Hydro Power	Gas Engine	Household
Capacity	460,000 kW	25,000 kW	312 kW	0.48 kW
Runtime	6,000 hours	4,800 hours	4,000 hours	8,760 hours
Power	2,760,000 MWh	120,000 MWh	1,248 MWh	4.20 MWh
Heat (MJ)	$9,936 \times 10^6 \text{ MJ}$	$432 \times 10^6 \text{ MJ}$	$4.5 \times 10^6 \text{ MJ}$	$0.015 \times 10^6 \text{ MJ}$
Energy <sub>(TOE)</sub>	$2,383.5 \times 10^3 \text{ TOE}$	$10.4 \times 10^3 \text{ TOE}$	$0.108 \times 10^3 \text{ TOE}$	$0.0032 \times 10^3 \text{ TOE}$

Calculate and fill the table.  
1kWh = 3.6 MJ  
1 TOE = 41.686 GJ  
1kcal = 4,166J

kilo	mega	giga	tera	peta
k	M	G	T	P
$10^3$	$10^6$	$10^9$	$10^{12}$	$10^{15}$



## 0.Emission Factors of Major Energy Sources

Fuel	Heat Value	COEF	EF	Gravity	
	TJ/MT	tCO <sub>2</sub> /TJ	tCO <sub>2</sub> /MT	t/m <sup>3</sup> :t/kl	
Furnace Oil	0.0410	77.4		0.972t/kl	tCO <sub>2</sub> /kl
Diesel Oil	0.0433	74.1		0.846t/kl	tCO <sub>2</sub> /kl
Residual Oil	0.0410	77.4		0.972t/kl	tCO <sub>2</sub> /kl
Coal	0.0293	101.0		1.300t/m <sup>3</sup>	tCO <sub>2</sub> /t
LPG	0.0502	63.1	3.168		3.168tCO <sub>2</sub> /kg
Natural Gas	0.0411	64.2	2.639		2.108kgCO <sub>2</sub> /Nm <sup>3</sup>
Grid Electricity					0.686tCO <sub>2</sub> /MWh

Data source

1. Energy Data 2007, Sustainable Energy Authority
2. IPCC Guideline for National Greenhouse Gas Inventories, 2006, Table 1-4
3. Natural Gas's gravity data was not available and utilized Japanese data for reference purposes. 7  
Nm<sup>3</sup> is a unit of gas under normal state.



## 0.Emission Factors of Major Energy Sources

Fuel	Heat Value	COEF	EF	Gravity	
	TJ/MT	tCO <sub>2</sub> /TJ	tCO <sub>2</sub> /MT	t/m <sup>3</sup> :t/kl	
Furnace Oil	0.0410	77.4	3.173	0.972t/kl	3.264tCO <sub>2</sub> /kl
Diesel Oil	0.0433	74.1	3.209	0.846t/kl	3.793tCO <sub>2</sub> /kl
Residual Oil	0.0410	77.4	3.173	0.972t/kl	3.264tCO <sub>2</sub> /kl
Coal	0.0293	101.0	2.816	1.300t/m <sup>3</sup>	3.661tCO <sub>2</sub> /t
LPG	0.0502	63.1	3.168		3.168tCO <sub>2</sub> /kg
Natural Gas	0.0411	64.2	2.639		2.108kgCO <sub>2</sub> /Nm <sup>3</sup>
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## More Questions

### Question A:

A volume of steel drum is 200litres.

- ① Calculate CO<sub>2</sub> emissions by combusting a full of furnace oil in steel drum . Also calculate heat value, one can derive from this combustion. heat value of fuel shall be derived as a product of unit heat value and gravity of fuel.
- ② Calculate how many kg of coal do you need to burn, if you earn same amount of heat? Also calculate CO<sub>2</sub> emissions from this coal combustion.



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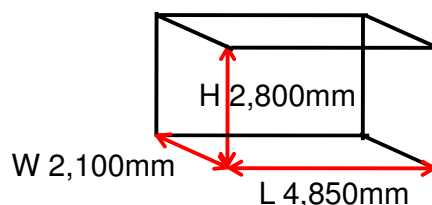
## Still More Questions

### Question B:

A factory is introducing sawdust alternate for furnace oil.

A dimension of cargo box of 4 tone loading truck(photo) is shown in figure below. A density of saw dust is 1.51kg/m<sup>3</sup> and unit heat value is 2000kcal/kg.

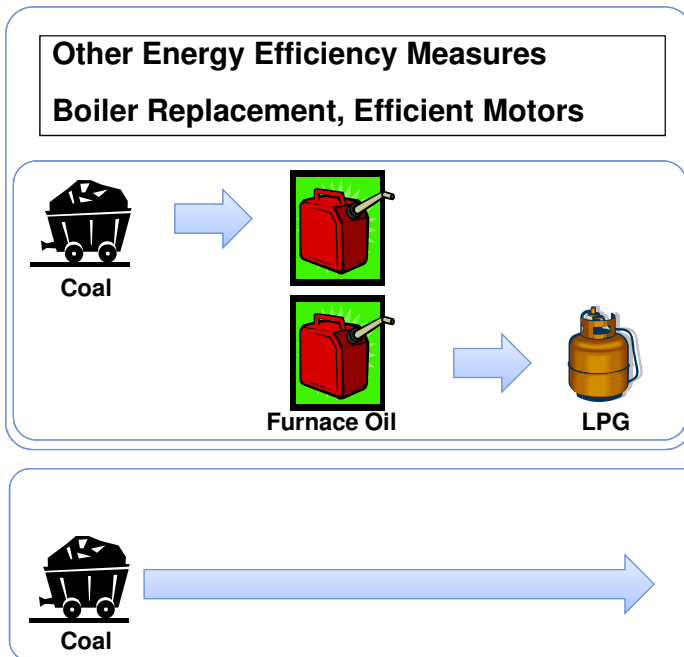
- ① Calculate heat and CO<sub>2</sub> emissions by combusting full cargo load of saw dust.
- ② Calculate how much furnace oil can replaced by amount of sawdust calculated in QB-1.



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# 1. What is Fuel Switching?



Fuel switch measures in this category will replace carbon-intensive fossil fuel with a less-carbon-intensive fossil fuel, whereas a switch from fossil fuel to renewable biomass is categorized as “renewable energy”.

**Biomass Fuel**



## In Reality....

**Number of CDM project registered and issued CER.**

	On Track	Registered	Issued	CER %
Total	71	57	---	
Coal to NG	9	5	3	65%
Coal to Oil	0	0	0	
Lignite to NG	0	0	0	
New NG plant*	30	26	14	42%
New NG plant utilize LNG	1	8	3	74%
Oil to Electricity	2	0	0	
Oil to LPG	1	0	0	
Oil to NG	28	18	13	100%

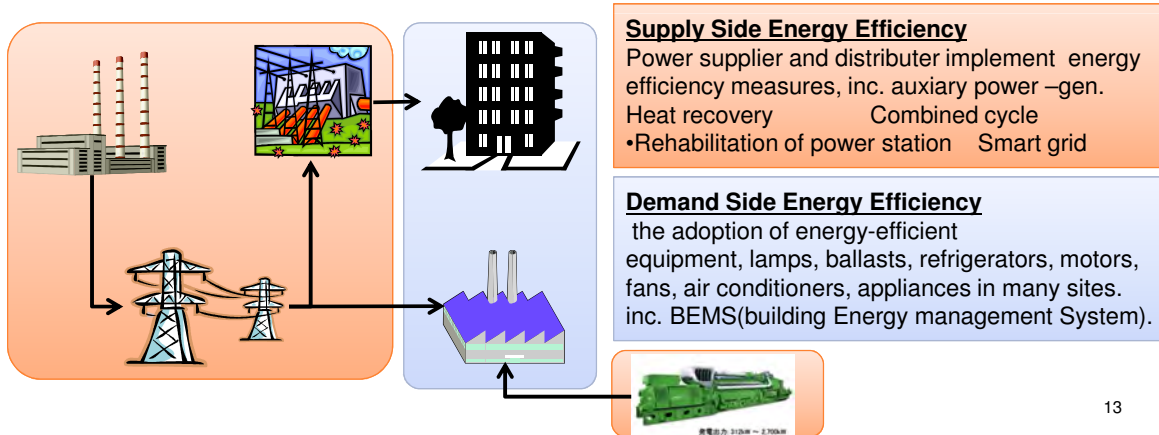
\*AM0029: Grid Connected electricity generation plants using natural gas is widely used in high performance combined cycle gas pwr generation projects in China and in India.



