EES Lab
Energy&Environmental Systems

KYUSHU
UNIVERSITY

Experience Using Co-benefits Tools for Projects in Asia

Hooman Farzaneh
Interdisciplinary Graduate School of Engineering Sciences
Kyushu University

Tools and Methods for Implementing Projects and Policies with Climate and Sustainable Development Co-benefits

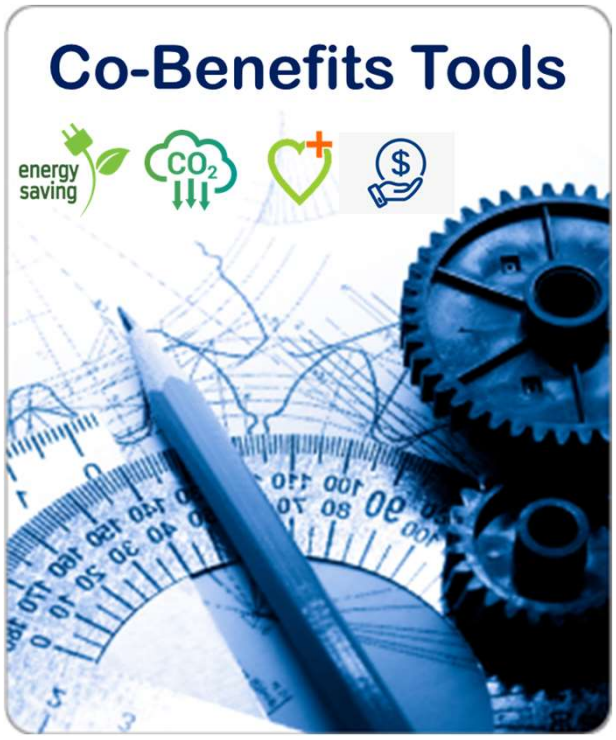
Jan 2022

Introduction

Quantitative Evaluation on Co-benefit Projects (2018~)

KYUSHU UNIVERSITY

IGES Institute for Global Environmental Strategies



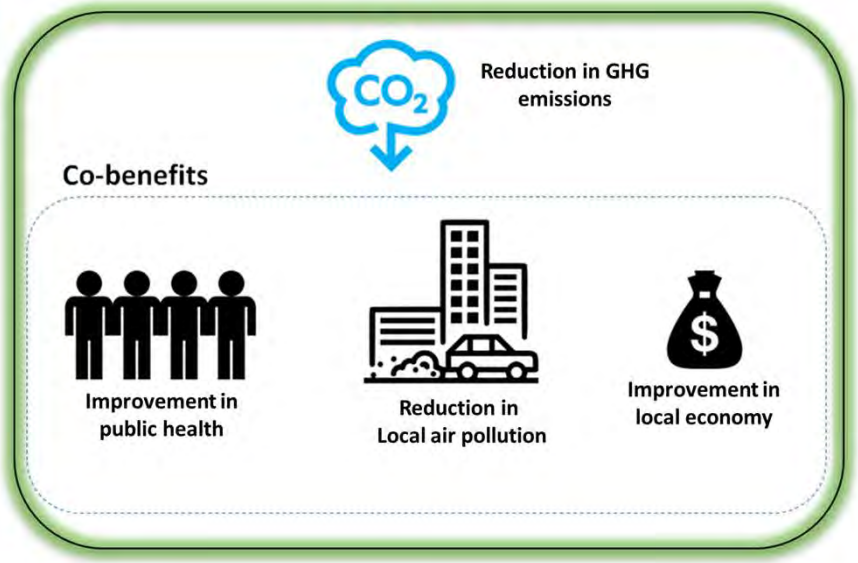
Mongolia

Heat Only Boiler

Solar Energy

Indonesia

Fish Industry Wastewater Treatment



Objective

Need for the Co-benefits assessment tool

A tool to be used as a first order screening for understanding the relative magnitude of emissions reduction of local and global scale pollutants

The tool uses a case study approach to evaluate:

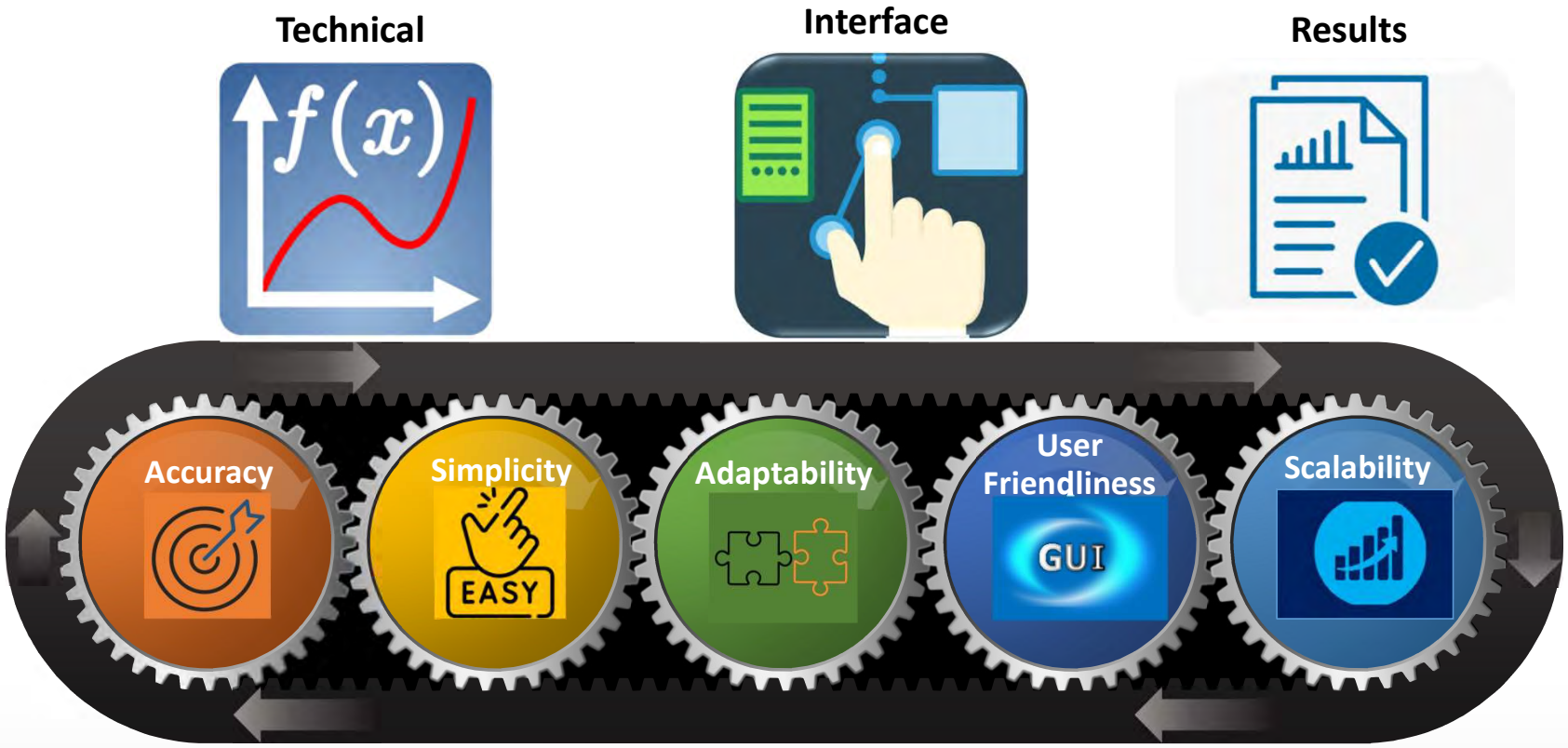
- How much?
- How come?

