Impact of Management Alternatives on GHG Emissions from the Waste Sector

Amani Maalouf, Mutasem El-Fadel

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Department of Civil and Environmental Engineering
Maroun Semaan Faculty of Engineering and

American University of Beirut
الجامعة الأمريكية في بيروت

National Council for Scientific Research

Concerns about the anthropogenic contribution to **global warming**

Solid waste management carbon footprint

Dependent on:
- Waste treatment method or process
- Type of waste, its physical composition
- Emission accounting method

Global Warming Impact

The waste sector contributes to greenhouse effect

	1
	21-34
	290 -**310**

Total MTCO₂E = (tonnes of CO_2 x1) +(tonnes of CH_4 x 21)+ (tonnes of N_2O x 310)

Worldwide

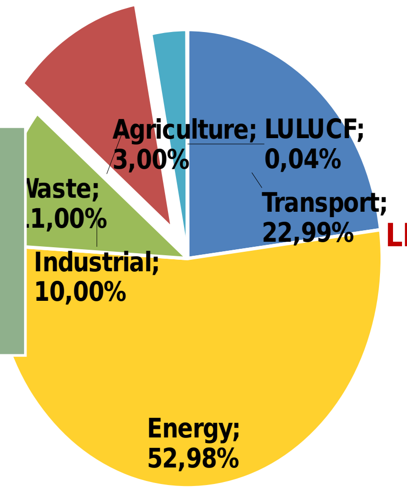
Small contributor to the overall GHG emissions (~3%)

Developing Economies

Major contributor to reduce GHG emissions (up to 15%)

Lebanon

- **11%** of national GHG emissions (> industrial sector)



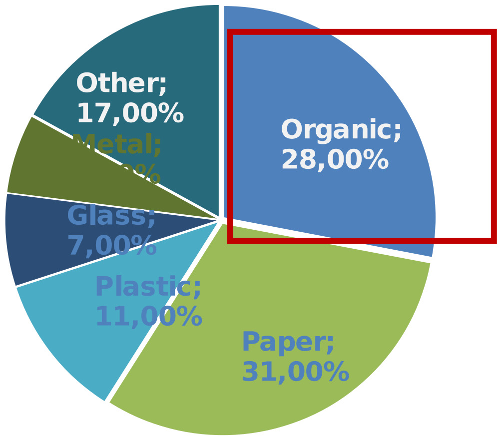
LEBANON GHG EMISSIONS BY SOURCE FOR 2012

(MoE/UNDP/GEF, 2015; AR5 of the IPCC, 2014)