## 2. What is Energy Efficiency project?

### Energy Efficiency Project

The category energy efficiency includes all measures aiming to enhance the energy efficiency of a certain system. Due to the project activity, a specific output or service requires less energy consumption. Waste energy recovery is also included in this category.

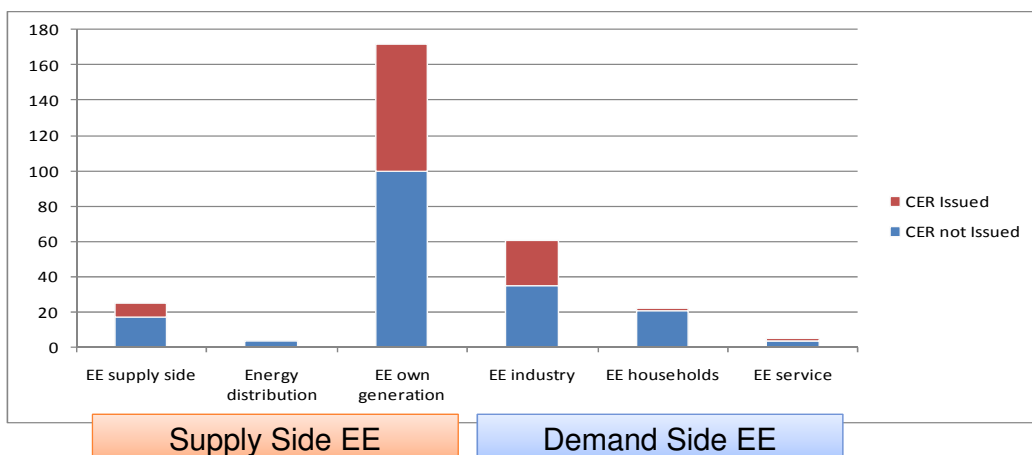


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## 2. Energy Efficiency Statistics

- As of May 2011, there are 289 registered Energy Efficiency CDM projects.
- Of which 88 projects are demand side energy efficiency projects and the rest are supply side (including transmission) energy efficiency projects.
- Of all the registered energy efficiency CDM,108 projects have issued CER.

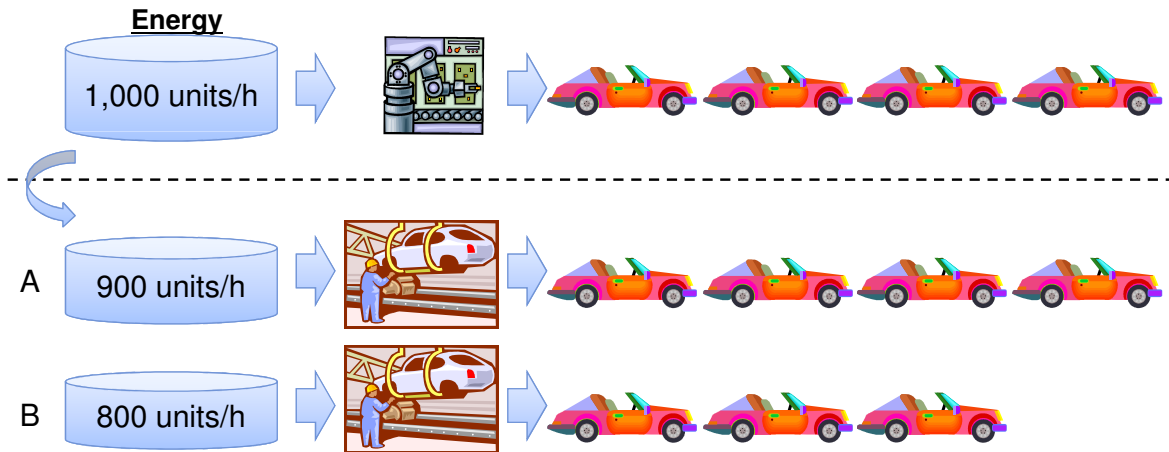


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## 2. Key Insight of Energy Efficiency Project

In project, the output has to be maintained before and after the energy efficiency project



Which is “energy efficient”??



## 3. Case: Project in Laundromat Services

The company is located in northern Japanese island. The facility receives linens and daily laundry through retail shops within 150km area's hotels, restaurants and households. The facility used heavy oil combustion boiler for 20 years. The regional natural gas catering company extends the pipeline to the neighborhood and connects to the company's facility.

The project has four components including,

- Replacing fuel from heavy oil to natural gas.
- Replace lamps to high efficient LEDs.







### 3. Case: Project in Laundromat Services (Cont'd)

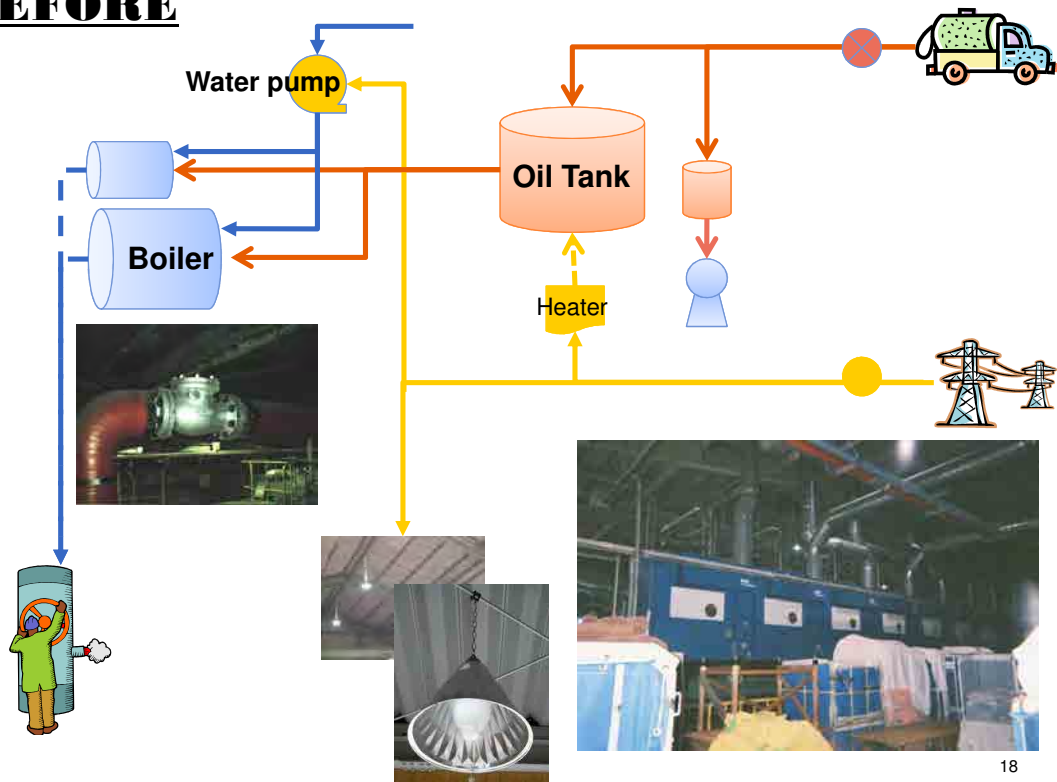
#### Feature of Energy Use

- ◆ Requires intensive energy for pressing (steam), laundry (hot water).
- ◆ Heat requirements varied with peripheral temperatures but stable for year-round.
- ◆ Outside temperature varies from 32°C in August to -20°C in February.
- ◆ Energy costs, electricity and fuel, occupies 50% of expenses.