Technical dimension of co-benefits [T]

Total co-benefit assessment = [G][T]

Institutional dimension acts as a multiplier of effectiveness to the technical analysis [G]

Characteristics



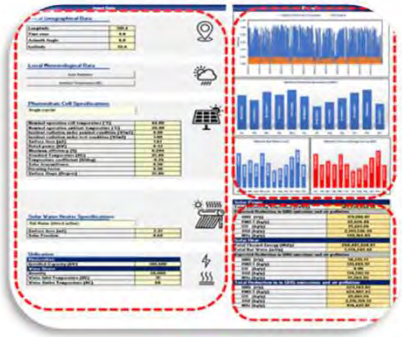
Bottom-up technology assessment spreadsheet tool to evaluate co-benefits of technical projects

Organization

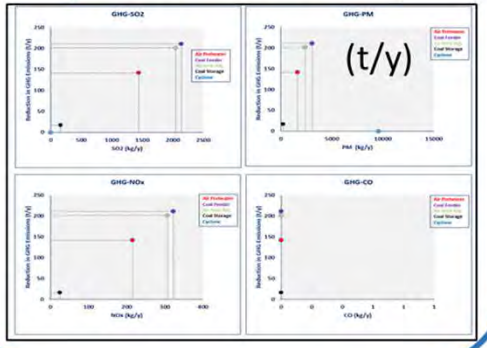
Region-wise

Technology-wise

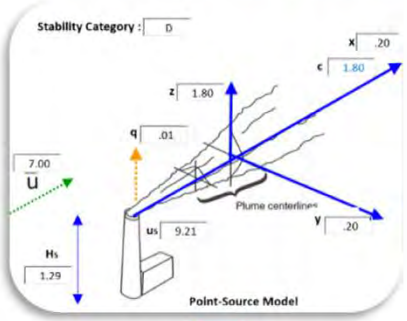
Scenario Analysis



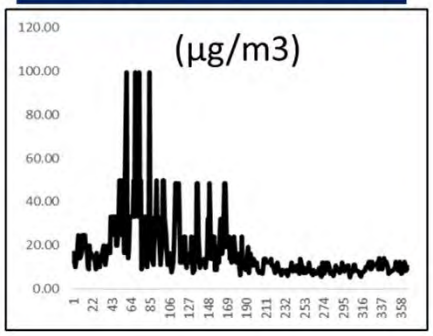
Avoided Emissions



Air Pollution Dispersion

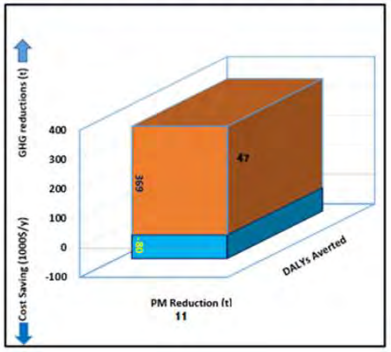


Avoided Concentration



Health and Economic Benefits

Avoided health cases and costs



Local Data
- Geographical
- Meteorological

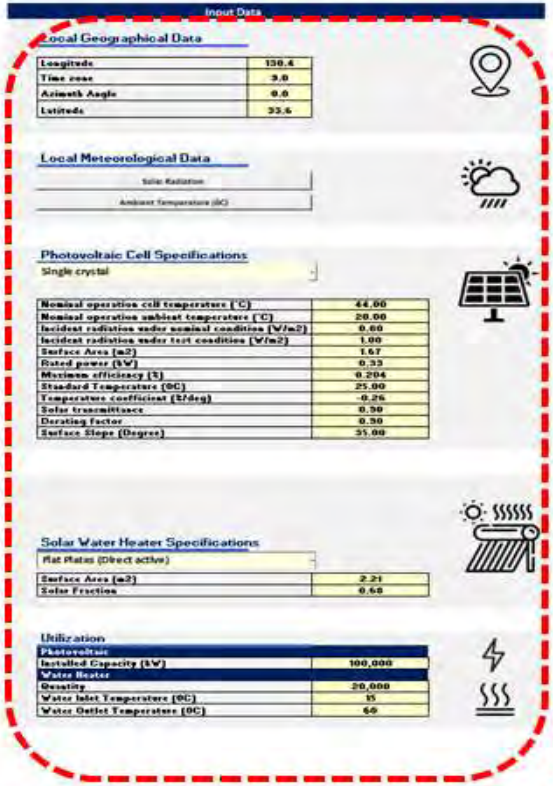
Technical Data
- Energy resources(Fossil and renewable)
- Technology (HOB, Solar panel, Wastewater treatment)

Emission Factors Inventory
- EPA Database
- Local inventory

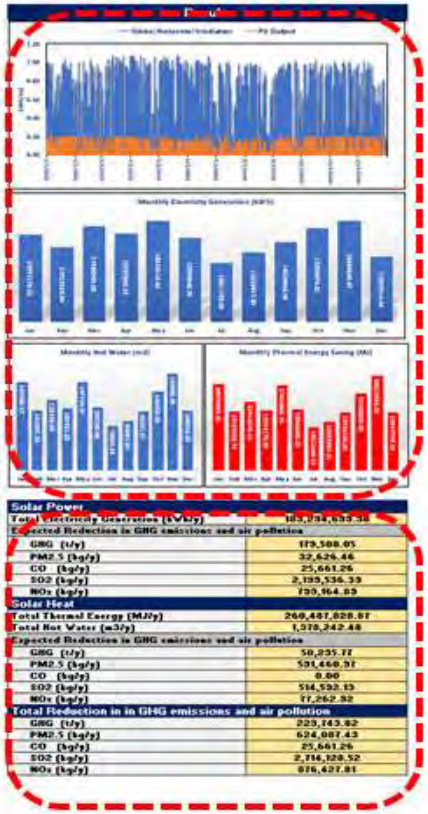
Health Data
- Annual DALYs per disease
- Mortality rates

Solar Energy Co-benefits Tool

Input Data



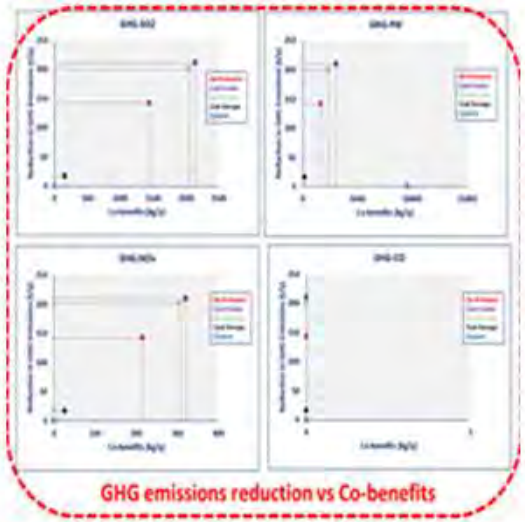
Results



PVs:
Single and Monocrystal

Collectors:
Flat plates and evacuated

Environmental Co-benefits

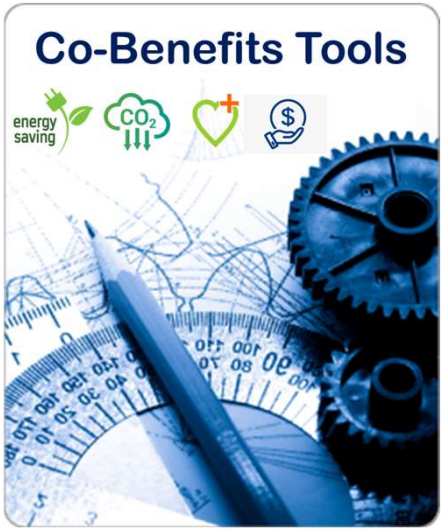


Health and Economic Co-benefits

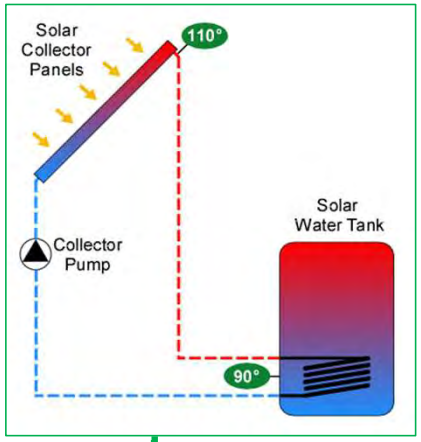
Input Data:
- ✓ Local geographical
- ✓ Local meteorological
- ✓ Solar panel and collector