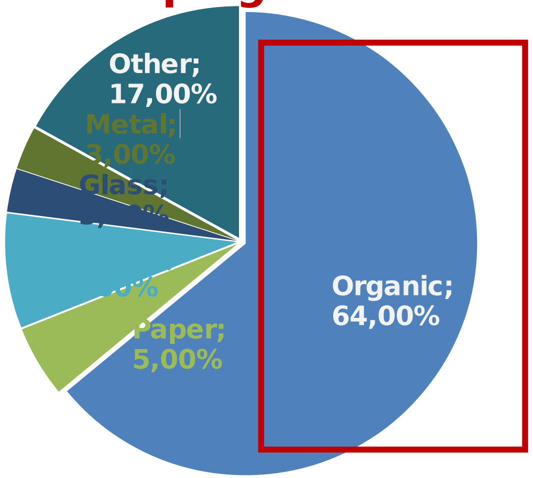
Developed vs. Developing Economies

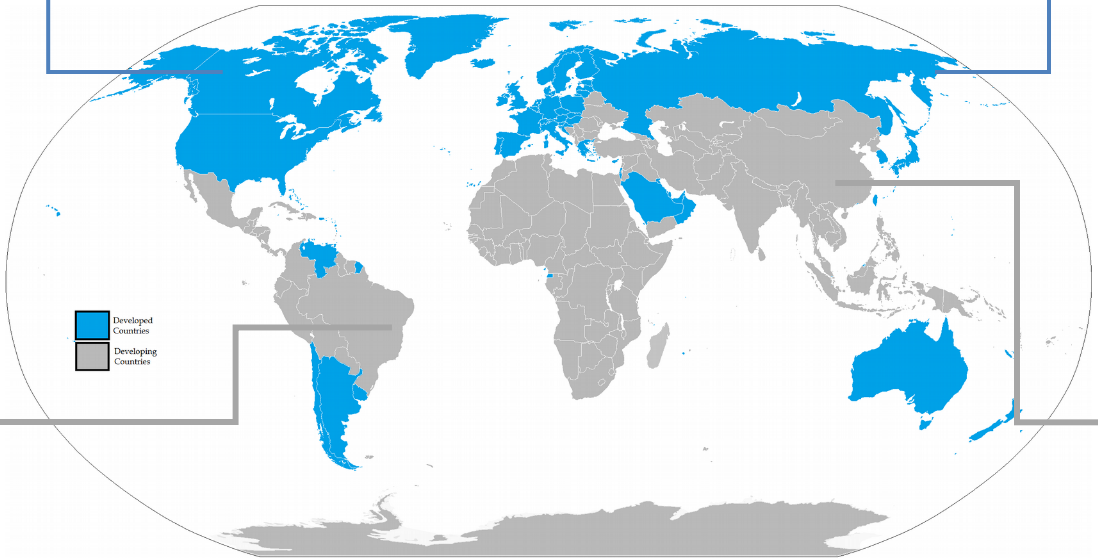
Waste Composition

Developed ECONOMIES



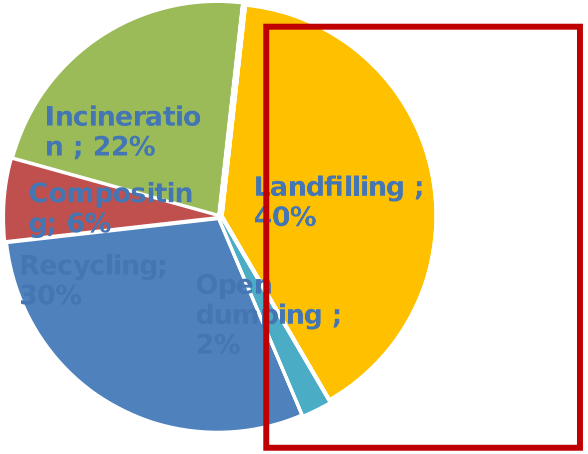
Developing ECONOMIES



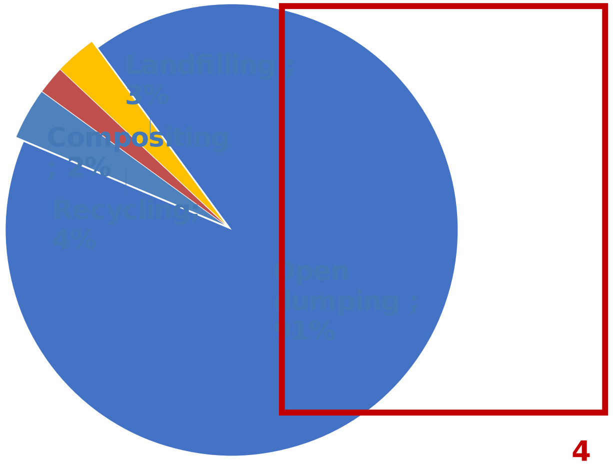


Waste Management Processes