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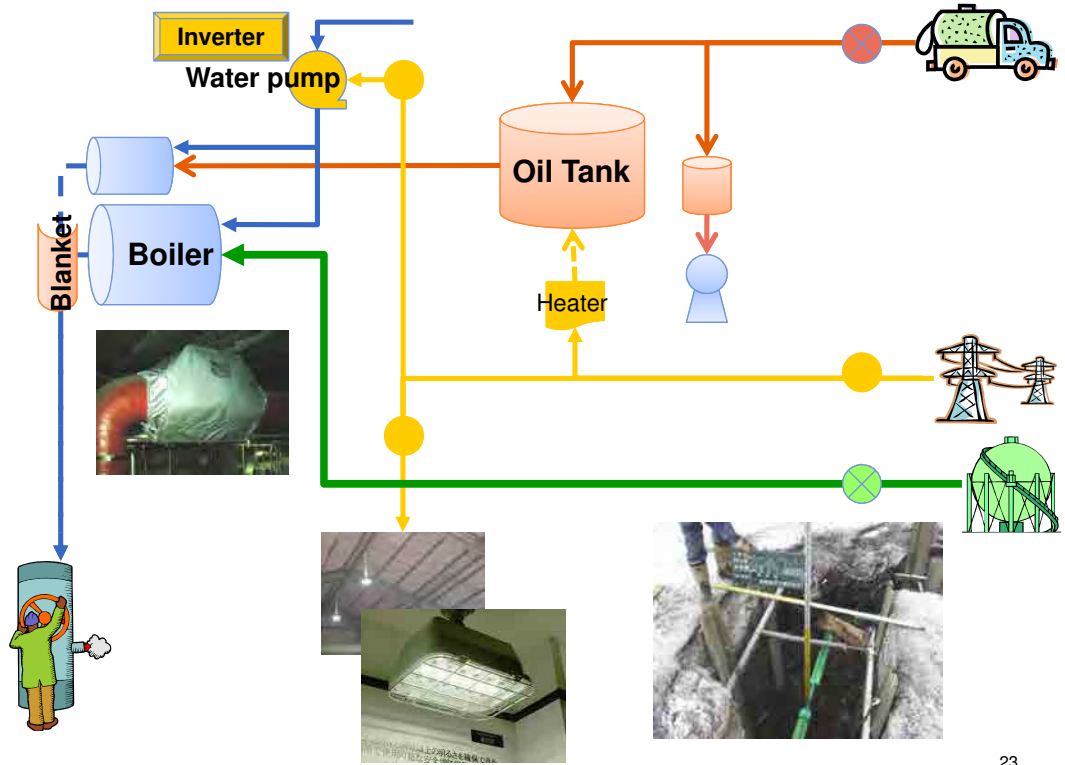
#### **BEFORE**



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## 4. Project A: Boiler Fuel Change

The factory runs 1 x 2.0t boiler and 1 x 0.5t boiler for back up to generate steam and hot water for laundry machine and dry clanging.  
Normally, only 2.0t boiler operates.

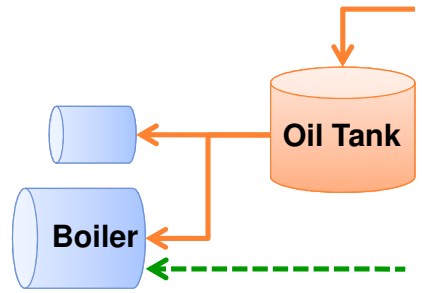
Both boiler uses heavy oil/furnace oil catered by a tanker truck of oil company upon order.

The project changes fuel only for 2.0t boiler from heavy oil to natural gas.

- Monitoring parameters
- ◆ Flow-meters at the heavy oil tank
  - ◆ Flow meters of the gas line
  - ◆ Invoice from gas/oil company

Project Baseline  
Continuous use of carbon intensive fossil fuel.

Fuel consumption	1,752	kl/year
Run-time	12	Hours/day
	264	Day/year





## 4. Project B: LED Lighting

Light Emitting Diode (LED) is a lighting devices to alternate traditional lamps.

LED gives more concentrated lighting than conventional lighting thus uses less electricity to give a same illuminance.

The price of LED light is still expensive compared to usual lightings, but it lasts longer and economy in longer term.

Project replace old halogen lamps in factory and warehouse space to LED.

Elec. Power of Hg lamp	400	W
Number of Hg lamp	137	Units
Elec. Power of LED lamp	118	W
Number of LED	83	Units
Operating Hours	3,168	hours



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### Monitoring

- ◆ Electric Power of light bulb (W)
- ◆ Number of light bulbs
- ◆ Operating hours to turn on light bulbs (hours)
- ◆ Emission factor of the electricity consumed (tCO<sub>2</sub>e/MWh)

### Project Baseline

Continuous use of conventional lamps.

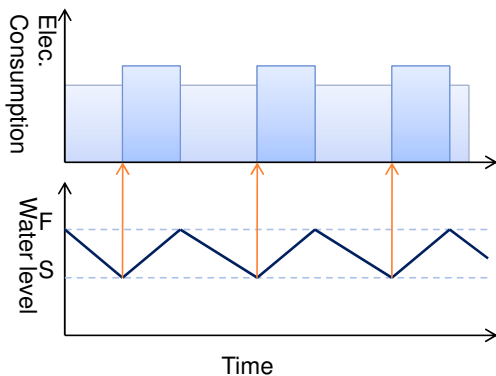


## 4. Project C: Inverter & Load Variable

Boiler water pump continuously pumping water, regardless water amount in the boiler tank.

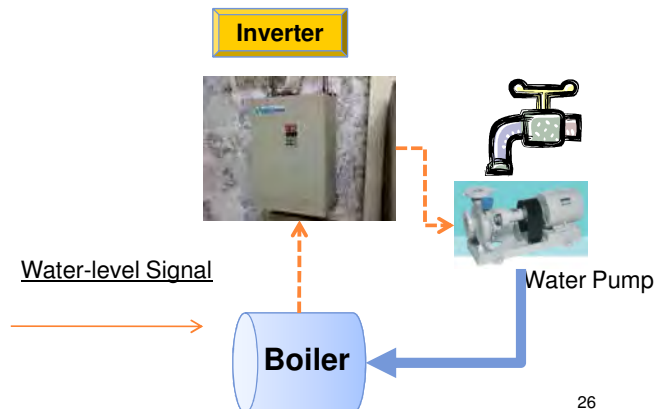
Inverter technology on/off the pump be referring water level of the tank.

By reducing idle time of the pump, it reduces an electricity consumption.