Output Data:
- ✓ Hourly and Monthly power and heat
- ✓ GHG and AP

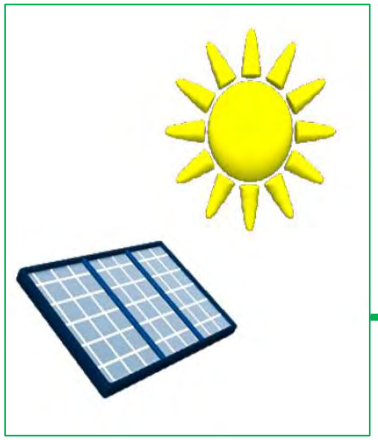
Solar Energy Project in Ulaanbaatar



Solar Water Heater



Photovoltaic

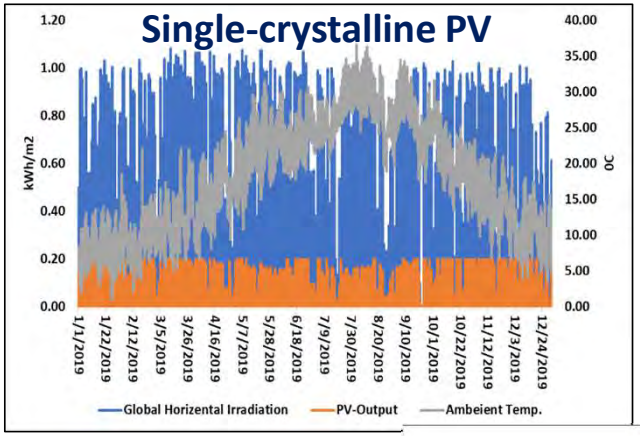


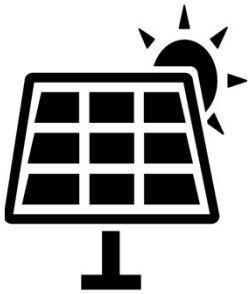
Coal Powerplant

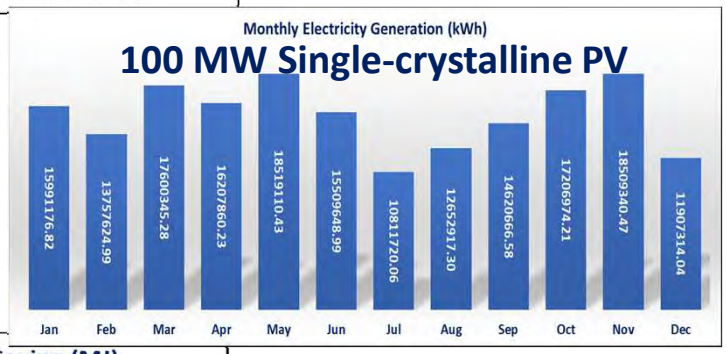
HOB

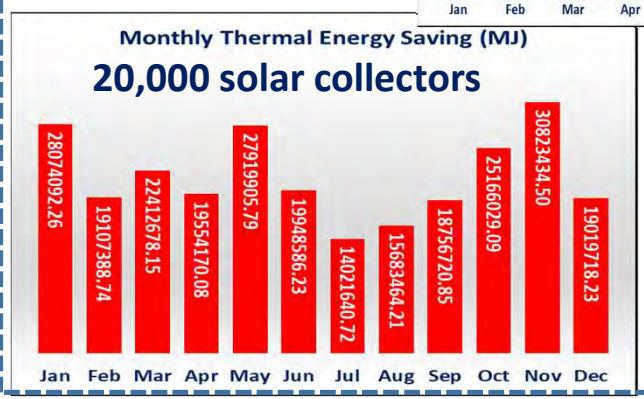
- How much of energy demand can be met by solar energy?
- How much GHG and AP can be reduced?
- How many healthy life years can be expected?

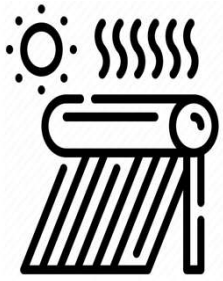
Solar Energy Project in Ulaanbaatar











Solar power scenario	
Total Electricity Generation (GWh/y)	**183.3**
Expected Reduction in GHG emissions and air pollution	
GHG (1000 t/y)	179.5
$PM_{2.5}$ (t/y)	32.6
CO (t/y)	25.7
SO_2 (t/y)	2199.5
NOx (t/y)	799.2
Solar heat scenario	
Total Thermal Energy (TJ/y)	**260.5**
Expected Reduction in GHG emissions and air pollution	
GHG (1000 t/y)	50.2
$PM_{2.5}$ (t/y)	591.5
CO (t/y)	0.0
SO_2 (t/y)	514.6
NOx (t/y)	77.3
Total Reduction in GHG emissions and air pollution	
GHG (1000 t/y)	**229.7**
$PM_{2.5}$ (t/y)	**624.1**
CO (t/y)	25.7
SO_2 (t/y)	2714.1
NOx (t/y)	876.4

Solar Energy Project in Ulaanbaatar

Deaths and DALYs (Baseline)

Exposure Level

Background Mortality Rate	(per 100000)
Chronic Obstructive pulmonary Disease (COD)	23
Ischemic Heart Disease(IHD)	150.9
Cerebrovascular disease (Stroke)	109.7
Lung Cancer (LC)	18.14
Acute Lower Respiratory Infections (ALRI)	276.82
Tuberculosis and Bronchus (TB)	15.7

Deaths and DALYs

DALYs	
Chronic Obstructive pulmonary Disease (COD)	1614
Ischemic Heart Disease(IHD)	11922
Cerebrovascular disease (Stroke)	9686
Lung Cancer (LC)	1490
Acute Lower Respiratory Infections (ALRI)	10804
Tuberculosis and Bronchus (TB)	2484

PM Emissions

PM Emissions

Baseline Scenario	
PM emissions (t/y)	1300.00
Population Weighted Concentration of PM (ug/m3)	57.00
Co-Benefits Scenario	
Reduction in PM from the Co-benefits Scenario (t/y)	624.09
Reduction in PM from the Co-benefits Scenario (ug/m3)	27.36
Co-benefits Scenario Concentration of PM (ug/m3)	29.64

Local Economy

Baseline Scenario	
Per Capita Gross Domestic Product, GDP ($/y)	1700.00
Unemployment rate(%)	6.36

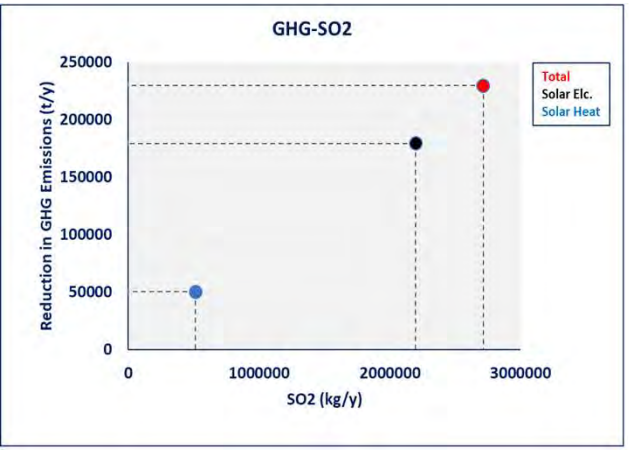
Results

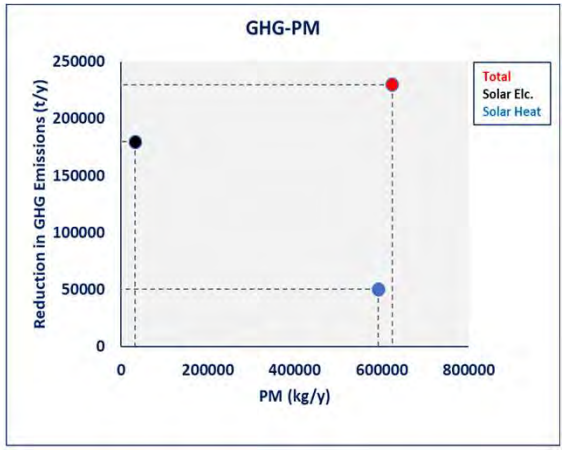
	COPD	IHD	Stroke	LC	ALRI	TB	Total
Baseline Scenario							
Relative Risk (Lower Limit)	1.100	1.239	1.169	1.088	1.306	2.125	
Relative Risk (Upper Limit)	1.311	1.842	1.768	1.520	1.437	2.338	
PAF (Lower Limit)	0.091	0.193	0.145	0.081	0.234	0.529	
PAF (Upper Limit)	0.237	0.457	0.434	0.342	0.304	0.572	
DALYs (Lower Limit)	146.8	2,299.5	1,400.5	120.0	2,532.9	1,314.9	7,814.7
DALYs Upper Limit)	382.6	5,448.4	4,206.8	509.8	3,284.8	1,421.2	15,253.6
Co-benefits Scenario							
Relative Risk (Lower Limit)	1.056	1.177	1.115	1.038	1.153	1.509	
Relative Risk (Upper Limit)	1.187	1.486	1.434	1.305	1.269	1.660	
PAF (Lower Limit)	0.053	0.150	0.103	0.037	0.133	0.337	
PAF (Upper Limit)	0.158	0.327	0.302	0.234	0.212	0.398	
DALYs (Lower Limit)	86	1793	996	55	1438	838	5205
DALYs Upper Limit)	255	3899	2930	348	2289	988	10708
Health Co-Benefit							
Averted DALYs (Lower Limit)	61	507	404	65	1095	477	2609
Averted DALYs Upper Limit)	128	1550	1277	162	996	433	4545
Local Economy Improvement							
Health Care Cost Savings ($/y)	77,273						
Unemployment Rate Reduction (%)	0.001						