Developed Economies

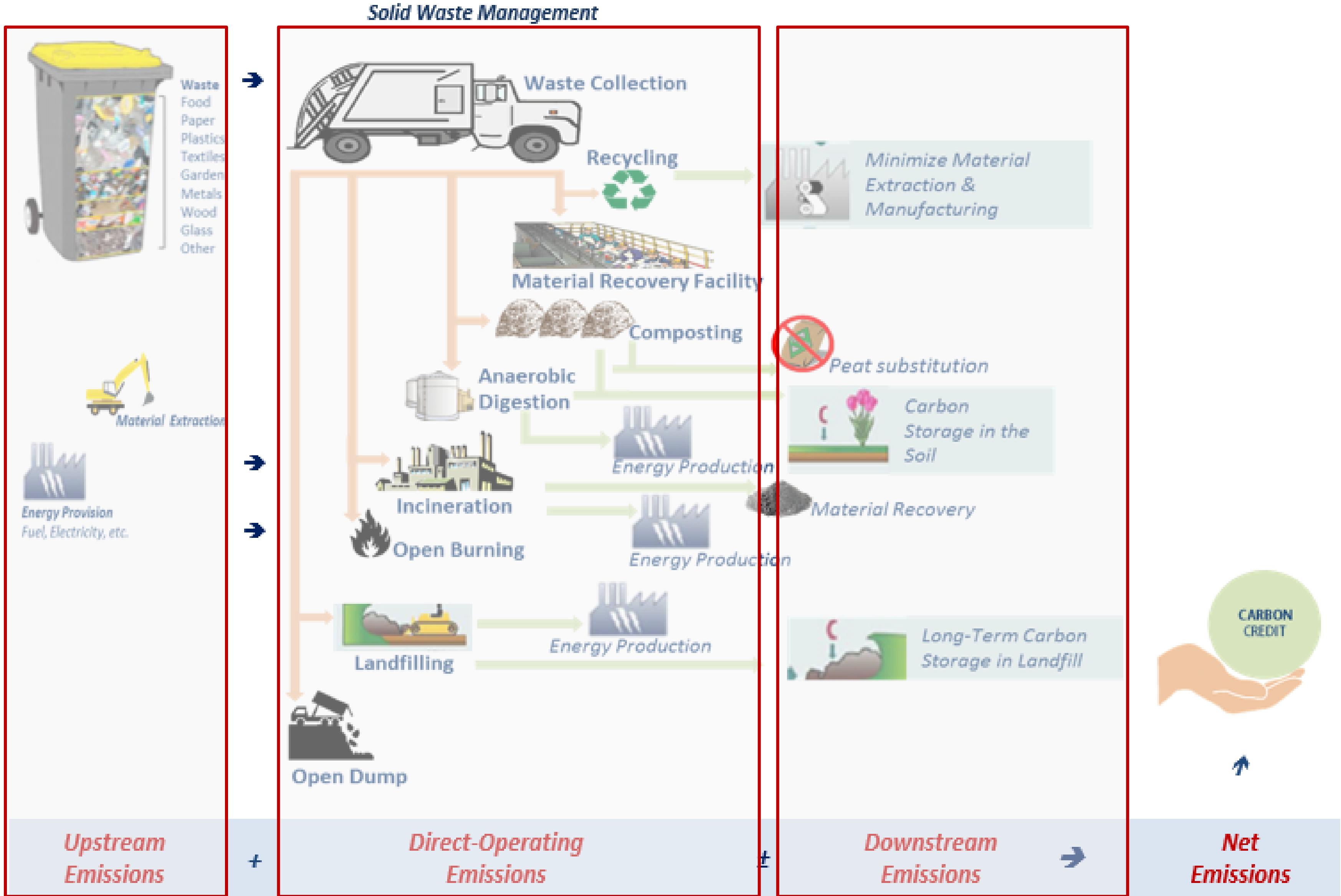


Developing Economies



(World Bank, 2018)

Life Cycle Assessment



Upstream Emissions

- Outside the waste management facility

Direct Emissions

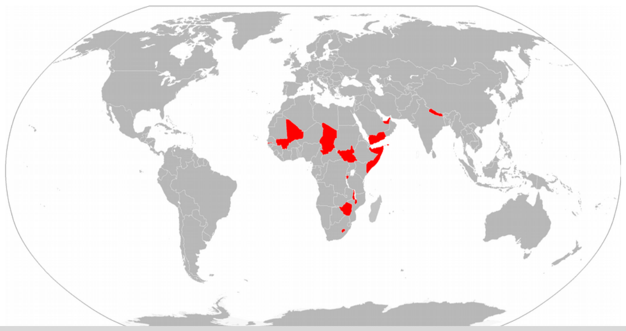
- System operation at waste management facility