### Monitoring

- ◆ Power consumption of the system (kWh)
- ◆ Number of operational hours (hrs)
- ◆ Emission factor of the electricity (tCO<sub>2</sub>e/kWh)



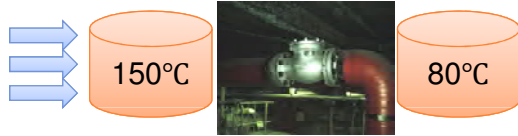
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## 4. Project D: Pipe Blanket

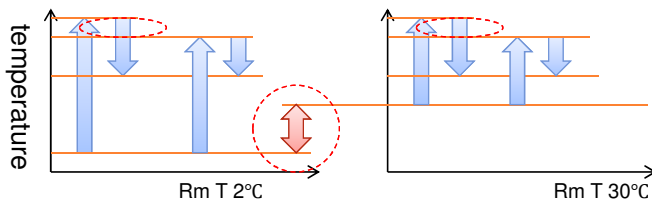
Pipe Blanket is a method to cover pipe and high temperature parts by glass wool.



### Monitoring

- ◆ Temperature of in/outflow (°C)
- ◆ External temperature (°C)
- ◆ Flow rate (m<sup>3</sup>/sec)
- ◆ Consumption of fuel/electricity to generate steam(L of fuel or kWh of electricity)
- ◆ Emission factors

Energy saving can be achieved due to external temperature and other multiple variables. Blanket project is difficult to prove causality.



## 4. What can be done in CDM & what not?

	Project A: Boiler Fuel Change	Project B: LED application	Project C: Inverter Application	Project D: Blanket Application
AMS Methodology	III.B	II.E	II.C	---
Baseline	Keep using furnace oil.	Keep using mercury lamp	Keep operating pump regardless load/demand	Expose valve where heat are easily leak.
Project	Replace furnace oil to natural gas.	Replace mercury lamp to LED lamp to reduce electricity consumption	Control and limit pump action depends on water level of boiler.	Cover valve to avoid heat expose to atmosphere
Monitoring	Gas consumption with gas flow meter with gas company's invoice.	Electricity Consumption with metering devices and electricity bill.	Metering devices	Continuous monitoring of temperature of fluid and exposed environment.
CDM?				



## 5. Calculations: Fuel Change

Fuel Consumption before the Project

Furnace Oil Consumption	1,752	kl/year
HV of furnace oil		GJ/kl
Heat obtained with furnace oil		GJ
CO <sub>EF</sub>		tCO <sub>2</sub> /kl
CO <sub>2</sub> Emissions_before		tCO <sub>2</sub>

Fuel Consumption after the Project

HV of natural gas		MJ/Nm <sup>3</sup>
Amount of Natural gas needed		Nm <sup>3</sup> /year
CO <sub>EF</sub>		kgCO <sub>2</sub> /Nm <sup>3</sup>
CO <sub>2</sub> Emissions_after		tCO <sub>2</sub> /year

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## 5. Calculations: Fuel Change

Fuel Consumption before the Project

Furnace Oil Consumption	1,752	kl/year
HV of furnace oil	39.85	GJ/kl
Heat obtained with furnace oil	69,817.2	GJ
CO <sub>EF</sub>	3.264	tCO <sub>2</sub> /kl
CO <sub>2</sub> Emissions_before	5,718.53	tCO <sub>2</sub>

Fuel Consumption after the Project

HV of natural gas	46.1	MJ/Nm <sup>3</sup>
Amount of Natural gas needed	1,514 x 10 <sup>3</sup>	Nm <sup>3</sup> /year
CO <sub>EF</sub>	2.108	kgCO <sub>2</sub> /Nm <sup>3</sup>
CO <sub>2</sub> Emissions_after	3,194.51	tCO <sub>2</sub> /year

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## 5. Calculations: LED Application

Electricity Consumption before the Project

Unit Elec. Cons of Hg light	400	W/unit
Number of lights	137	Units
Daily Working hours	12	Hours/day
Annual Working days	264	Days/year
Electricity Consumption		kWh/year

Electricity Consumption after the Project

Unit Elec. Cons of LED	118	W/unit
Number of lights	83	Units
Annual Working hours	3168	Hours/year
Electricity Consumption		kWh/year
Electricity Saving		kWh/year
CO <sub>EF</sub>	0.686	tCO <sub>2</sub> /MWh
ER <sub>LED</sub>		tCO <sub>2</sub>

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## 5. Calculations: LED Application

Electricity Consumption before the Project

Unit Elec. Cons of Hg light	400	W/unit
Number of lights	137	Units
Daily Working hours	12	Hours/day
Annual Working days	264	Days/year
Electricity Consumption	173,606.4	kWh/year

Electricity Consumption after the Project

Unit Elec. Cons of LED	118	W/unit
Number of lights	83	Units
Annual Working hours	3168	Hours/year
Electricity Consumption	31,027.39	kWh/year
Electricity Saving	142,579.0	kWh/year
CO <sub>EF</sub>	0.686	tCO <sub>2</sub> /MWh
ER <sub>LED</sub>	97.81	tCO <sub>2</sub>

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## 6. Grand-Sum of Project

Fuel Change		
CO <sub>2</sub> Emissions_before	5,718.53	tCO <sub>2</sub> /year
CO <sub>2</sub> Emissions_after	3,194.00	tCO <sub>2</sub> /year
ER_Fuel Change	2,524.53	tCO <sub>2</sub> /year
LED Application		
ER_LED	97.81	tCO <sub>2</sub> /year
Total		
	2,622.34	tCO <sub>2</sub> /year



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***THE ONLY THING WE KNOW ABOUT THE FUTURE IS THAT IT WILL BE DIFFERENT.  
PETER DRUCKER*** <sup>34</sup>

# Status and Outlook of Carbon Market

Prepared for Training Program for CCD, MOE Sri Lanka  
May 27, 2011

JICA Expert Team



# Answers for Fuel Switch & Energy Efficiency CDM Project Case Study,

## JICA Training program lecture series

### Page 3. Table of Energy Scale

5	Fukushima 1	33
6	460,000kW x 6,000 hours	34
7	460MW x 6,000 hours	35 Gas Engine
8 =	276 x 10 <sup>4</sup> MWh	36 312kW x 4,000hours
9 (1MWh =1,000kWh = 10 <sup>3</sup> kWh)		37 = 0.312 MW x 4,000hours
10 =	2,760,000 MWh	38 = 1,248 MWh
11		39
12	276 x 10 <sup>7</sup> kWh x 3.6 MJ/kWh	40 1,248MWh x 3.6 MJ/kWh
13 =	993.6 x 10 <sup>7</sup> MJ	41 (1,248 x 10 <sup>3</sup> kWh) x 3.6 MJ/kWh
14 =	9,936 x 10 <sup>6</sup> MJ	42 = 4,492 x 10 <sup>3</sup> MJ
15		43
16	9,936 x 10 <sup>6</sup> MJ ÷ 41.686GJ/TOE	44 4,492 x 10 <sup>3</sup> MJ ÷ 41.686 GJ/TOE
17 =	(993,600 x 10 <sup>3</sup> GJ) ÷ 41.686GJ/TOE	45 = (4.492 x 10 <sup>3</sup> GJ) ÷ 41.686 GJ/TOE
18 =	2,383.53 x 10 <sup>3</sup> TOE	46 = 107.9 TOE
19		47 = 0.108 x 10 <sup>3</sup> TOE
20	Hydro Power Station	48
21	25,000kW x 4,800hours	49 Household
22 =	25MW x 4,800 hours	50 0.48 kW x 8,760 hours
23 =	120,000MWh	51 = 4,204.8 kWh
24		52 = 4.20 MWh
25	(120,000MWh) x 3.6 MJ/kWh	53
26 =	(120 x 10 <sup>6</sup> kWh) x 3.6MJ/kWh	54 4.200kWh x 3.6 MJ/kWh
27 =	432 x 10 <sup>6</sup> MJ	55 = 15,120 MJ
28		56 = 0.015 x 10 <sup>6</sup> GJ
29		57 = 15 x 10 <sup>3</sup> GJ
30	432 x 10 <sup>6</sup> MJ ÷ 41.686GJ/TOE	58
31 =	(432 x 10 <sup>3</sup> GJ) ÷ 41.686GJ/TOE	59 15 x 10 <sup>3</sup> GJ ÷ 41.686 GJ/TOE
32 =	10.36 x 10 <sup>3</sup> TOE	60 = 0.0032 x 10 <sup>3</sup> TOE