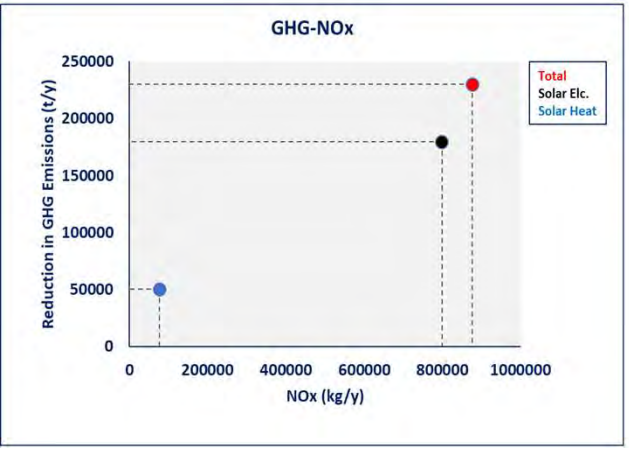
- Chronic Obstructive pulmonary Disease (COD)
- Ischemic Heart Disease (IHD)
- Cerebrovascular disease (Stroke)
- Lung Cancer (LC)
- Tuberculosis and Bronchus (TB)
- Acute Lower Respiratory Infections (ALRI)

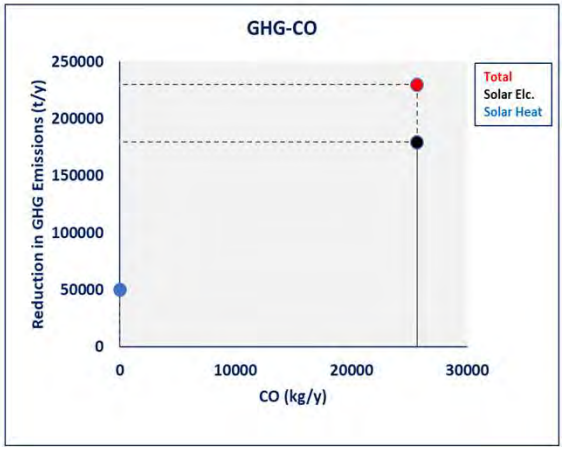
Solar Energy Project in Ulaanbaatar

Environmental Co-benefits from the combined scenario

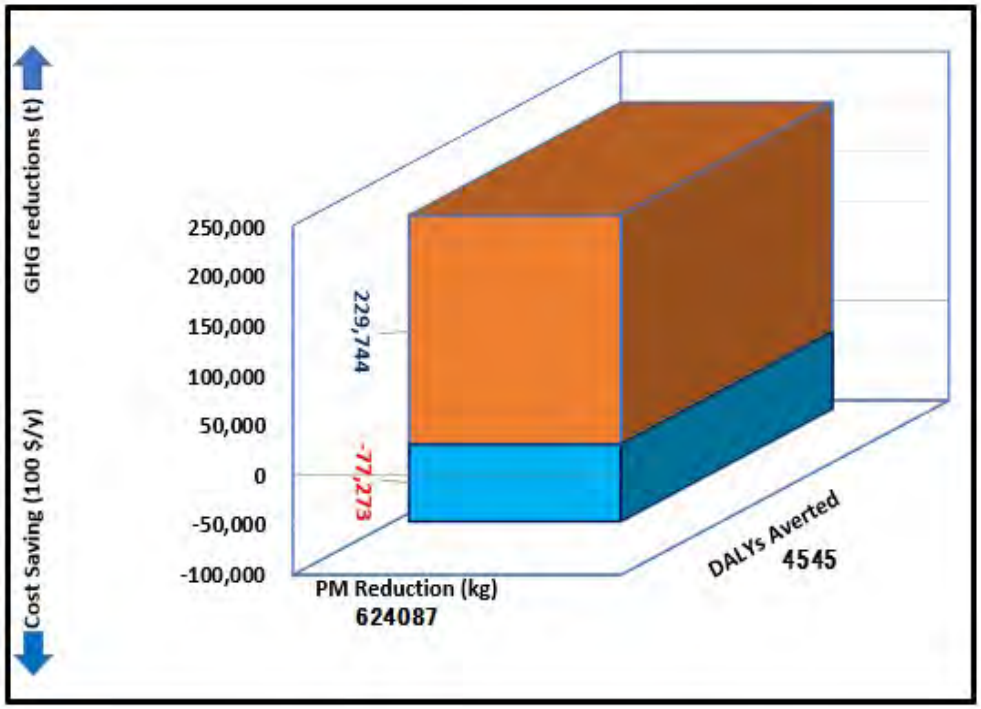








Multiple benefits from the combined scenario



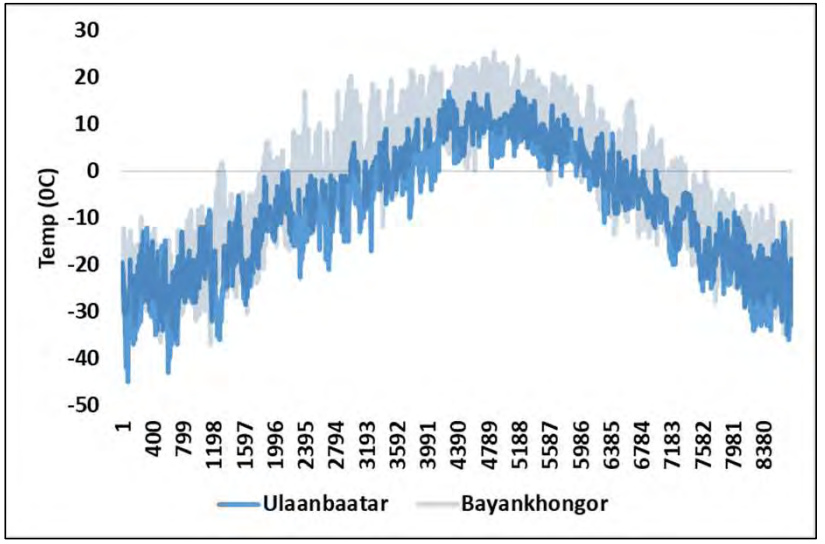
Reduction in GHG emissions (1000 t)	229.7
Reduction in PM emission (t)	624.1
Averted DALYs	4545
Savings (M$)	7.727
Reduction in unemployment rate (%)	0.1
Energy security in terms of fuel-saving (t/y)	117

Solar Energy Project in Ulaanbaatar

100 Solar Water Heaters (Region-Wise Assessment)

	Ulaanbaatar	Arkhangai	Bayankhongor	Bayan-Olgii	Bulgan	Uvs
Heat (GJ)	1589.6	1445.6	1681.8	1520.5	1435.6	1421.4
GHG (t/y)	307	279	324	293	277	274
PM2.5 (t/y)	3.6	3.4	3.8	3.5	3.3	3.2
DALYs	16	14	17	15	14	14
Savings (100 $/y)	270	246	286	258	244	241

Ambient temperature has a great impact on the PV cell's temperature



HOB Co-benefit Tool

Input
Output
Co-benefits
Database

Input
- ✓ Technology
- ✓ Weather
- ✓ Coal type

Heating Load Demand
Method 1

Net heat quantity supplied (kW)	260

Method 2 — Utility Demand

Hot water demand (kg/s)	
Inlet Temp. (℃)	
Outlet Temp. (℃)	

Method 3 — Building thermal load demand

Heat flux density (J/(h*m^3*℃))	
Volume of building (m^3)	
Outdoor temperature (℃)	
Indoor temperature (℃)	

Ambient Condition

Relative humidity (kg/kg drg air)	0.0204
Ambient temperature (℃)	10
Wind speed (m/s)	3.5

Boiler Specifications

Coal Feeder	Hand-feed
Rated Power (MW)	0.6
Surface temperature (℃)	60
Lateral surface area (m2)	18

Fuel
Type of coal
Ultimate Analysis (%)