Downstream Emissions

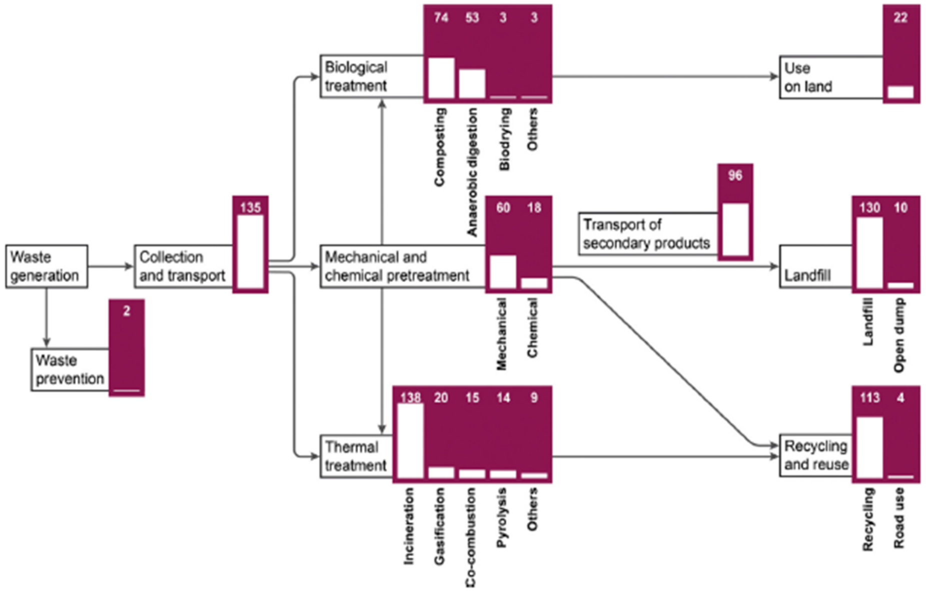
- Avoided emissions from material and energy recovery

Estimating GHG emissions from waste management processes

Many studies have estimated GHG emissions from various waste management processes in the context of **developed economies** whether by applying the life cycle assessment (LCA) modeling or the 2006 IPCC Guidelines at a regional scale



Need for more efforts aiming at quantifying and assessing emissions from the waste sector in **developing economies**



GAP

Limited application in developing economies

1- Study area

2- Scenario definition

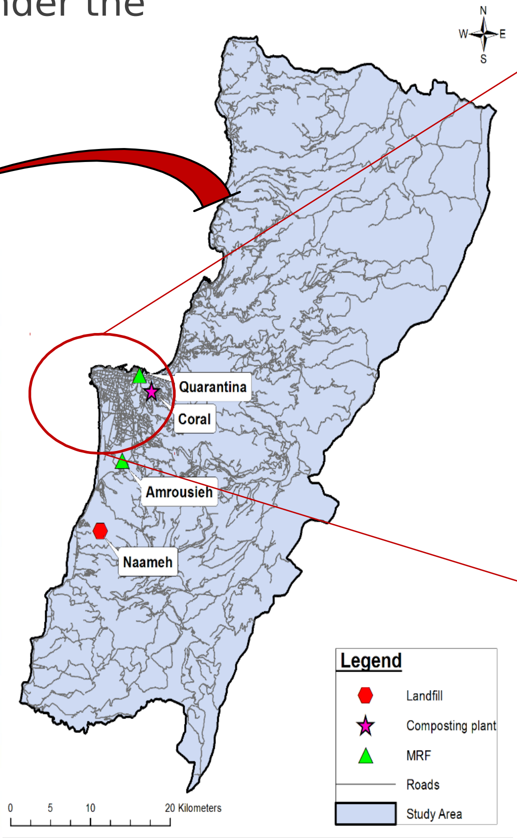
The GHG inventory of the integrated waste management system following a life cycle approach : A case study for a developing economy

