

Economical Evaluation of Co-benefits of Clean Development Mechanism (CDM) Projects in Municipal Solid Waste Landfills in Vietnam



Presenter: Nguyen Thi Ngoc Mai
Supervisor: Prof. Yoshiro Higano

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BACKGROUND

Status of municipal solid waste (MSW) in Vietnam

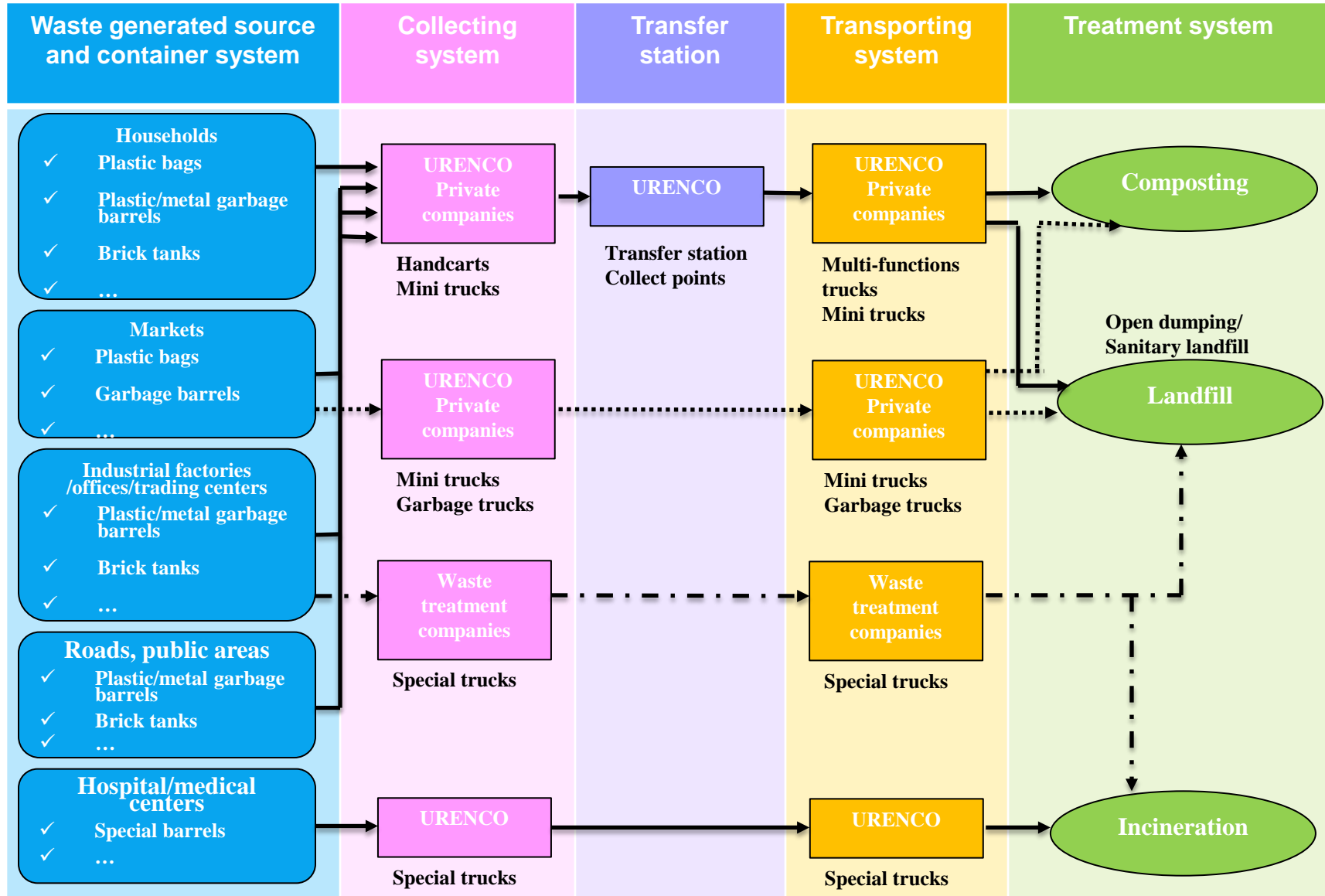
- Municipal solid waste (MSW) account for 60-70% of total urban solid waste generated
- Amount of MSW generated in Vietnam, 2007.

| City Type | Amount of MSW generated per capita (kg/per/day) | Amount of MSW generated | |
|--------------|---|-------------------------|------------------|
| | | Tons/day | Tons/year |
| Special | 0,96 | 8000 | 2.920.000 |
| Level 1 | 0,84 | 1885 | 688.025 |
| Level 2 | 0,72 | 3433 | 1.253.045 |
| Level 3 | 0,73 | 3738 | 1.364.370 |
| Level 4 | 0,65 | 626 | 228.490 |
| Total | | 17.582 | 6.453.930 |

(Source: MONRE, 2011)

BACKGROUND

Status of municipal solid waste (MSW) in Vietnam



BACKGROUND

CDM status in waste sector

- ❖ 76-82% amount of MSW are treated by landfilling.
- ❖ Currently, Vietnam has 98 solid waste landfills, while:
 - 16 landfills have sanitary treatment facilities and CH₄ recovering systems
 - Only 3 landfills are accepted to implement CDM projects by CDM EB

| Landfill | Area (ha) | Area used for CH ₄ recovery | Capability (ton/day) | Amount of solid waste received (ton) | Status | CH ₄ recovery technology | Estimated results |
|---|-----------|--|----------------------|--------------------------------------|----------------|---|---|
| Dong Thanh landfill - Ho Chi Minh city | 45 ha | 165,662 m ² | - | 3,191,724 | Closed in 2002 | CH ₄ recovery systems for electricity generation | 180,870 MWh or 1,033,328 tCO ₂ e (2009 – 2015) |
| Phuong Hiep I landfill – Ho Chi Minh city | 43 ha | 195,297 m ² | 2500-3000 | 1,940,891 | Closed in 2007 | CH ₄ recovery systems for electricity generation | 140,824 MWh or 926,454 tCO ₂ e (2009 – 2015) |
| Nam Son landfill - Hanoi | 83.5 ha | 400,000 m ² | 3000 | 7,500,000 | 1999-2015 | CH ₄ recovery systems for electricity generation | 2,589,649 tCO ₂ e (2010-2017) |