Carbon	63.3
Hydrogen	4.5
Sulphur	1.1
Nitrogen	1.1
Oxygen	19
Ash	11.1
Moisture	33.3
Low calorific value (kJ/kg)	14687.328
Gross calorific value (kJ/kg)	16491

Exhaust Gas Analysis
Method 1

Excess air %	200
Exhaust gas temperature(℃)	190

Method 2 — Component analysis

CO2 (%)	
O2 (%)	
CO (%)	
Exhaust gas temperature(℃)	

Plant Factor

Hours per year	5000

Scenario Definition

Coal Storage

Storage period	○	
Number of Days	Default	0
Number of Days	New	

Moisture content of coal

Moisture content (%)	Default	33.3
Moisture content (%)	New	28.3

Cyclone

Type of cyclone	High efficiency
Removal efficiency (%)	90

Air Preheater

Inlet Air Temp. (0C)	40

Coal Feeder

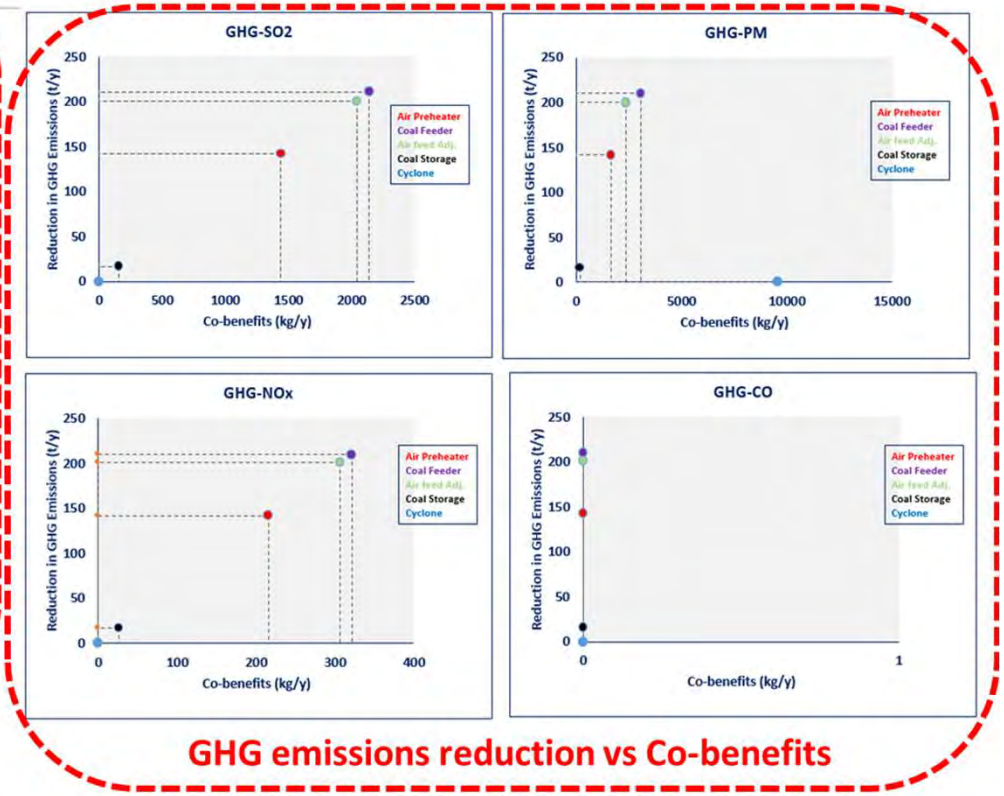
Type of Feeder	Vibrating Stoker

Air Feed Adjustment

Excess Air (%)	40
Electricity consumption (W)	135

RUN

Scenario Definition
- ✓ Coal Feeder
- ✓ Air Preheater
- ✓ Cyclone dust removal
- ✓ Air Feed Adjustment
- ✓ Moisture Control



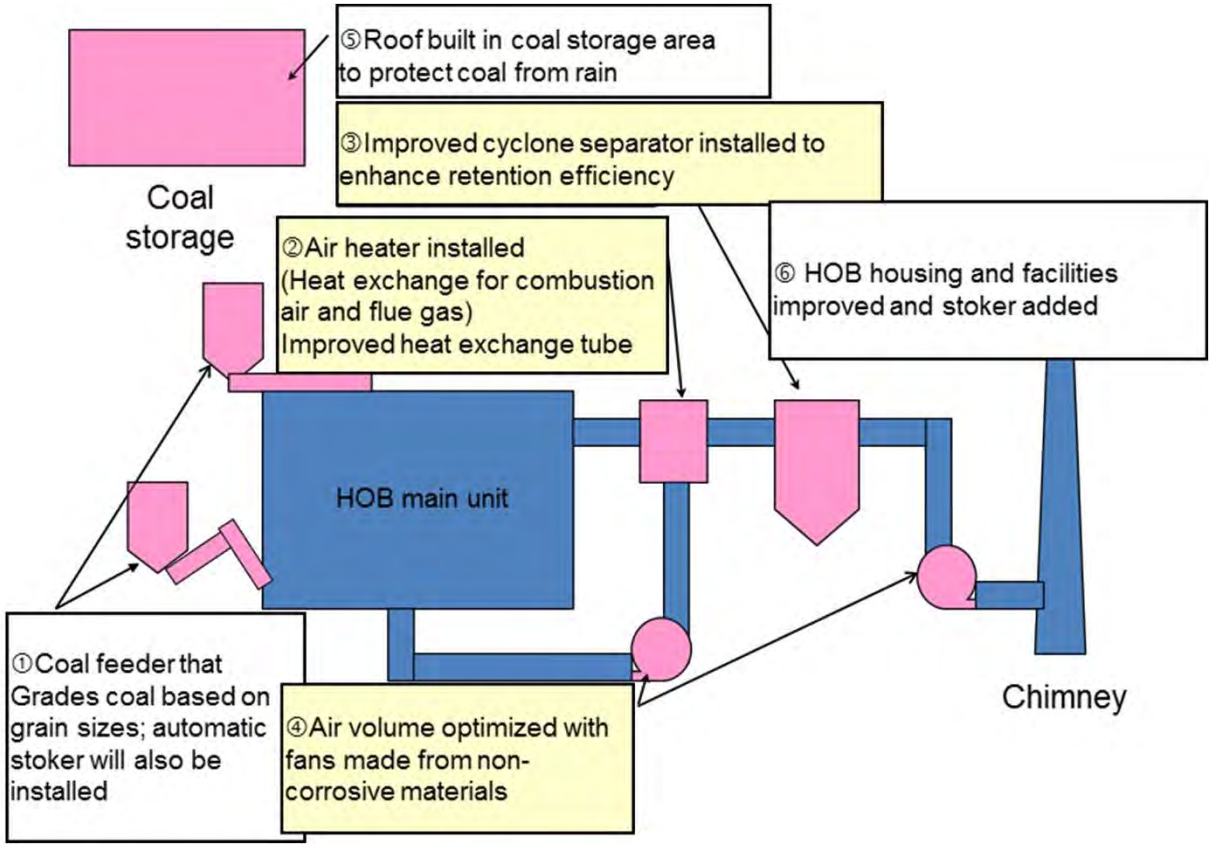
GHG emissions reduction vs Co-benefits

HOB project in Ulaanbaatar

Air pollution in Ulaanbaatar's ger areas

Credit: UBDHC, Erbar Agarjav

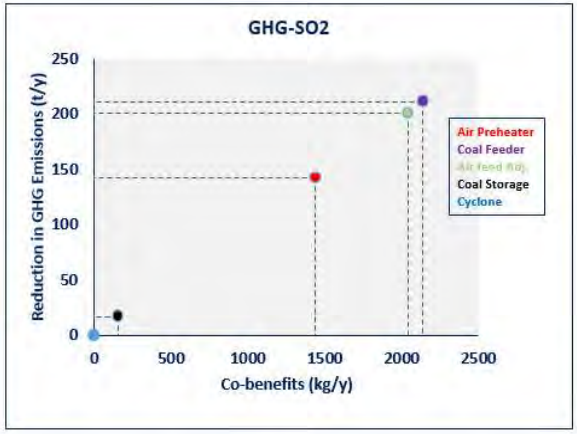
Low efficient stoves and Heat ONLY Boilers (HOB)