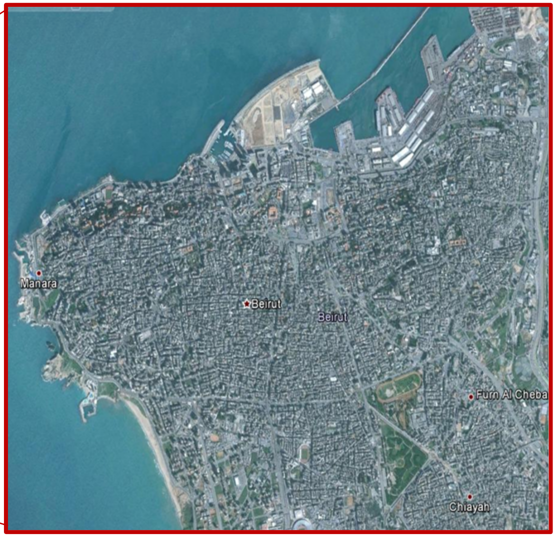
- **Objective:** Identify economically viable waste management alternatives with minimal environmental externalities including best strategies for GHG emission reduction
- **Ultimate objective**: Assess emissions reporting targets under the UNFCCC commitments or guide decision making and reduction targets using carbon credit to meet NDCs under the Paris Agreement

BEIRUT & SURROUNDING

Located on the eastern shore of the Mediterranean Sea

LEBANON



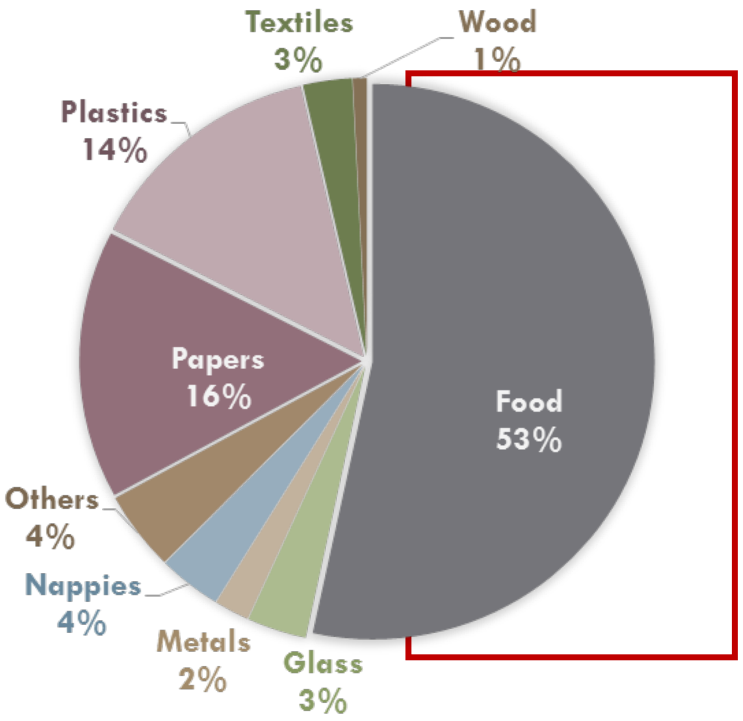


World Bank: upper-middle-income economies
~ 1,986 Km²
~ 297 municipalities
~ 2 Million inhabitants
2,800-3,000 Tons of MSW per day