Landfill without methane recovery system



**Odour and
Pollution gases**



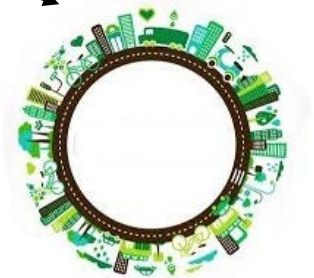
**Fire and
Explosion
risks**



**Contribution to
global
warming**



**Wasting of
Renewable
energy**



**Lack of space
for landfill**

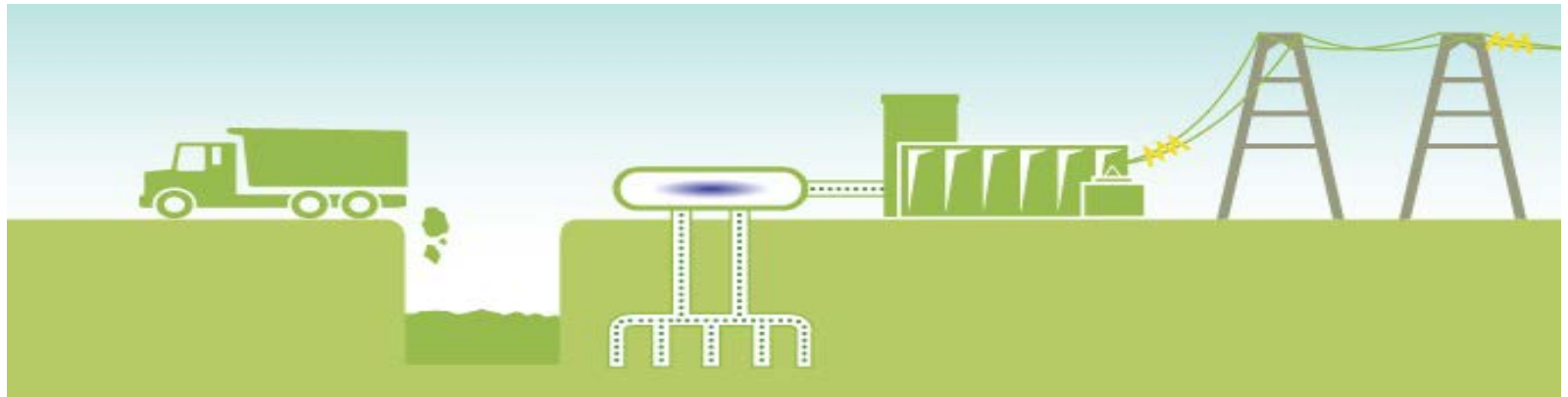


It is necessary to promote CDM projects in solid waste landfills

INTRODUCTION OF RESEARCH

Title & Objectives

❖ *Title: Economical Evaluation of Co-benefits of Clean Development Mechanism (CDM) Projects in Municipal Solid Waste Landfills in Vietnam*



❖ *Objective:*

To encourage the implementation of CDM projects in landfills of Vietnam, therefore promoting climate change mitigation and renewable resources utilization.

INTRODUCTION OF RESEARCH

Methodologies

Literature Review

- International studies
- Data from related authorities

Survey method

- Interview through questionnaires with local people
- Analyse obtained results through Excel

Economical valuation

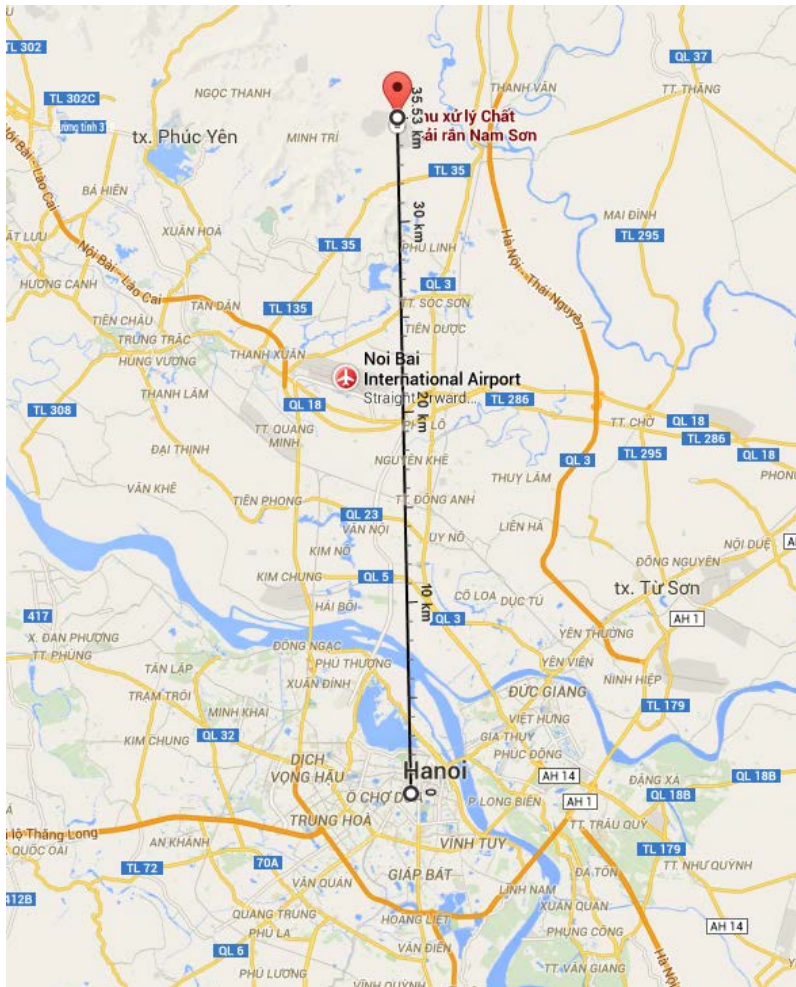
- Use evaluation tools to calculate in monetary term the co-benefits of CDM projects