61  
62  
63  
64

#### p.4 Emission Coefficient Table

Basic equation is as follows.

$$\text{Heat Value} \times \text{COEF} = \text{EF}, \text{EF} \times 1/\text{Gravity} = \text{trade unit's EF}$$

Fuel	Heat Value	COEF	EF	Gravity	
	TJ/MT	KgCO <sub>2</sub> /TJ	tCO <sub>2</sub> /MT	t/m <sup>3</sup> :t/kl	
Furnace Oil	0.0410	77.4	3.173	0.972t/kl	3.084tCO <sub>2</sub> /kl
Diesel Oil	0.0433	74.1	3.209	0.846t/kl	2.714tCO <sub>2</sub> /kl
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LPG	0.0502	63.1	3.168		3.168tCO <sub>2</sub> /kg
Natural Gas	0.0411	64.2	2.639		2.108kgCO <sub>2</sub> /Nm <sup>3</sup>
Grid Electricity					0.686tCO <sub>2</sub> /MWh

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#### p.5: Question A

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① The emission factor of furnace oil is derived from the table in previous page.

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Furnace Oil's heat value is given as 0.0410TJ/MT and its density is given as 0.972MT/kilo-liter.

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Normally furnace oil traded with a unit of kilo-liters.

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Hence

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$$0.0410\text{TJ/MT} \times 0.972\text{MT/kilo-liter}$$

71

$$= 0.0410 \times 10^6\text{MJ/MT} \times 0.972 \text{ MT/kl}$$

72

$$= 39,852 \text{ MJ/kl}$$

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Therefore, heat derived from 200 liters furnace oil is

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$$200 \text{ liters} \times 39,852 \text{ MJ/kl}$$

76

$$= 0.2\text{kl} \times 39,852 \text{ MJ/kl}$$

77

$$= 7.97 \times 10^3 \text{ MJ}$$

78

79

$$200 \text{ liters} \times 3.086\text{tCO}_2/\text{kl}$$

80

$$0.2\text{kl} \times 3.086\text{tCO}_2/\text{kl}$$

81

$$= 0.6172\text{tCO}_2$$

82

83

$$\textcircled{2} \quad 7.97 \times 10^3 \text{ MJ} \div 0.0293\text{TJ/MT}$$

84

$$= 7.97\text{GJ} \div 29.3\text{GJ/MT}$$

85

$$= 0.272\text{MT}$$

86

$$= 272\text{kg}$$

87

88

#### p.6: Question B

89

$$2,800\text{mm} \times 2,100\text{mm} \times 4,850\text{mm}$$

90

$$= 2.8\text{m} \times 2.1\text{m} \times 4.85\text{m}$$

91

$$= 28.518\text{m}^3$$

92

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$$28.518\text{m}^3 \times 1.51\text{kg/m}^3 \times 2,000\text{kcal/kg}$$

$$= 86,124.36\text{kcal}$$

$$1\text{kcal} = 4,166\text{J}$$

$$86,124.36 \text{ kcal} \times 4,166 \text{ J}$$

$$= 358,794,084\text{J}$$

$$= 358.8\text{MJ}$$

Furnace Oil's HV is derived as 0.039852 TJ/kl, which is 39.85GJ/kl

Therefore,

$$358.8\text{MJ} \div 39.85\text{GJ/kl}$$

$$358.8\text{MJ} \div 39.85 \text{ MJ/l}$$

$$= 9.0 \text{ liters}$$

p.26: Fuel Change

furnace Oil Consumption in volume	1,752	kl/year
Emission factor of furnace oil	3.086	tCO <sub>2</sub> /kl
CO <sub>2</sub> Emissions_before	5,406	tCO <sub>2</sub> /year
Conversion rate of weight/volume	0.972	t/kl
Heavy Oil Consumption in weight	1,703	t/year
Unit HV of furnace oil	41.0	GJ/t
Heat derived from furnace Oil	69,823	GJ/year

HV of natural gas	46.1	MJ/m <sup>3</sup>
Amount of Natural gas needed	1,515 x10 <sup>3</sup>	m <sup>3</sup> /year
Emission Factor of natural gas	2.108	kgCO <sub>2</sub> /m <sup>3</sup>
CO <sub>2</sub> Emissions_after	3,194	tCO <sub>2</sub> /year

Consumption of furnace oil before the project is 1,752kl/year.

109

CO2 emission factor of furnace oil is 3.086tCO2/kl

Therefore, CO2 emission from furnace oil is derived as

$$1,752\text{kl/year} \times 3.086\text{tCO}_2/\text{year}$$

$$= 5,406.67 \text{ tCO}_2$$

114

As the gravity of furnace oil is 0.972t/kl.

Thus the amount of furnace oil consumed is

$$1,752\text{kl/year} \times 0.972\text{t/kl}$$

$$= 1,703\text{t/year}$$

119

Heat value of furnace oil is 41.0GJ/t from the table (0.0410TJ/t = 41.0GJ/t)

The heat derived from furnace oil combustion is

$$1,703 \text{ t/year} \times 41.0\text{GJ/t}$$

$$= 69,823\text{GJ/year}$$

124

125 The natural gas's heat value is given as  $0.0461\text{GJ}/\text{m}^3 = 46.1\text{MJ}/\text{m}^3$

126  $69,823\text{GJ}/\text{year} \div 46.1\text{MJ}/\text{m}^3$

127 =  $1,515 \times 10^3 \text{m}^3$

128

129 CO2 emission factor of natural gas given as  $2.108\text{kgCO}_2/\text{m}^3$

130  $1,515 \times 10^3 \text{m}^3 \times 2.108 \text{kgCO}_2/\text{m}^3$

131 =  $3,194\text{tCO}_2/\text{year}$

132

133 p.27 LED lump application

Unit Elec. Cons of Hg light	400	W/unit
Number of lights	137	Units
Daily Working hours	12	Hours/day
Annual Working days	264	Days/year
Electricity Consumption	173,606.4	kWh/year

Unit Elec. Cons of LED	118	W/unit
Number of lights	83	Units
Annual Working hours	3168	Hours/year
Electricity Consumption	31,027.39	kWh/year
Electricity Saving	142,579.0	kWh/year
CO <sub>EF</sub>	0.686	tCO <sub>2</sub> /MWh
ER_LED	97.81	tCO <sub>2</sub>

134 Electricity consumption of halogen lamp is

135  $400\text{W}/\text{unit} \times 137 \text{units} \times 12 \text{hours}/\text{day} \times 264\text{days}/\text{year}$

136 =  $54.8\text{kW} \times 3,168 \text{hours}/\text{year}$

137 =  $173,606.4\text{kWh}/\text{year}$

138 By converting to LED lamp

139  $118\text{W}/\text{unit} \times 83 \text{units} \times 12 \text{hours}/\text{day} \times 264\text{days}/\text{year}$

140 =  $9.794\text{kW} \times 3,168 \text{hours}/\text{year}$

141 =  $31,027.39\text{kWh}/\text{year}$

142

143 The emission coefficient of electricity is derived as  $0.686\text{tCO}_2/\text{MWh}$

144  $(173,606.4\text{kWh}/\text{year} - 31,027.39\text{kWh}/\text{year}) \times 0.686\text{tCO}_2/\text{MWh}$