Waste Composition

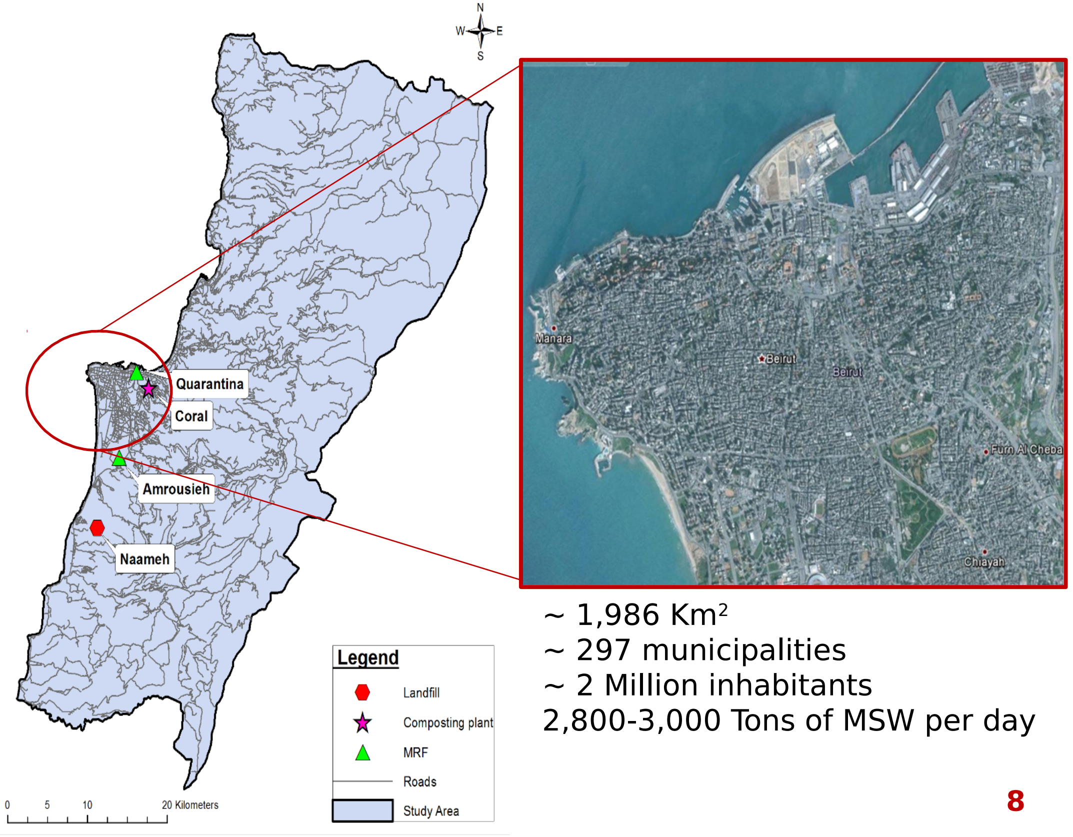
1- Study area

2- Scenario definition



- MSW data collected from year 1994 to 2013 in **Beirut & surroundings**
- **2013** selected as the inventory year