Cost-benefit analysis

- Make cost-benefit analysis to prove for the effectiveness of CDM projects

INTRODUCTION OF RESEARCH

Study site



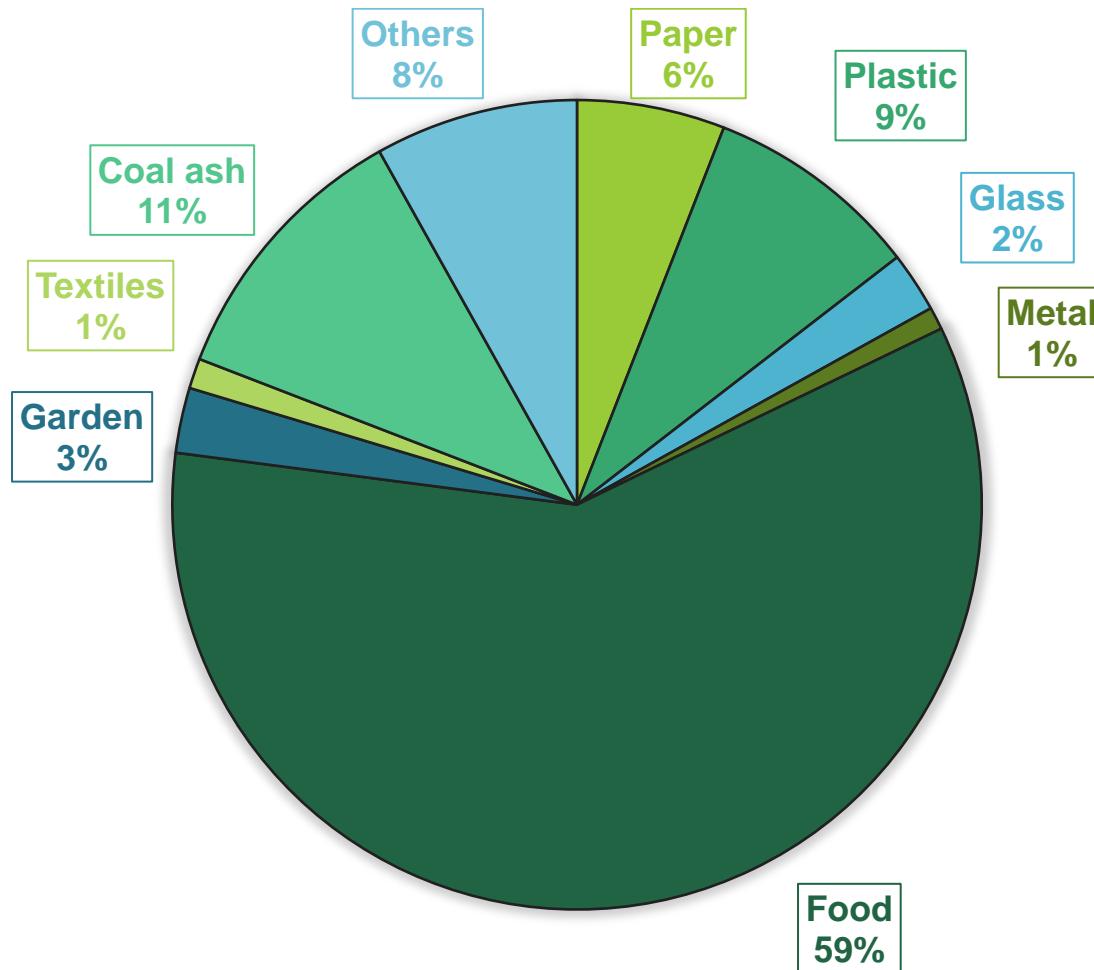
Nam Son landfill

- The biggest landfill of Hanoi
- Located in the northern part, 35km far from Hanoi's central area
- Area: 83.5 ha – 9 cells (planned to be widened 73.7 ha more)
- Designed to receive 1000 tons MSW/day (3500-4000 tons MSW/day in reality)

INTRODUCTION OF RESEARCH

Study site

- Waste compositions

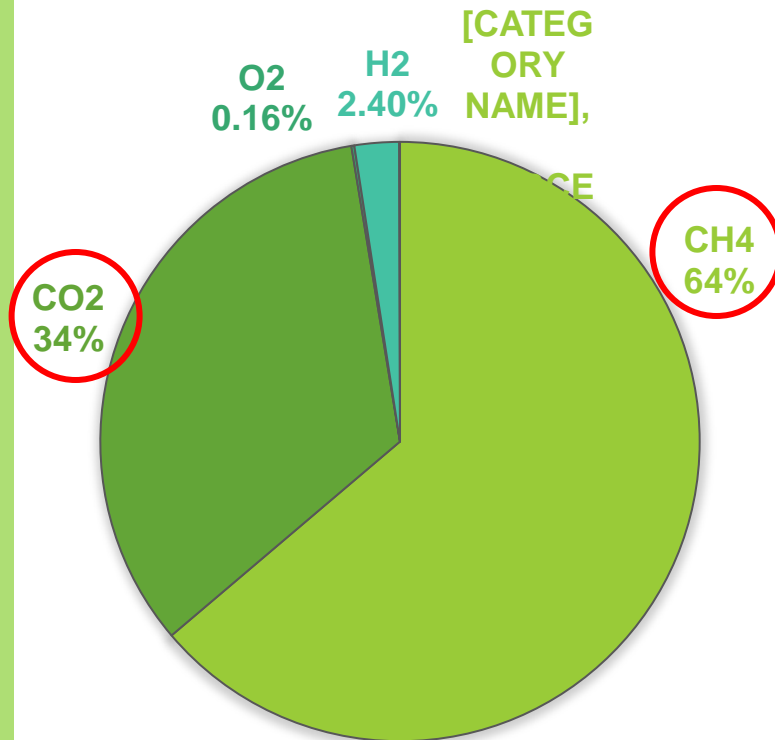


INTRODUCTION OF RESEARCH

Study site

- Environmental quality: Air quality (2010)

Landfill gas compositions



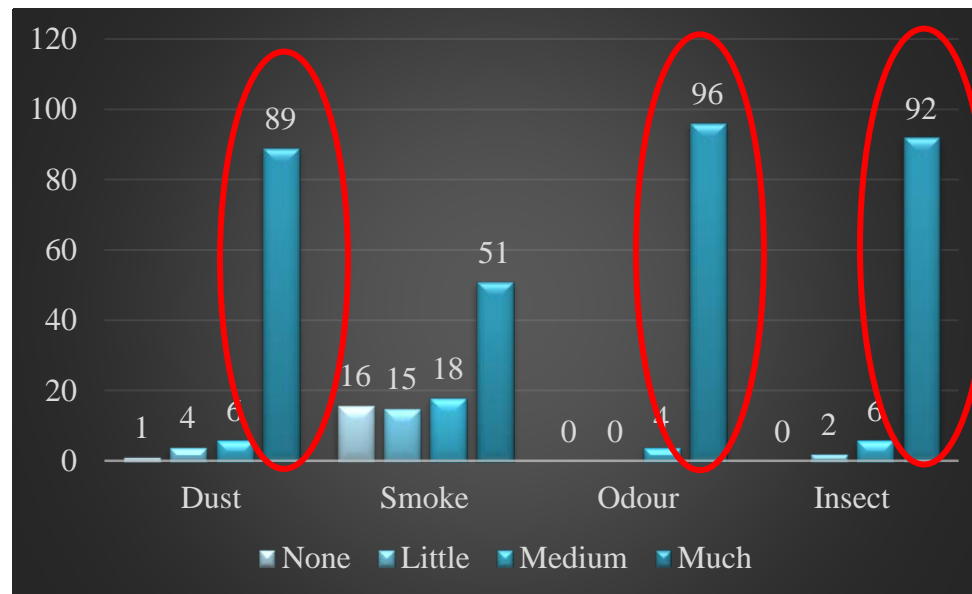
Air quality in Dumping Plot No.7

| Parameter | Unit | Concentration | | National standard on air quality |
|-----------|-------------------|-----------------|---------------------------------|----------------------------------|
| | | On dumping plot | 300 meter far from dumping plot | |
| SO2 | mg/m ³ | 2.71 | 1.12 | 0.05 |
| NO2 | mg/m ³ | 1.54 | 0.75 | 0.04 |
| CO | mg/m ³ | 7.32 | 2.15 | 10 |
| CH4 | mg/m ³ | 122.25 | 67.61 | - |
| H2S | mg/m ³ | 0.97 | 0.52 | - |
| TSS | mg/m ³ | 1.32 | 0.87 | 0.025-0.05 |
| Pb | mg/m ³ | 0.03 | 0.01 | 0.0005 |