145 =  $142,579\text{kWh}/\text{year} \times 0.686\text{tCO}_2/\text{MWh}$

146 =  $142.58\text{MWh}/\text{year} \times 0.686\text{tCO}_2/\text{MWh}$

147 =  $97.81\text{tCO}_2/\text{year}$

148

149 p.28 Grand-Sum

150 Deduct CO2 emissions of natural gas from furnace oil combustion as follows.

151  $5,406.67\text{tCO}_2/\text{year} - 3,193.62\text{tCO}_2/\text{year}$

152 =  $2,213.05\text{tCO}_2/\text{year}$

153

154 As a grand-sum of project, it reduces

155  $2,213.05\text{tCO}_2/\text{year} + 97.81\text{tCO}_2/\text{year}$

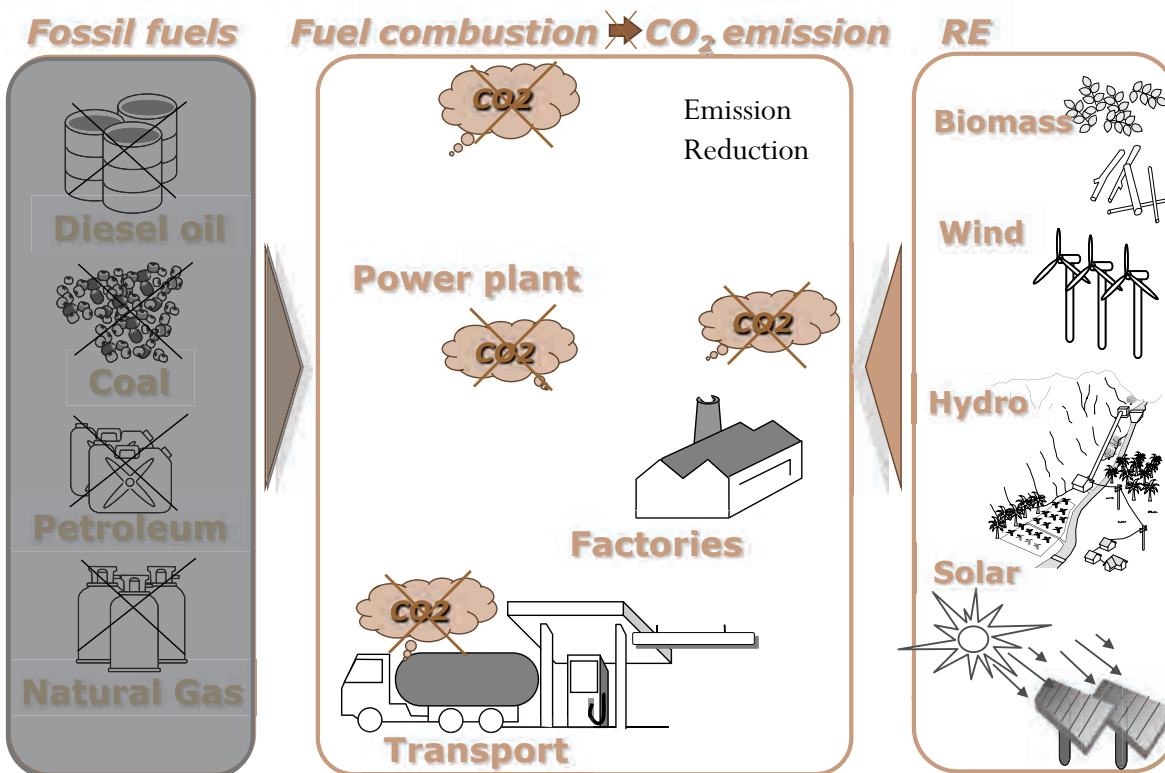
156 =  $2,310.86\text{tCO}_2/\text{year}$

# Renewable Energy CDM Projects (Review Session)

8<sup>th</sup> July 2011  
JICA Expert Team  
Ai Kawamura

## Summary of the Lecture of Renewable Energy

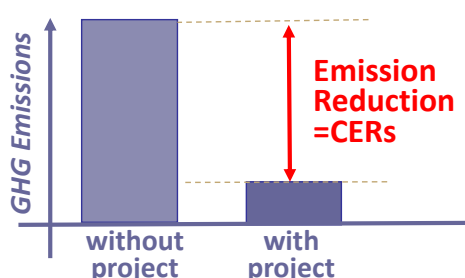
# 1. How emission reduction is achieved by RE Project (2)



RE reduces GHG emissions by reducing the use of fossil fuel.

# 2. Energy Source of Renewable Energy

- **Non-biomass:**
  - Wind
  - Hydro
  - Solar
  - Others (geothermal & wave etc)
- **Biomass:**
  - Residue biomass (wood residue, rice husk, bagasse & garbage etc)
  - Energy crops (gliricidia, jatropha etc)





## 5. Basic Formula for Emission Reduction Calculation of RE project (1)

### • Basic formula

$$\text{GHG Emission Reduction by RE project (tCO}_2\text{)} = \text{Amount of energy to be replaced [A]} \times \text{Emission factor of energy to be replaced [B]} - \text{Project/Leakage Emission [C]}$$

1) Grid electricity replacement

$$= \text{[A] Amount of electricity (MWh)} \times \text{[B] Grid emission factor [tCO}_2\text{/MWh]} - \text{Project/Leakage Emission [C]}$$

Unit Check  
 $\text{MWh} \times \frac{\text{tCO}_2}{\text{MWh}} = \text{tCO}_2$

2) Replacement of Electricity Generated On-site

$$= \text{[A] Amount of fuel used for electricity generation (ton_fuel)} \times \text{[B] Emission factor of fuel used for electricity generation [tCO}_2\text{/ton_fuel]} - \text{Project/Leakage Emission [C]}$$

Unit Check  
 $\text{Ton} \times \frac{\text{tCO}_2}{\text{Ton}} = \text{tCO}_2$

- Emission from on-site electricity and fossil fuel consumption in the project scenario
- Emission from transportation (for biomass)
- Emission from biomass competition (for biomass)

## 6. Calculation of Grid Emission Factor (2)

Simplified formula for grid emission factor calculation:

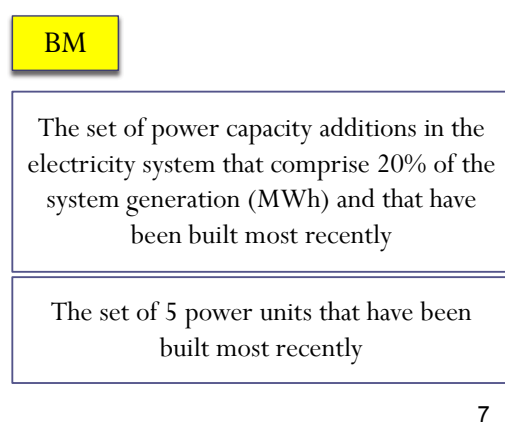
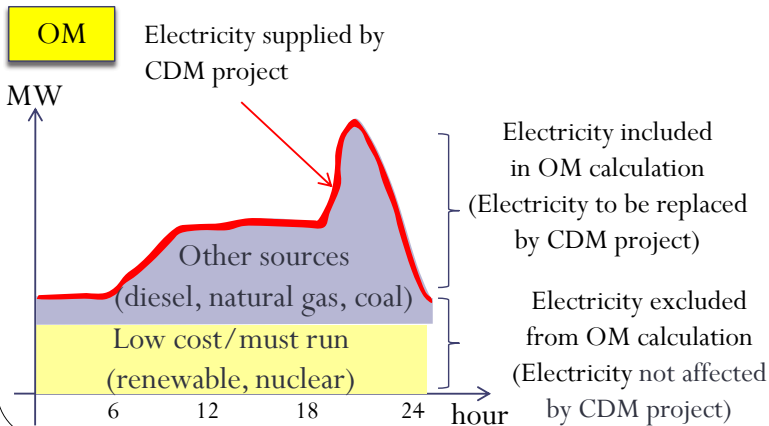
$$\text{Grid Emission Factor in year } y \text{ [tCO}_2\text{/MWh]} = \frac{\text{Total CO}_2 \text{ emission from all the power plants that are connected to the grid in year } y \text{ if the CDM project activity did not take place [tCO}_2\text{/y]}}{\text{Total MWh of electricity produced by all the power plants that are connected to the grid in year } y \text{ if the CDM project activity did not take place [MWh/y]}}$$