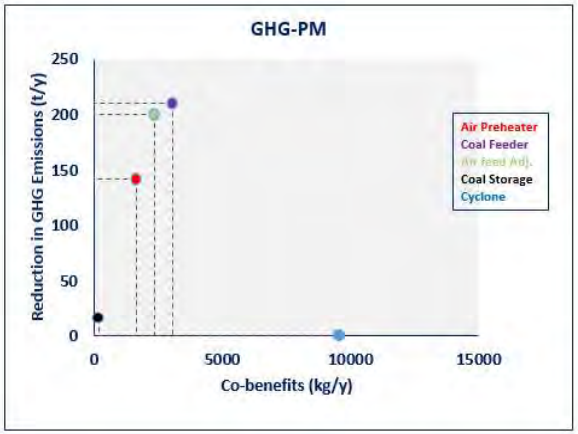


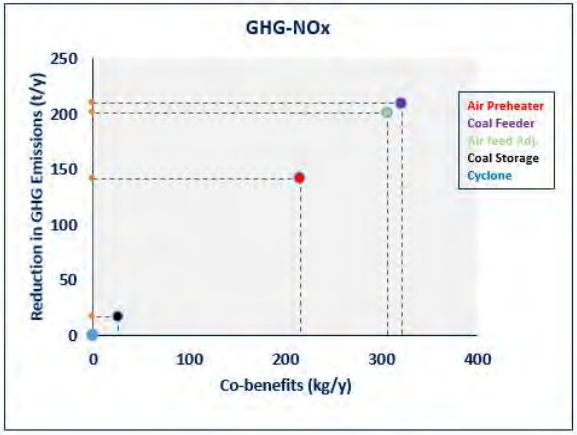
In alignment with the Japan-Mongolia partnership to promote the JCM for low-carbon development

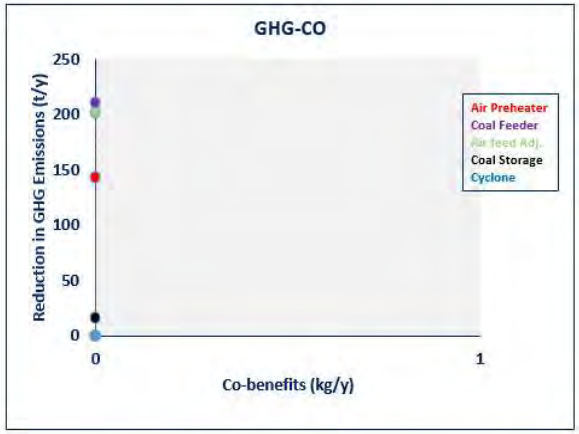
HOB Project in Ulaanbaatar

Environmental Co-benefits from the combined scenario

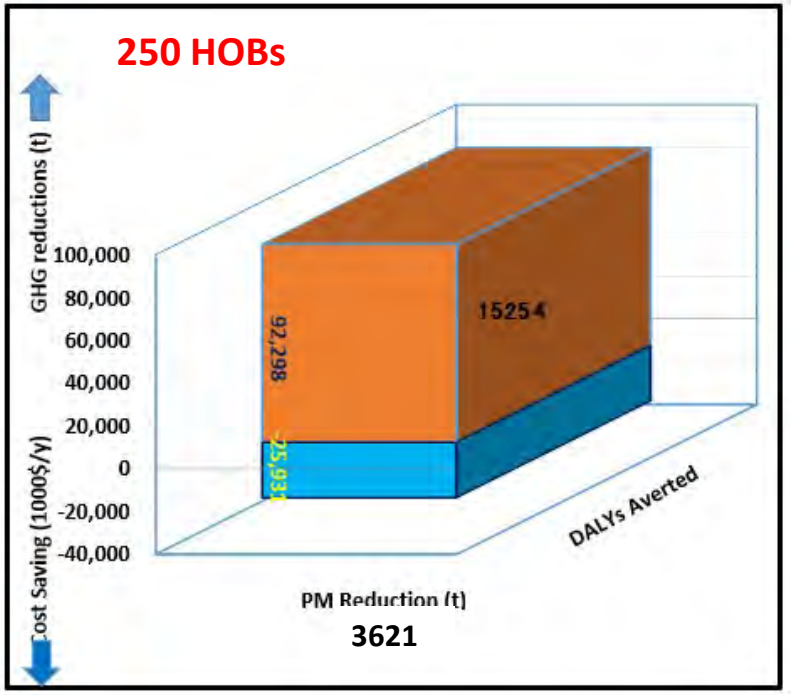








Multiple benefits from the combined scenario



Co-benefits	
Reduction in GHG emissions (t)	92,298
Reduction in PM emission (t)	3,621
Averted DALYs	16,000
Savings (M$)	26
Reduction in unemployment rate (%)	0.32
Energy Security in terms of fuel-saving (t/y)	200

Wastewater Co-benefits Assessment Tool

Tool Menu

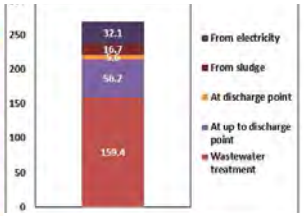
- Technology Selection
- Anaerobic
- Aerated Activated Sludge
- Swimbed
- UASB
- UASB+Swimbed
- Assessment
- Comparative Analysis
- Environmental Co-Benefit
- Health & Economic Co-Benefits
- Database
- References
- Calculation Method

Input:
Technologies
Wastewater

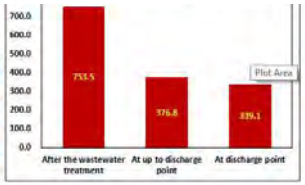
Anaerobic lagoon

Input	Unit	Value
Amount of the Wastewater	m3/d	35,965.0
COD Concentration in Wastewater	g/m3	1,507.0
Total Nitrogen in Wastewater	g/m3	120.6
COD removal efficiency at first step	%	50.0
COD degradation rate at up to discharge poin	%	50.0
COD degradation rate at discharge point	%	10.0
Maximum methane formation potential	kgCH4/kgCOD	0.2
Methane emission/kg generated sludge	kgCH4/kg Sludge	0.2
Amount of generated sludge	kg/d	5,306.0
Electricity Use	kWh/d	42,561.0

GHG Emissions



COD Concentration



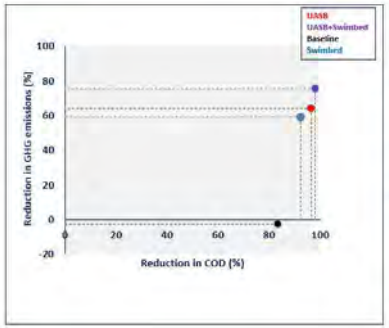
Scenario Analysis

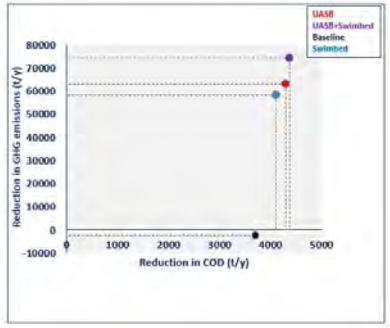
Output	Unit	Value
COD concentration at the different stages		
After the wastewater treatment	g/m3	753.5
At up to discharge point	g/m3	376.8
At discharge point	g/m3	339.1
GHG emissions at the different stages		
Wastewater treatment	kg CO2e/d	159,417.0
At up to discharge point	kg CO2e/d	56,169.4
At discharge point	kg CO2e/d	5,616.9
From sludge	kg CO2e/d	16,713.9
From electricity	kg CO2e/d	52,091.0
Total GHG emission, including N2O	kg CO2e/d	270,008.3

	Baseline	Swimbed	UASB	UASB + Swimed
GHG Emissions Reduction (%)*	-2.8	59.2	63.9	75.2
COD Removal (%)	83.2	92.3	96.6	98.1
GHG Emissions Reduction (kt/y)	-2724.9	58353.6	62938.7	74097.4
COD Removal (t/y)	3704.7	4106.9	4301.8	4365.1