INTRODUCTION OF RESEARCH

Study site

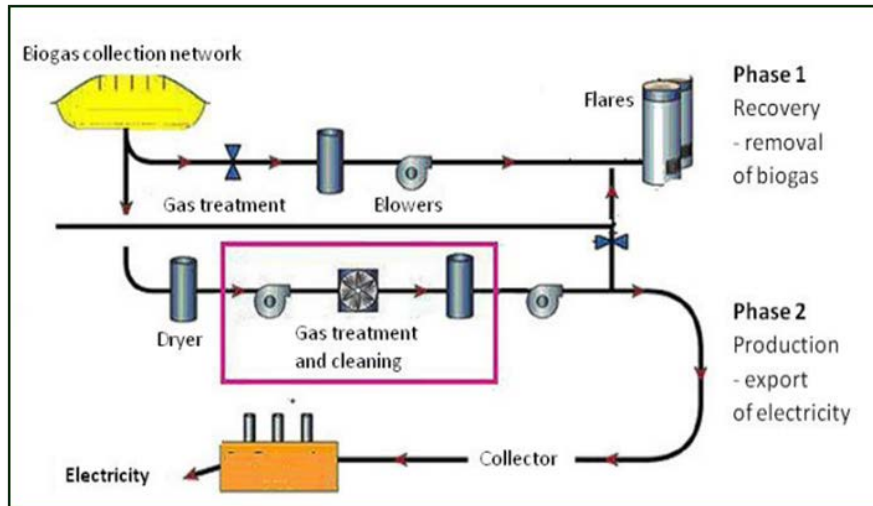
- Air quality survey results (100 respondents)
 - Location: Nam Son landfill (3 adjacent communes)
 - Number of respondents: 100 people
 - Objective: Asking about local people's opinions on air quality
 - Results:
 - + 99% of respondents said that the air is polluted
 - + 98% of respondents said that Nam Son landfill is the cause of air pollution
 - + 96% of respondents said that air pollution causes bad impacts on people's health, 85% is having health problems related to air pollution



INTRODUCTION OF RESEARCH

Study site

- CDM project:



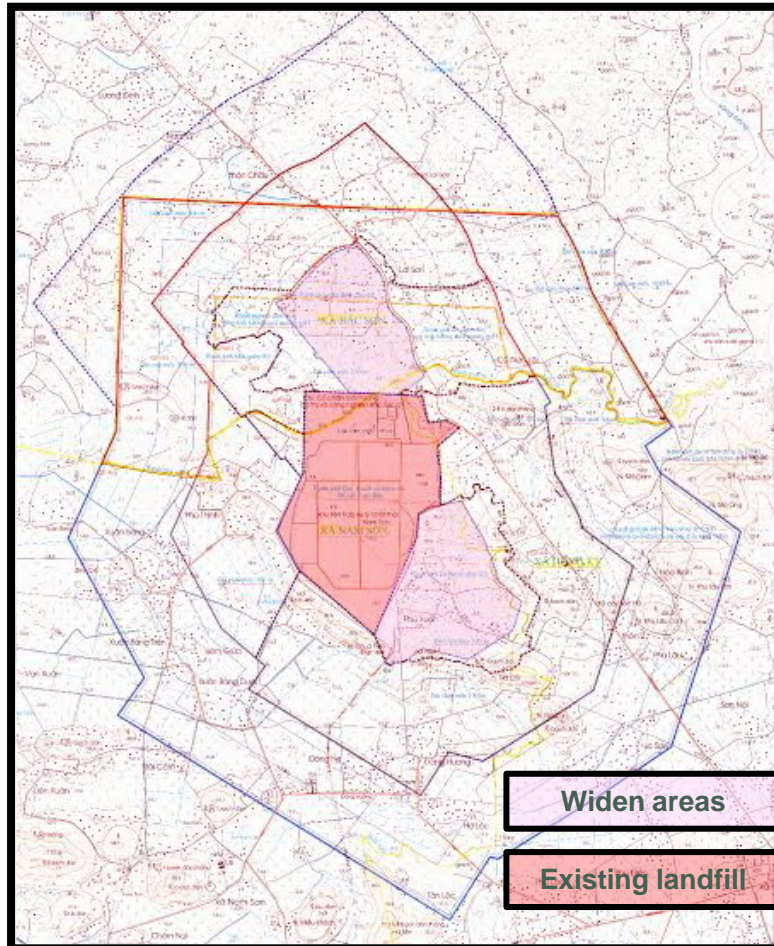
- Registered for CDM project since 2010 (2010-2016) (cover 40 ha of 83.5 ha of Nam Son landfill)
- Estimation of amount of emission reduction over the crediting period:

| Year | Amount of emission reduction (tCO ₂ e) |
|--------------|---|
| 2010-2011 | 301,711 |
| 2011-2012 | 346,557 |
| 2012-2013 | 383,904 |
| 2013-2014 | 425,354 |
| 2014-2015 | 435,389 |
| 2015-2016 | 380,036 |
| 2016-2017 | 305,878 |
| Total | 2,578,829 |

INTRODUCTION OF RESEARCH

Study site

- Widening plan:



- Total area of expanding part: 73.7 ha
 - Northern area: 37.47 ha
 - Southern area: 36.26 ha
- Located on 3 communes: Bac Son, Hong Ky and Nam Son
- As designed, there will be LFG collecting pipeline in widen part, but no methane recovery system



RESULTS

Co-benefits of CDM project in study site

CDM project

Market-values

Non-market value

CERs trading

Energy producing

Land conservation

Environmental improvement

IPCC

LandGEM

Guideline from EB version 03.1

Calculating based on increased landfill capacity

Contingent Valuation Method (CVM)