Reference: "Tool to calculate the emission factor for an electricity system"

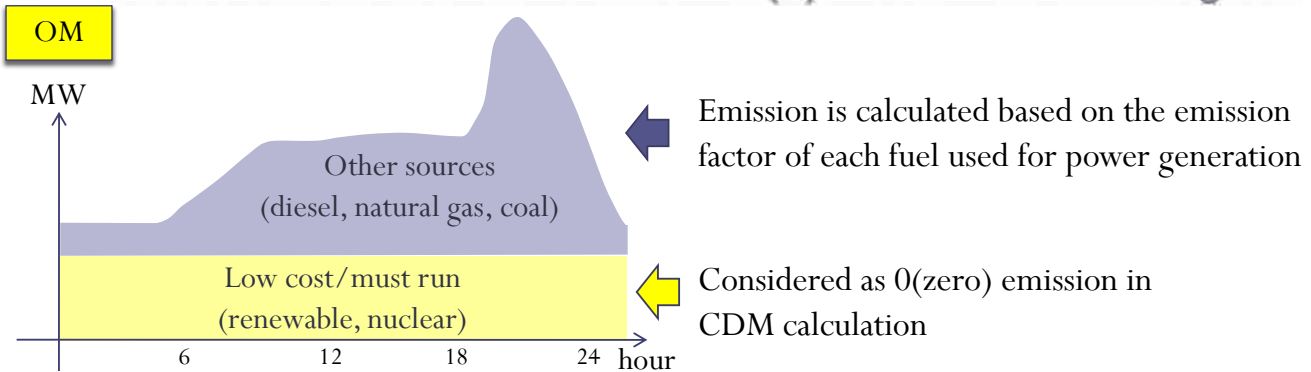
- Grid Emission Factor is necessary for:
  - Renewable energy project that displaces grid electricity
  - Energy efficiency projects that reduces the use of the grid electricity
  - Projects using grid electricity in the project scenario (project emissions)
- Currently, all the registered Sri Lankan CDM projects requires grid emission factor data.
- Grid Emission Factor: 0.65~0.73 tCO<sub>2</sub>/MWh  
(National official figure is under preparation, Currently, PP has to calculate by themselves)

## 6. Calculation of Grid Emission Factor (3) Essential Terminologies

Terminology	Explanation
Operating Margin (OM)	Emission factor that refers to the group of existing power plants whose current electricity generation would be affected by the proposed CDM project activity.
Built Margin (BM)	Emission factor of the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity.
Combined Margin (CM)	Weighted average of OM & BM of the electricity system.
Low-cost/must-run resources	Power plants with low marginal generation costs or power plants that are dispatched independently of the daily or seasonal load of the grid.



## 6. Calculation of Grid Emission Factor (3) Essential Terminologies



Emission factor of each fuel	Fuel Type	Net Calorific Value (TJ/t) [a]	CO <sub>2</sub> Emission Factor(tCO <sub>2</sub> /TJ) [b]	Oxidation factor [c]	CO <sub>2</sub> emission factor(tCO <sub>2</sub> /t) [a]*[b]*[c]
	Furnace Oil	0.041	77.4	1.0	3.173
	Gas/Diesel Oil	0.0433	74.1	1.0	3.209
	Naphtha	0.0456	73.3	1.0	3.342
	Residual Oil	0.041	77.4	1.0	3.173
	Source	Energy Data 2007, SEA	2006 IPCC Guidelines for National GHG Inventories, vol.2		

Grid Electricity factor for CDM project

Grid Emission Factor: 0.65~0.73 tCO<sub>2</sub>/MWh  
(National official figure is under preparation, Currently, PP has to calculate by themselves)

Grid emission factor for existing electricity consumers is not the same

# Calculation Exercise

## Non-biomass, Biomass

### 1. Calculation Exercise: Biomass(1)

- Company B has a CDM project plan with the following details:
  - Biomass power generation project selling the electricity to CEB
  - The biomass to be used is saw dust and rice husk
  - Net electricity generation operation rate: 1.0 MW
  - Daily operating hours: 20 hours
  - Monthly operating days: 25 days
  - Seasonal operation: operation is constant
  - Grid emission factor: 0.70 kgCO<sub>2</sub>/kWh
  - Furnace oil required for operation of the new plant: 5ton/month
  - Diesel required for transportation of biomass: 10 ton/month
  - Emission factor of fossil fuel is shown as below:

Fuel Type	CO <sub>2</sub> emission coefficient (tCO <sub>2</sub> /t)
Furnace Oil	3.173
Diesel Oil	3.209

#### (Question)

**How much emission reduction is expected by this project activity?**

# 1. Calculation Exercise: Biomass(2)

Step1

- How many hours does the plant operate annually?

Step2

- How much electricity to be sold to the grid annually?

Step3

- How much GHG emission is reduced annually by selling the electricity to the grid? [baseline emission]

Step4

- How much fossil fuel is required for operating the plant annually?
- How much fossil fuel is required for biomass transportation annually?
- How much fossil fuel is required by the project activity ?

Step5

- How much GHG is emitted annually through fossil fuel consumption by the project activity? [project emission]

Step6

- How much GHG emission is reduced annually by the project activity? [Emission reduction]

# 1. Calculation Exercise: Biomass(3)

Step1

- How many hours does the plant operate annually?

- Daily operating hours: 20 hours
- Monthly operating days: 25 days
- Seasonal operation: operation is constant

**Annual operation hours**

$$20 \frac{\text{hours}}{\text{day}} \times 25 \frac{\text{days}}{\text{month}} \times 12 \frac{\text{month}}{\text{year}} = 6,000 \frac{\text{hour}}{\text{year}}$$

Unit Check

$$\frac{\text{hours}}{\cancel{\text{day}}} \times \frac{\cancel{\text{days}}}{\cancel{\text{month}}} \times \frac{\cancel{\text{month}}}{\text{year}} = \frac{\text{hour}}{\text{year}}$$

# 1. Calculation Exercise: Biomass(4)

Step2

- How much electricity to be sold to the grid annually?