* Including N2O

Environmental Co-benefits



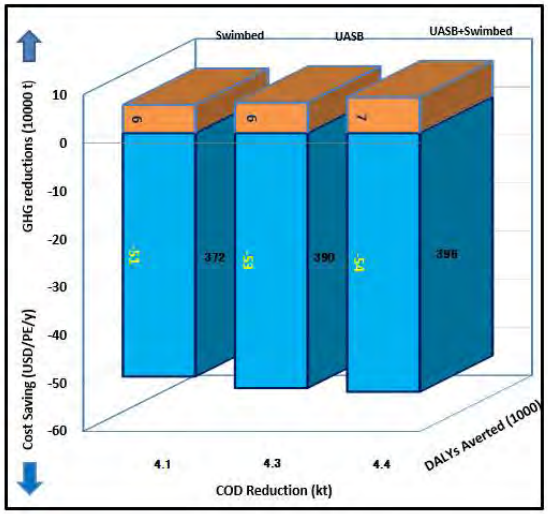


Health and Economic Co-benefits

Wastewater Balance	Influent COD (g/m3)	Influent PE*	Effluent COD (g/m3)	Effluent PE	Share in total wastewater treatment (%)
Anaerobic	1,507	802,952	339	401,476	11.9%
Aerated Activated Sludge	1,507	802,952	57	134,652	19.8%
Swimbed	1,507	802,952	26	62,099	22.0%
UASB	1,507	802,952	11	26,930	23.0%
UASB+Swimbed	1,507	802,952	7	15,525	23.3%
Total		4,014,760		640,683	100.0%

* Population Equivalent

Region	West Kalimantan
Health Burden	
Population Attributable Risk Fraction (PAF) (%)	72.03
Total burden of diarrhoeal disease (DALYs/y)	53,664
Burden of diarrhoeal diseases related to Wastewater (DA	38,654
Health & Economic Co-Benefits	
DALYs Averted	
Swimbed	372
UASB	390
UASB+Swimbed	396
Health Care Cost Savings ($/PE/y)	
Swimbed	50.6
UASB	53.0
UASB+Swimbed	53.8
Unemployment Rate Reduction (%)	
Swimbed	0.7583
UASB	0.7943
UASB+Swimbed	0.8063



Output:
DALYs averted
Economic benefits

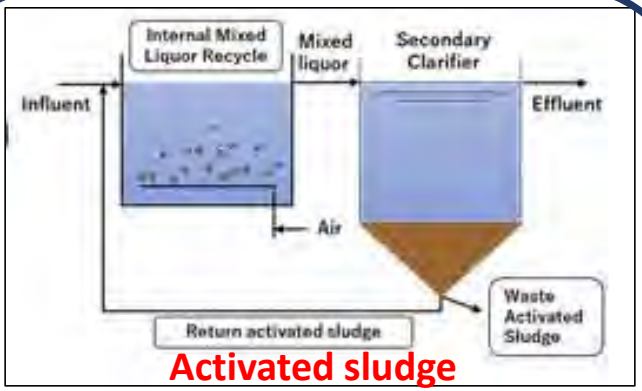
Wastewater Co-benefits project in Indonesia

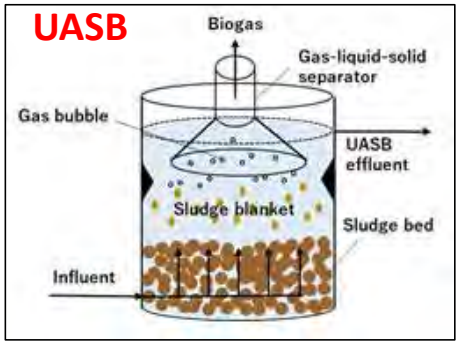
Reference Scenario (BAU): Anaerobic lagoon.

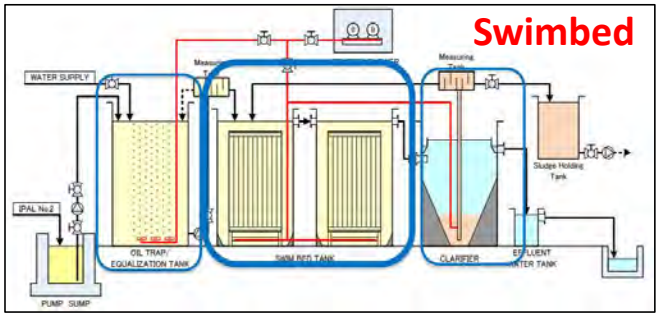
Source: Soedjono, 2011

Intervention Scenarios

- **Scenario I (Baseline):** A pre-stage aerobic lagoon treatment followed by activated sludge method
- **Scenario II:** Swimbed
- **Scenario III (UASB):** Up-flow Anaerobic Sludge Blanket (UASB)
- **Scenario IV:** Combined UASB and Swimbed

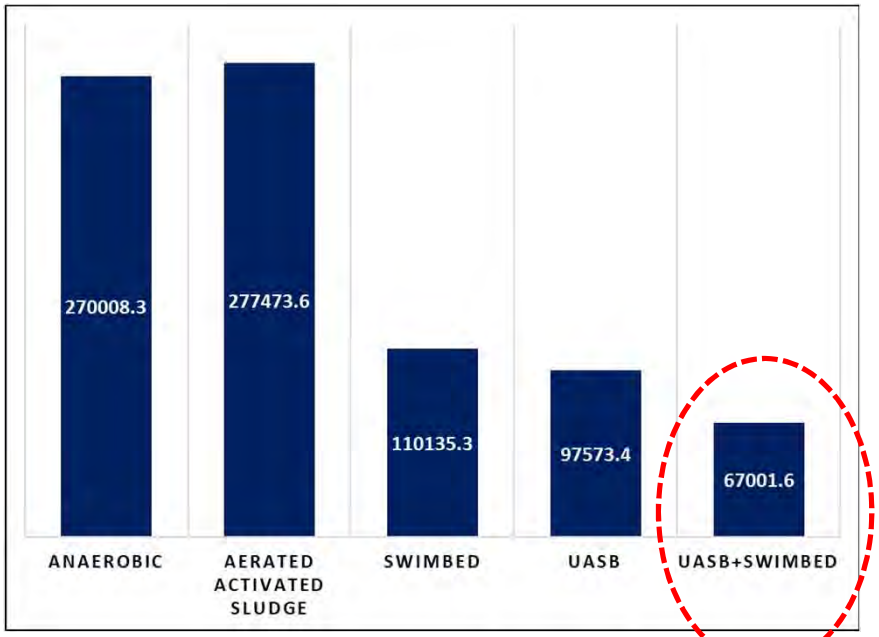




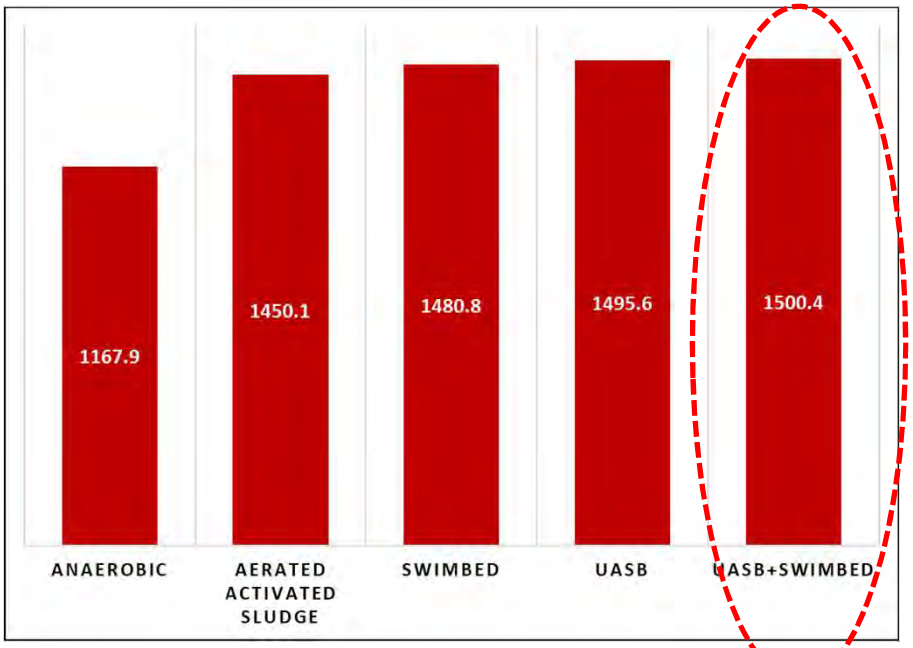


Wastewater Co-benefits project in Indonesia

Comparative analysis for a given 35,965 m^3/d wastewater flow rate in Indonesia



GHG emission reduction (kg CO_{2eq}/day)