RESULTS

CERs Trading

- IPCC method

$$\text{CH}_4 \text{ emission} = \text{MSW}_T * \text{MSW}_F * \text{MCF} * \text{DOC} * \text{DOC}_F * F * (16/12 - R) * (1 - \text{OX})$$

| Variable | Unit | Meaning | Description |
|----------------|--------------------|---|---|
| MSW_T | Gg y ⁻¹ | Total municipal solid waste (MSW) generated | Unknown |
| MSW_F | % | Fraction of MSW disposed of at the disposal sites | Unknown |
| MCF | - | Methane correction factor (fraction) | MCF = 1.0 (IPCC) |
| DOC | - | Degradable organic carbon (fraction). | DOC = 0.4 (A) + 0.17(B) + 0.15 (C) + 0.3 (D) = 2.84 + 0.442 + 8.865 + 0.3 = 12.447 % Where: A: percentage of paper and textile; B: percentage of garden waste, park waste and other non-food organic putrescible waste; C: percentage of food waste; D: percentage of wood or straw |
| DOC_F | - | Fraction DOC dissimilated | $\text{DOC}_F = 0.014 \times T + 0.28 = 0.84$ |
| F | - | Fraction of methane in LFG | 53% |
| R | - | Recovered methane | 60% |
| OX | Gg y ⁻¹ | Oxidation factor | Default is 0 |

RESULTS

CERs Trading

- LandGEM**

$$Q = \sum_{i=1}^n \sum_{j=0.1}^1 kL_0 \left[\frac{M_i}{10} \right] (e^{-kt_{ij}})$$

Where:

Q: Maximum expected generation flow rate of methane for M_i tons of solid waste ($m^3/year$)

i: 1 year increment

n: (year of calculation)-(initial year of waste acceptance)

j: 0.1 year time increment

k: Methane generation rate (1/yr)

L_0 : Potential methane generation capacity (m^3/Mg)

M_i : Mass of solid waste disposed in the i th year (Mg)

t_{ij} : Age of the j th section of waste mass M_i disposed in the i th year (decimal years)

| Input requirements | Value |
|---|---|
| Methane generation rate (k) | k = 0.05 (IPCC default value) |
| Potential Methane Generation Capacity (L_0) | $L_0 = MCF * DOC * DOC_f^*$ (16/12)*F (IPCC) = 73.9 m^3/ton MSW |
| Nonmethane Organic Compound Concentration | LandGEM default values |
| Methane Content | 53% |
| Waste Acceptance Data | Unknown |

RESULTS

Energy Producing

Estimate amount of methane recovered and destroyed

- **Amount of methane recovered and destroyed**

$$= MD_{\text{project,y}} = Q / \text{GWP}_{\text{CH}_4} * R_r * F_E$$

- Q: methane generated by the landfill
- GWPCH4: Global Warming Potential value for methane for the first commitment period
- Rr: Capture efficiency of the system used in the project activity
- FE: Efficiency of the flaring system

Estimate net quantity of electricity exported

- $EL_{\text{LFG,y}} = MD_{\text{project,y}} / \text{CEF}_{\text{elec,BL}}$,
- $\text{CEF}_{\text{elec,BL,y}}$: CO2 emissions intensity of the baseline source of the electricity displaced (Vietnam) (CO2e/MWh)

Estimate monetary value of Economical benefit

- **Monetary benefit of Economical Profit =**
 $EL_{\text{LFG,y}} * y * \text{Price of electricity}$
- y: number of years of project (year)

| Input requirements | Value |
|---------------------------------|---------------------------------|
| Q | Unknown (depend on first value) |
| GWPCH4 | 21tCO2e/tCH4 |
| Rr | 55% |
| FE | Default value = 90% |
| $\text{CEF}_{\text{elec,BL,y}}$ | 0,5974 |
| y | 20 years |
| Price of electricity | 1,581 VND / kWh (including tax) |

RESULTS

Land Conservation

| Step | Equation | Reference | Result |
|--|---|--|---|
| Estimate increased volume of disposed solid waste thank to methane recovery system | Volume of increased solid waste= Designed capacity * 22.5% (average value of 15% and 30%) | Nam Son landfill's designed capacity: 34,011,211 m ³ of solid waste in 2018 | 2,186,435 m ³ |
| Estimate area of land conserved thank to methane recovery system | Area of land conserved = Volume of increased solid waste/ Standard height of a dumping hole | Standard height from bottom to top of a landfill slot has to be from 15 – 25m (governmental guidance) | 109,321.75 m ² |
| Estimate monetary value of Land conservation benefit | Monetary benefit of Land conservation benefit = Area of land conserved * Price of land | The price of Nam Son Commune is 476,500 VND/m ² in average (governmental document) | 52.1*10 ⁹ VND ≈ 2,504,808 USD |

RESULTS

Environment Improvement

- Contingent Valuation Method (CVM)

Method of data collection: face-to-face interview with questionnaire

Survey site:

- Bac Son commune (pop: 14,773)
- Hong Ky commune (pop: 11,200)
- Nam Son commune (pop: 8887)

Number of questionnaires: 100

| Dependent variable | Independent variables |
|--------------------|---|
| Willingness-to-pay | <ul style="list-style-type: none">- Age- Gender- Income- Education- Distance to landfill- Reliability rate |