- Annual operation hour: 6,000 hours/y
- Electricity generation operation rate: 1.0 MW

**Amount of electricity to be sold to the grid**

$$6,000 \text{ hours/year} \times 1.0 \text{ MW} = \underline{\underline{6,000 \text{ MWh/y}}}$$

Unit Check

$$\frac{\text{hour}}{\text{year}} \times \text{MW} = \frac{\text{MWh}}{\text{year}}$$

# 1. Calculation Exercise: Biomass(5)

Step3

- How much GHG emission is reduced annually by selling the electricity to the grid? [baseline emission]

- Amount of electricity to be sold to the grid annually: 6,000 MWh/y
- Grid emission factor: 0.70 kgCO<sub>2</sub>/kWh

**Baseline emission (tCO<sub>2</sub>/y)**

=

**Amount of Electricity (MWh/y)**

×

**Grid emission factor (tCO<sub>2</sub>/MWh)**

=

6,000 MWh/y

×

0.70 tCO<sub>2</sub>/MWh

=

**4,200 tCO<sub>2</sub>/y**

Unit Check

$$\frac{\text{kg}}{\text{kWh}} = \frac{1000 \times \text{kg}}{1000 \times \text{kWh}} = \frac{\text{t}}{\text{MWh}}$$

$$\frac{\text{MWh}}{\text{year}} \times \frac{\text{t}_{\text{CO}_2}}{\text{MWh}} = \frac{\text{t}_{\text{CO}_2}}{\text{MWh}}$$

# 1. Calculation Exercise: Biomass(6)

- Step4**
- How much fuel is required for operating the plant annually?
  - How much fuel is required for biomass transportation annually?

- Furnace oil required for operation of the new plant: 5ton/month
- Diesel required for transportation of biomass: 10ton/month

**On-site fossil fuel consumption**

$$5 \text{ ton/month} \times 12 \text{ months/year} = \underline{60 \text{ ton/year}}$$

**Fossil fuel consumption for biomass transport**

$$10 \text{ ton/month} \times 12 \text{ months/year} = \underline{120 \text{ ton/year}}$$

Unit Check

$$\frac{\text{ton}}{\cancel{\text{Month}}} \times \frac{\cancel{\text{Month}}}{\text{Year}} = \frac{\text{ton}}{\text{Year}}$$

# 1. Calculation Exercise: Biomass(7)

- Step5**
- How much GHG is emitted annually through fossil fuel consumption by the project activity? [project emission]

- Furnace oil required for operation of the new plant: 60ton/year
- Diesel required for transportation of biomass: 120ton/year

**Emission associated to on-site fossil fuel consumption**

$$60 \text{ t/year} \times 3.173 \text{ tCO}_2/\text{t} = \underline{190.4 \text{ tCO}_2/\text{y}}$$

**Emission associated to biomass transport**

$$120 \text{ t/year} \times 3.209 \text{ tCO}_2/\text{t} = \underline{385.1 \text{ tCO}_2/\text{y}}$$

**Project emissions**

$$190.4 \text{ tCO}_2/\text{y} + 385.1 \text{ tCO}_2/\text{y} = \underline{575.5 \text{ tCO}_2/\text{y}}$$

Fuel Type	Net Calorific Value (TJ/t)	Effective CO2 emission factor (tCO2/TJ)	Oxidation factor	CO2 emission coefficient (tCO2/t)
	(a)	(b)	(c)	(a)*(b)*(c)
Furnace Oil	0.041	77.4	1.0	3.173
Gas/Diesel Oil	0.0433	74.1	1.0	3.209
Naphtha	0.0456	73.3	1.0	3.342
Residual Oil	0.041	77.4	1.0	3.173
Source	Energy Data 2007	2006 IPCC Guidelines for National GHG Inventories, Volume 2: Energy, Table 1.4		

# 1. Calculation Exercise: Biomass(8)

Step6

- How much GHG emission is reduced annually by the project activity?  
[Emission reduction]

- Baseline emissions: 4,200 tCO<sub>2</sub>/year
- Project emissions: 575.5 tCO<sub>2</sub>/year

$$\begin{aligned} \text{Emission reduction (tCO}_2\text{/y)} &= \text{Baseline emission (tCO}_2\text{/y)} - \text{Project emission (tCO}_2\text{/y)} \\ &= 4,200 \text{ tCO}_2\text{/y} - 575.5 \text{ tCO}_2\text{/y} \\ &= \underline{3,624.5 \text{ tCO}_2\text{/y}} \end{aligned}$$

**Answer:**  
**3,624.5 tCO<sub>2</sub>/y**

# 2. Calculation Exercise: Mini-hydro power(1)

- Company A has a CDM project plan with the following details:
  - New mini-hydro power plant project selling the power to CEB
  - Capacity: 1.1 MW
  - Expected operation: (dry season) 0.6MW, (wet season) 1.1MW
  - 0.1MW of generated electricity is required for operating the mini-hydro plant
  - Daily operating hours: 24 hours
  - Monthly operating days: 25 days
  - Season: (dry season) 4 months, (wet season) 8 months
  - Grid emission factor: 0.70 kgCO<sub>2</sub>/kWh

**(Question)**

**How much emission reduction is expected by this project activity?**



## 2. Calculation Exercise: Mini-hydro power(2)

Step1

- How many hours does the plant operate in dry season?
- How many hours does the plant operate in wet season?

Step2

- How much electricity to be sold to the grid in dry season?
- How much electricity to be sold to the grid in wet season?

Step3

- How much is the total electricity to be sold to the grid annually?

Step4

- How much GHG emission is reduced annually by the project?

## 2. Calculation Exercise: Mini-hydro power(3)

Step1

- How many hours does the plant operate in dry season?
- How many hours does the plant operate in wet season?

- Daily operating hours: 24 hours
- Monthly operating days: 25 days
- Season: (dry season) 4 months, (wet season) 8 months

**Dry season:**

$$24 \text{ hours/day} \times 25 \text{ days/month} \times 4 \text{ months/y} = \underline{\underline{2,400 \text{ hours/y}}}$$

**Wet season:**

$$24 \text{ hours/day} \times 25 \text{ days/month} \times 8 \text{ months/y} = \underline{\underline{4,800 \text{ hours/y}}}$$



## 2. Calculation Exercise: Mini-hydro power(4)

Step2

- How much electricity to be sold to the grid in dry season?
- How much electricity to be sold to the grid in wet season?

- Operating hours in each season: (Dry) 2,400 hours, (Wet) 4,800hours
- Expected operation: (dry season) 0.6MW, (wet season) 1.1MW
- Electricity requirement by the plant: 0.1MW

Amount of electricity to be sold to the grid can be obtained by operation ratio (MW) times number of operating hours.

**Dry season:**

$$2,400 \text{ hours/y} \times (0.6 \text{ MW} - 0.1\text{MW}) = \underline{\underline{1,200 \text{ MWh/y}}}$$

**Wet season:**

$$4,800 \text{ hours/y} \times (1.1 \text{ MW} - 0.1\text{MW}) = \underline{\underline{4,800 \text{ MWh/y}}}$$

## 2. Calculation Exercise: Mini-hydro power(5)

Step3

- How much electricity to be sold to the grid annually?

- Amount of electricity to be sold to the grid in dry season: 1,200 MWh/y
- Amount of electricity to be sold to the grid in wet season: 4,800 MWh/y

**Annual  
Electricity**

=

**Electricity  
(Dry season)**

+

**Electricity  
(Wet season)**

=

1,200 MWh/y

+

4,800 MWh/y

=

**6,000 MWh/y**

## 2. Calculation Exercise: Mini-hydro power(6)

Step4

- How much emission is reduced annually by the project?

- Amount of electricity to be sold to the grid annually: 6,000 MWh/y
- Grid emission factor: 0.70 kgCO<sub>2</sub>/kWh

**Emission  
Reduction  
(tCO<sub>2</sub>/y)**

=

**Amount of  
Electricity  
(MWh/y)**

×

**Grid emission  
factor  
(tCO<sub>2</sub>/MWh)**

=

6,000 MWh/y

×

0.70 tCO<sub>2</sub>/MWh

=

**4,200 tCO<sub>2</sub>/y**

Emission Reduction = Baseline emission – Project emission  
= 4,200 tCO<sub>2</sub>/y – 0 tCO<sub>2</sub>/y  
= 4,200 tCO<sub>2</sub>/y

**Answer:**

**4,200 tCO<sub>2</sub>/y**