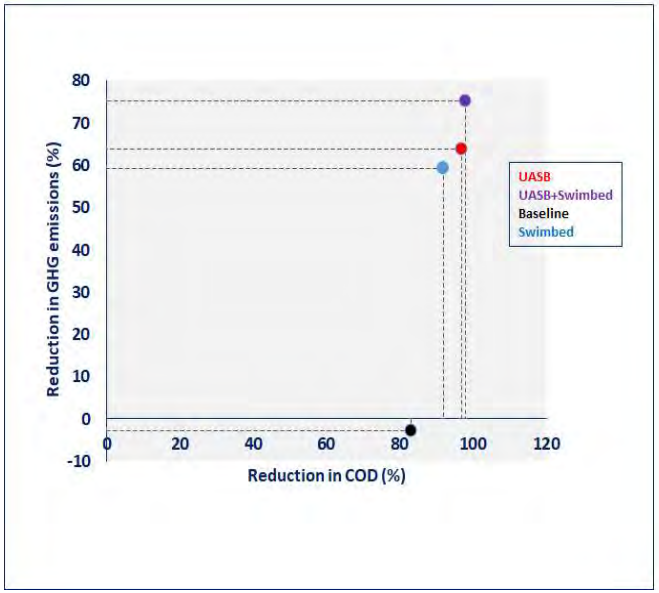
COD removal (g/m^3)

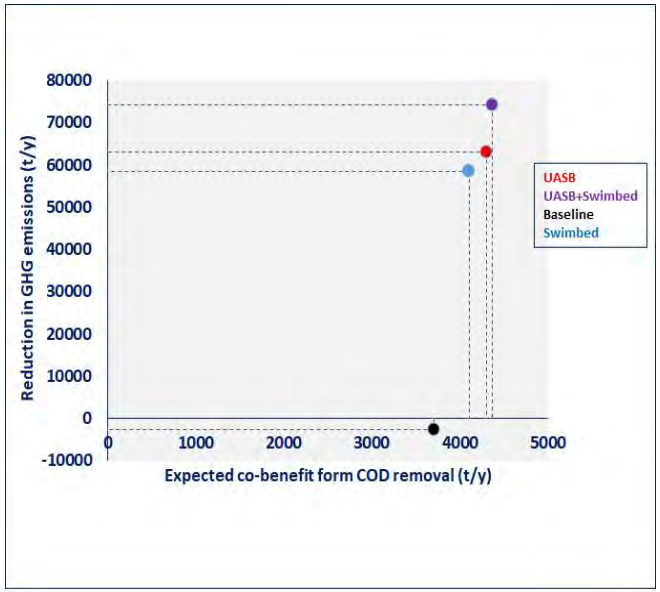
Impacts related to water pollution gradually decline as a consequence of the implementation of high-performing technologies such as **UASB+Swimbed**

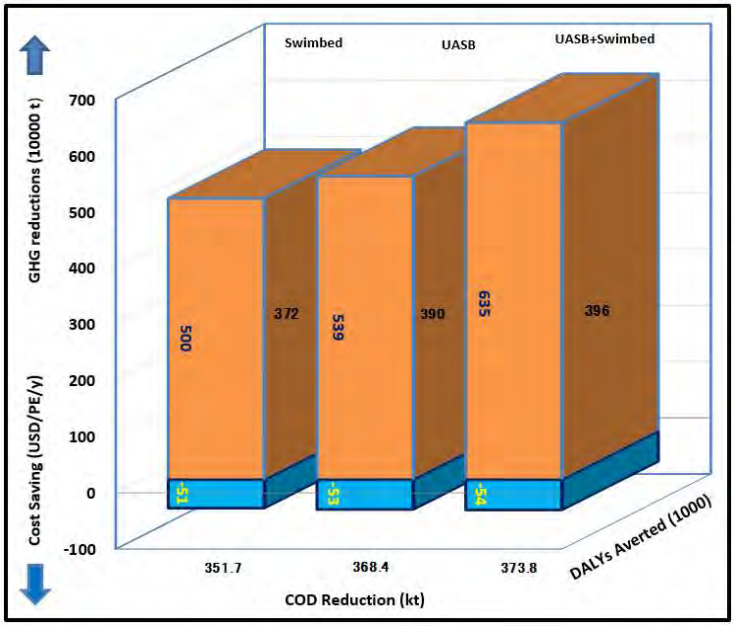
Wastewater Co-benefits project in Indonesia

Multiple benefits from the treatment of 3.4 Mt/day wastewater in Indonesia fish processing industry

Scenario	Reduction in GHG emissions (Mt/y)	Reduction in COD (kt/y)	Averted DALYs (1000)	Savings ($/PE/Y)	Reduction in the Unemployment rate (%)	Energy Security (GWh/y)
Swimbed	5.0	352	372	50.6	0.573	32.1
UASB	5.4	370	390	53.0	0.571	43.6
UASB+Swimbed	6.3	374	396	53.8	0.580	48.8



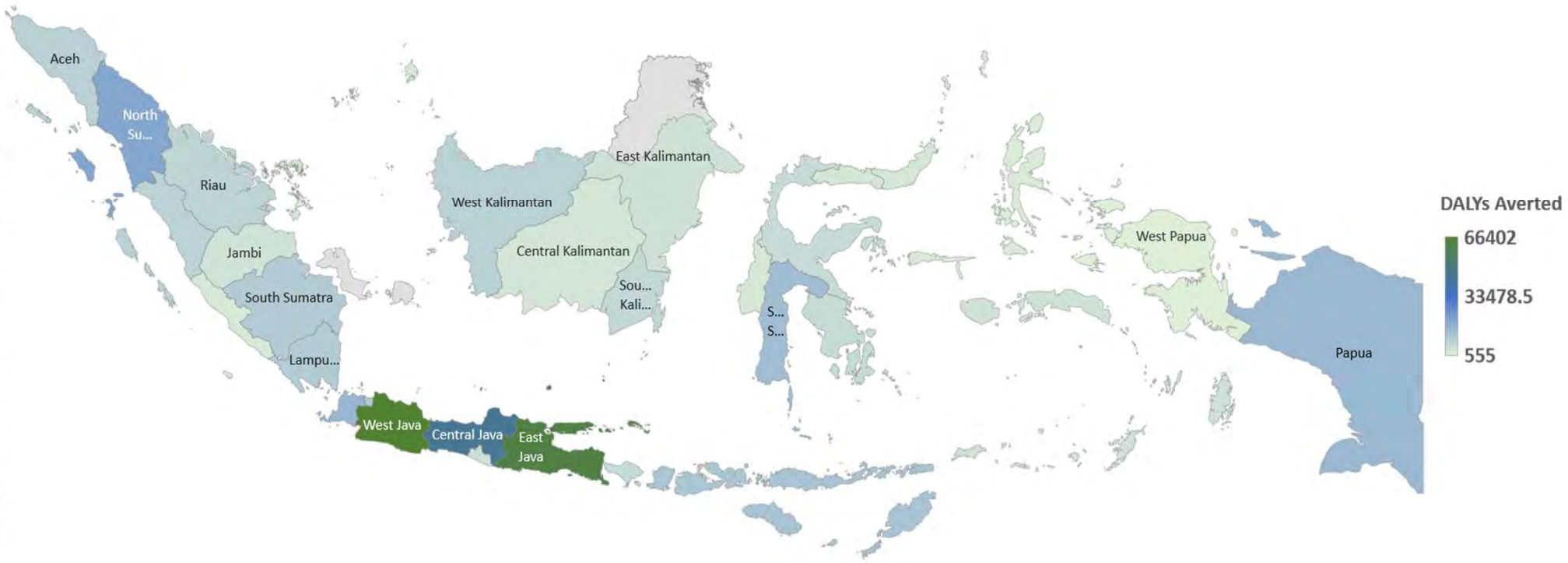




Wastewater Co-benefits project in Indonesia

Region
Aceh
Bali
Bangka-Belitung Island
Banten
Bengkulu
Central Java
Central Kalimantan
Central Sulawesi
East Java
East Kalimantan
East Nusa Tenggara
Gorontalo
Jakarta
Jambi
Lampung
Maluku
North Kalimantan
North Maluku
North Sulawesi
North Sumatra
Papua
Riau
Riau Islands
South Kalimantan
South Sulawesi
South Sumatra
Southeast Sulawesi
West Java
West Kalimantan
West Nusa Tenggara
West Papua
West Sulawesi
West Sumatra
Yogyakarta

Region-wise Health Impact Assessment of Advanced Wasterwater Techology in Indonesia



Thank you very much for your attention

Hooman Farzaneh
Associate Professor
Interdisciplinary Graduate School of Engineering Sciences
Department of Energy and Environmental Engineering

farzaneh.hooman.961@m.kyushu-u.ac.jp