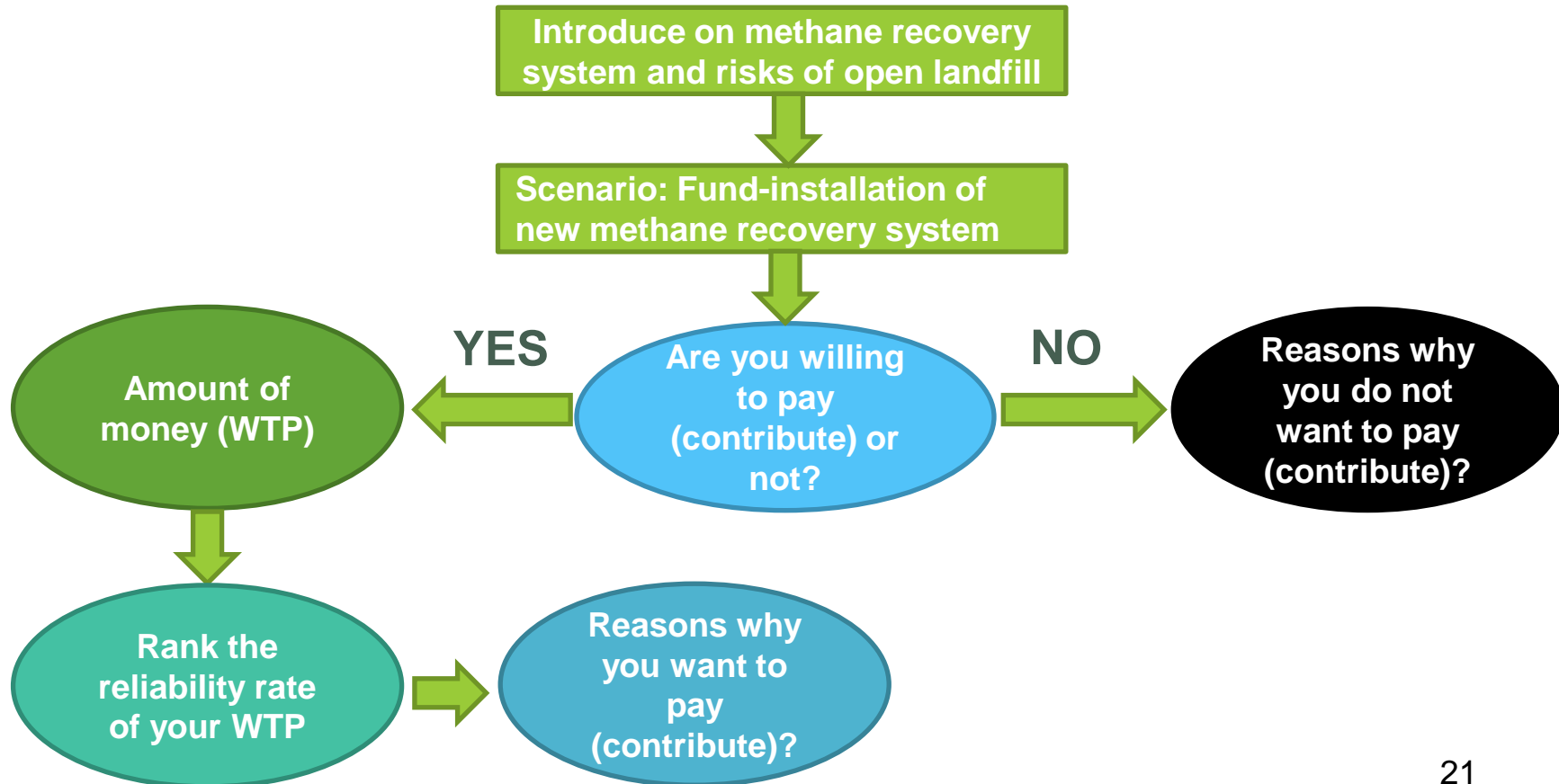


RESULTS

Environment Improvement

- Contingent Valuation Method (CVM) (cont)

Structure of questionnaire:



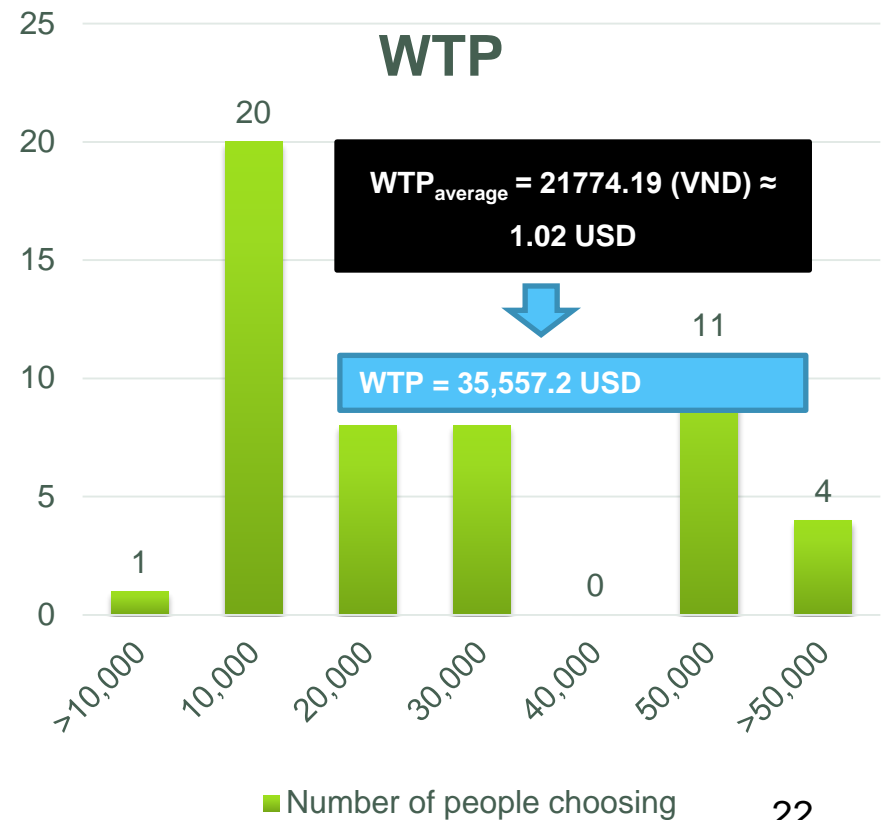
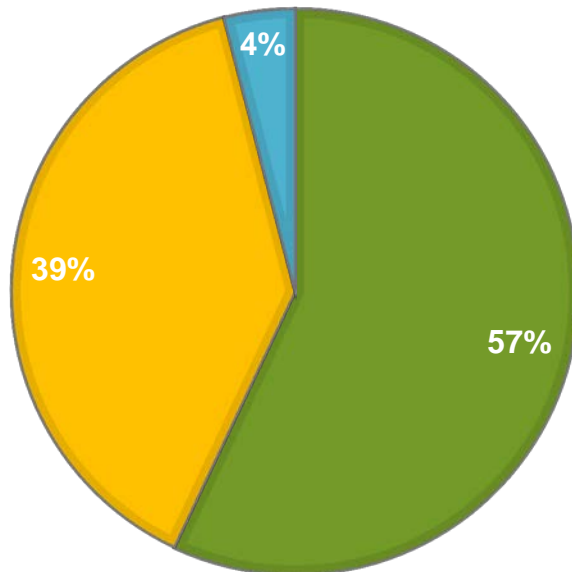
RESULTS

Environment Improvement

- Contingent Valuation Method (CVM) (cont)

ARE YOU WILLING TO PAY FOR AIR QUALITY IMPROVEMENT?

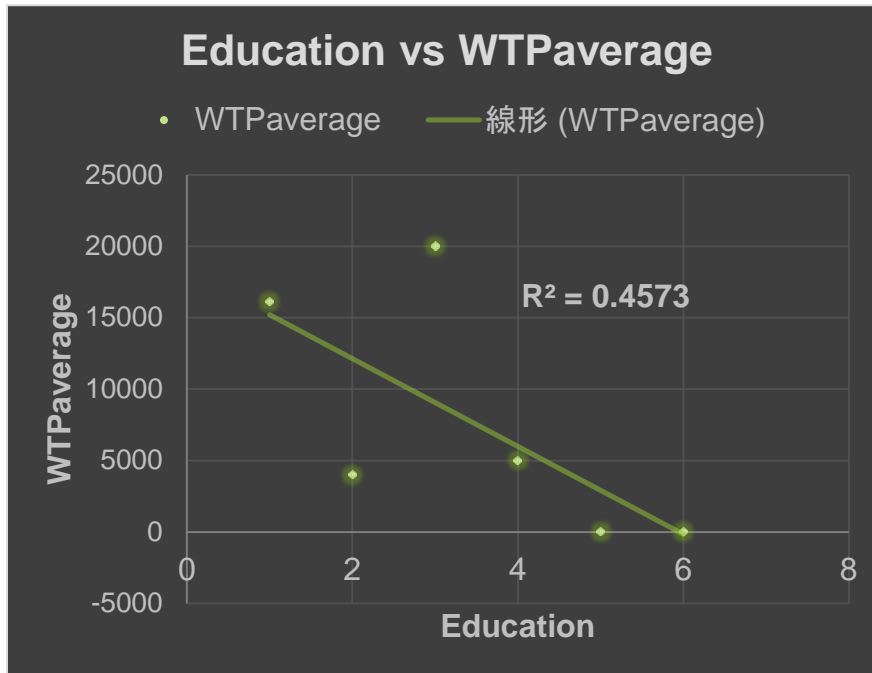
■ Yes ■ No ■ Not sure



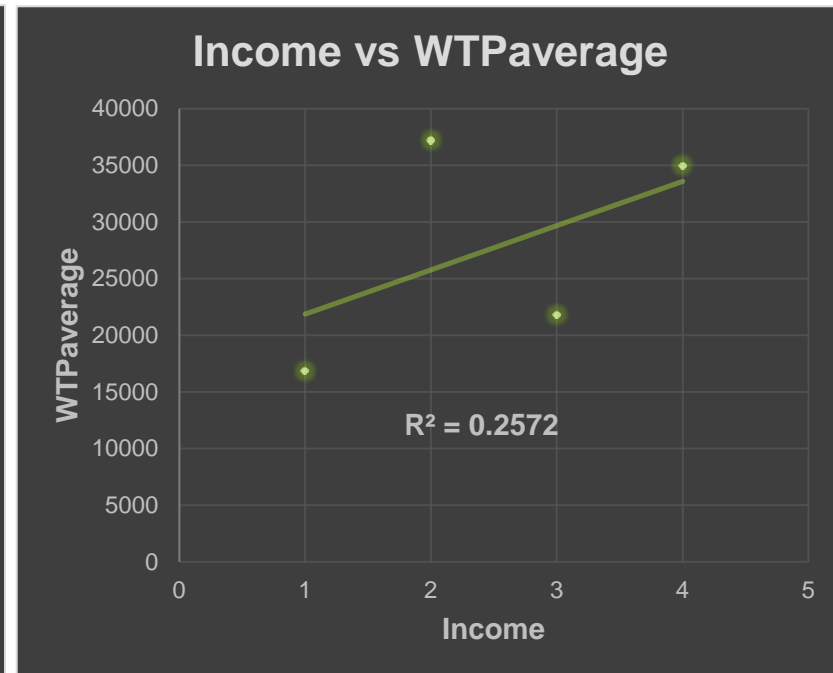
RESULTS

Environment Improvement

- Contingent Valuation Method (CVM) (cont)
Correlation between WTPaverage and other variables



Education
1: Primary; 2: Secondary; 3: High school;
4: University; 5: Postgraduate; 6: Other



Income
1: <3mil.VND; 2: 3-5mil VND;
3: 5-10 mil.VND; 4: >10 mil.VND

Conclusion

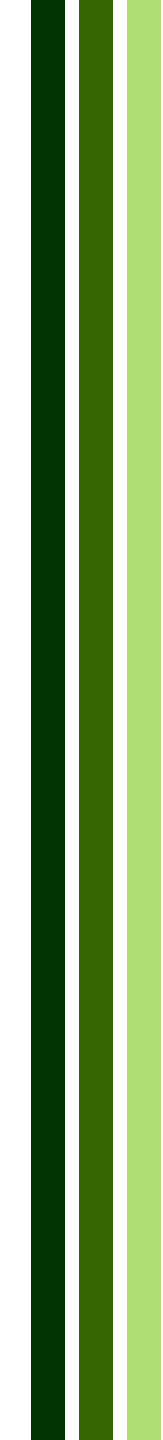
- The air of Nam Son landfill and surrounding areas are being polluted seriously.
- It is necessary to propose a methane recovery system in widening areas and lengthen/propose more CDM project in Nam Son landfill
- The study evaluates in monetary value four benefits of landfill CDM project to prove for the effectiveness of this type of project
- Market-based values include: CERs trading, energy producing and land conservation. The value of land conservation benefit is estimated as 2,504,808 USD.
- Non-market value is environmental improvement which are calculated based on WTP of local people. The total WTP is estimated as 35,557.2 USD. The relations between WTP with Education and Income are weak.

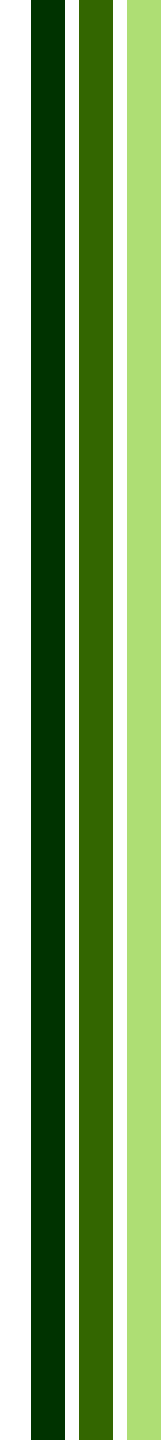
FUTURE PLAN

- Get information on waste input to calculate CERs trading and energy producing benefits. Sensitivity analysis for obtained results
- Analyse more correlations between WTP and other variables such as Reliability rate, Age, Distance to landfill...
- Cost-benefits analysis to demonstrate for the effectiveness of CDM project



Thank you
for your
attention!





Production of landfill gas from MSW and selected waste fractions

| Waste fraction | Landfill gas production Nm ³ /tonne (wet material) | Data type | Source |
|----------------|---|------------------------------|-----------------------------|
| MSW | 372 | Theoretical calculation | Gendebien et al. (1991) |
| MSW | 229 | Theoretical calculation | Ehrig (1991) |
| MSW | 270 | Calculated from Italian data | Ruggeri et al. (1991) |
| MSW | 120-160 | Laboratory scale experiments | Ehrig (1991) |
| MSW | 190-240 | Measured at landfills | Ham et al. (1979) |
| MSW | 60-180 | Measured at landfills | Tabasaran (1976) |
| MSW | 222 | Mean UK landfills yield | Richard and Aichison (1991) |
| MSW | 135 | Estimated average | IFEU (1992) |
| MSW | 200 | Estimated average | De Baere et al (1987) |
| MSW | 100-200 | Estimated average | Carra and Cossu (1990) |

Calculation of CERs trading

- MCF

SWDS classification and methane correction factors (MCF) (IPCC, 2006)

| Type of Site | MCF Default Values |
|--|--------------------|
| Managed – Anaerobic | 1.0 |
| Managed – Semi-aerobic | 0.5 |
| Unmanaged – deep (>5m waste) and/or high water table | 0.8 |
| Unmanaged – shallow (<5m waste) | 0.4 |
| Uncatergorised | 0.6 |

- DOC

$$\text{DOC} = 0.4 (A) + 0.17(B) + 0.15 (C) + 0.3 (D)$$

$$= 2.84 + 0.442 + 8.865 + 0.3 = 12.447 \%$$

Where

A: percentage of paper and textile; (7.1)

B: percentage of garden waste, park waste and other non-food organic putrescible waste; (2.6)

C: percentage of food waste; (59.1)

D: percentage of wood or straw (~1)

Source: Luong Thi Mai Huong, Nguyen Chau Thuy

| Category | Proportion (%) |
|-----------------|----------------|
| Paper | 5.9 |
| Plastic | 8.6 |
| Glass | 2.4 |
| Metal | 0.9 |
| Food | 59.1 |
| Flower, garden | 2.6 |
| Textiles | 1.2 |
| Rubber, leather | 0.5 |
| Ceramics | 0.6 |
| Coal ash | 11 |
| Others | 7 |

Calculation of CERs trading (cont)

- DO Cf

This factor may vary from 0.42 for 10°C to 0.98 for 50°C. In fact, in many deep landfills (>20m), temperatures of more than 50°C have been registered in gas streams from highly productive gas wells (thus clearly anaerobic). In the Nam Son landfill, the height of site now is 18 m. Expected height in the future is 30m. In this case, assumption of average temperature of anaerobic zone is 40°C, therefore DO Cf = 0.84.

- $F = 0.53$

Results of LFG sample analysis at NS landfill (Source: Nguyen Chau Thuy)

| Location of sampling | No of Sample | Microclimate | | | CH ₄ (%) | CO ₂ (%) |
|----------------------|--------------|------------------|--------------|---------------------|---------------------|---------------------|
| | | Temperature (°C) | Moisture (%) | Wind velocity (m/s) | | |
| Cell 1 | 1 | 20.2 | 66.9 | 0.12 | 57.6 | 40.3 |
| | 2 | 19.8 | 65.3 | 0.15 | 56.2 | 34.5 |
| | 3 | 19.2 | 67.9 | 0.14 | 55.2 | 0.92 |
| Cell 3 | 4 | 18.4 | 74.2 | 0.17 | 55.2 | 42.0 |
| | 5 | 23.5 | 75.3 | 0.11 | 50.2 | 36.5 |
| | 6 | 21.3 | 77.4 | 0.15 | 54.2 | 35.6 |
| Cell 4B | 7 | 18.4 | 74.2 | 0.11 | 53.2 | 12.3 |
| | 8 | 19.2 | 78.3 | 0.12 | 50.1 | 33.5 |
| | 9 | 20.1 | 75.6 | 0.15 | 48.2 | 45.3 |

Calculation of CERs trading (cont)

- LandGEM result (until 2013 only)

| Year | Waste accepted | | Methane | |
|------|----------------|------------------|-----------|-------------------|
| | (Mg/year) | (short ton/year) | (Mg/Year) | (short tons/year) |
| 2000 | 410,990 | 452,089 | 0 | 0 |
| 2001 | 475,960 | 523,556 | 9.907E+02 | 1.090E+03 |
| 2002 | 537,280 | 591,008 | 2.090E+03 | 2.299E+03 |
| 2003 | 586,190 | 644,809 | 3.283E+03 | 3.611E+03 |
| 2004 | 632,910 | 696,201 | 4.536E+03 | 4.989E+03 |
| 2005 | 700,210 | 770,231 | 5.840E+03 | 6.424E+03 |
| 2006 | 812,210 | 893,431 | 7.243E+03 | 7.968E+03 |
| 2007 | 932,760 | 1,026,036 | 8.848E+03 | 9.733E+03 |
| 2008 | 930,960 | 1,024,056 | 1.066E+04 | 1.173E+04 |
| 2009 | 1,089,490 | 1,198,439 | 1.239E+04 | 1.363E+04 |
| 2010 | 1,230,730 | 1,353,803 | 1.441E+04 | 1.585E+04 |
| 2011 | 1,384,020 | 1,522,422 | 1.667E+04 | 1.834E+04 |
| 2012 | 1,486,590 | 1,635,249 | 1.920E+04 | 2.112E+04 |
| 2013 | 1,458,560 | 1,604,416 | 2.184E+04 | 2.403E+04 |

Calculation of Energy producing

- R_r

As taking into consideration the actual conditions of the landfill, covering layer and density of collection wells, the capture efficiency is estimated as 55% (ISEM, 2013)

- $CEF_{elec, BL}$

Currently, there is no published emission intensity of electricity ($CEF_{elec, BL, y}$) in Vietnam, therefore, the paper use the average value of emission from a number of power CDM projects (hydro and wind power) in Vietnam which have been successfully registered with the Intergovernmental Committee on Climate Change IPCC as follows:

| No | Code | Name of project | Registered day | $CEF_{elec, BL, y}$ |
|---------|------|---|----------------|---------------------|
| 1 | 2891 | Ta Niet Hydro Power Project, Son La | 21/11/2009 | 0,5679 |
| 2 | 2627 | Nam Pia Hydro Power Project, Son La | 05/09/2009 | 0,5629 |
| 3 | 2372 | So Lo Hydro Power Project, Hoa Binh | 17/08/2009 | 0,6233 |
| 4 | 2367 | Phu Mau Hydro Power Project, Lao Cai | 05/06/2009 | 0,6233 |
| 5 | 2371 | Muong Sang Hydro Power Project, Son La | 05/06/2009 | 0,6233 |
| 6 | 2368 | Suoi Tan Hydro Power Project, Son La | 27/07/2009 | 0,6233 |
| 7 | 2228 | Wind Power Plant No.1 - Binh Thuan 30MW, Binh Thuan | 06/04/2009 | 0,6448 |
| 8 | 2878 | An Diem 2 Hydropower Project , Quang Nam | 14/12/2009 | 0,5104 |
| Average | | | | 0,5974 |

- Electricity price

According to the electricity price of the Vietnam Electricity Group (EVN) under the guidance of Ministry of Industry and Trade (Circular No.38/2012 / TT-BTC dated 29th December, 2012), the average electricity price is 1,437 VND / kWh (excluding tax), equivalent to 1,581 VND / kWh₃₃ (including tax)