BEIRUT & SURROUNDING



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~ 297 municipalities
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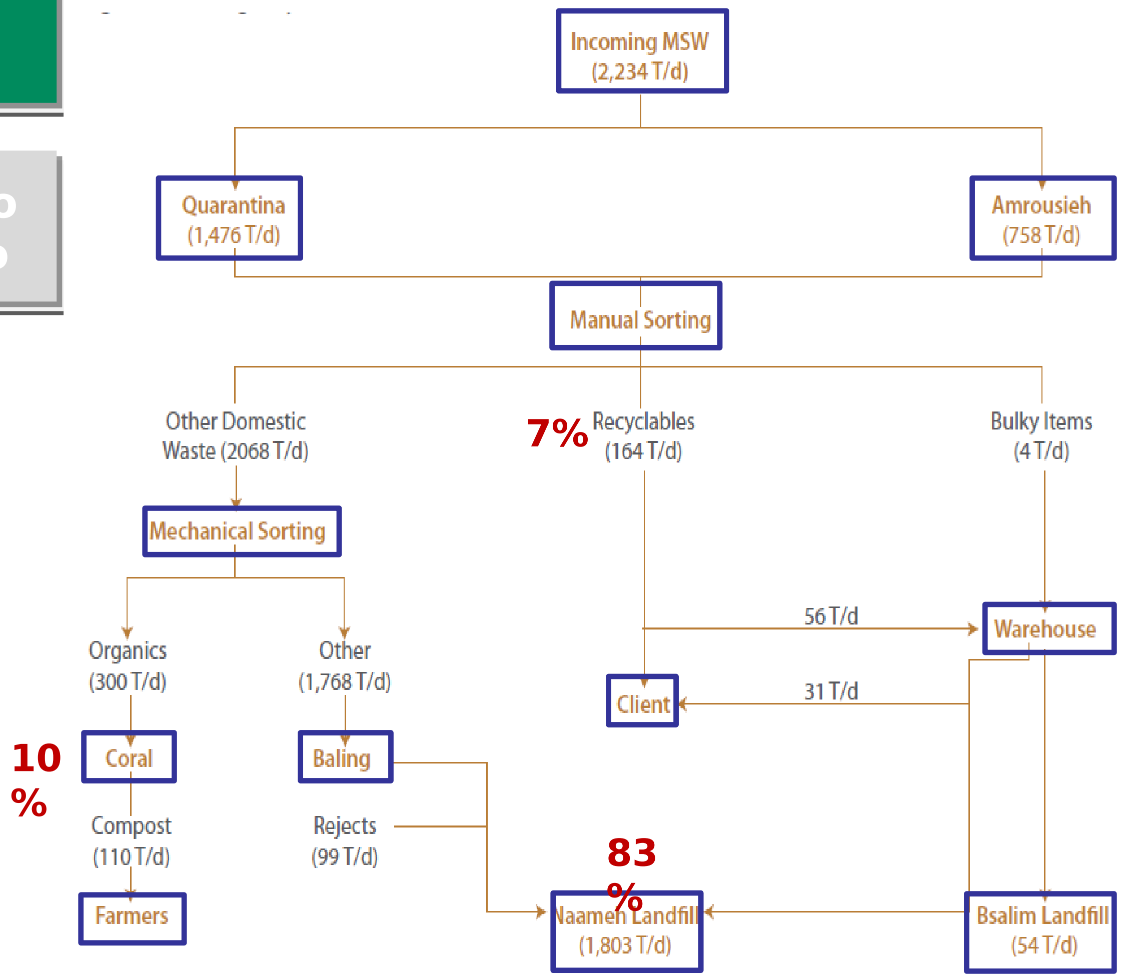
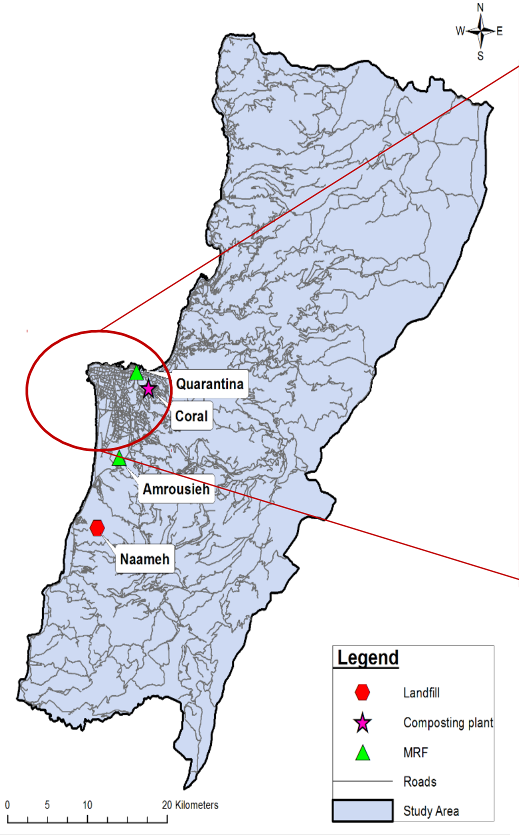
The current MSW management scenario

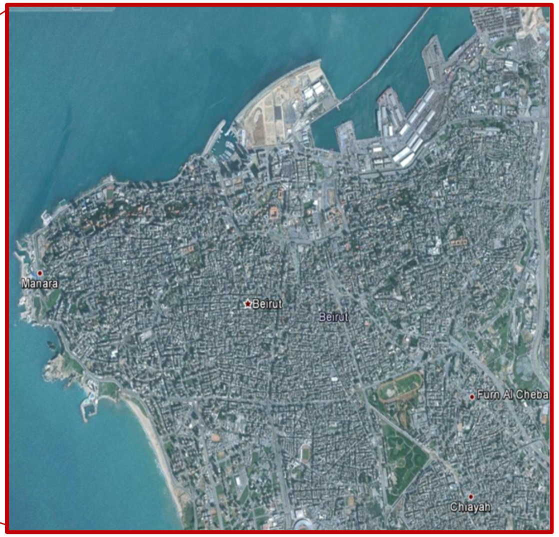
1- Study area

2- Scenario definition



BEIRUT & SURROUNDING





~ 1,986 Km^2
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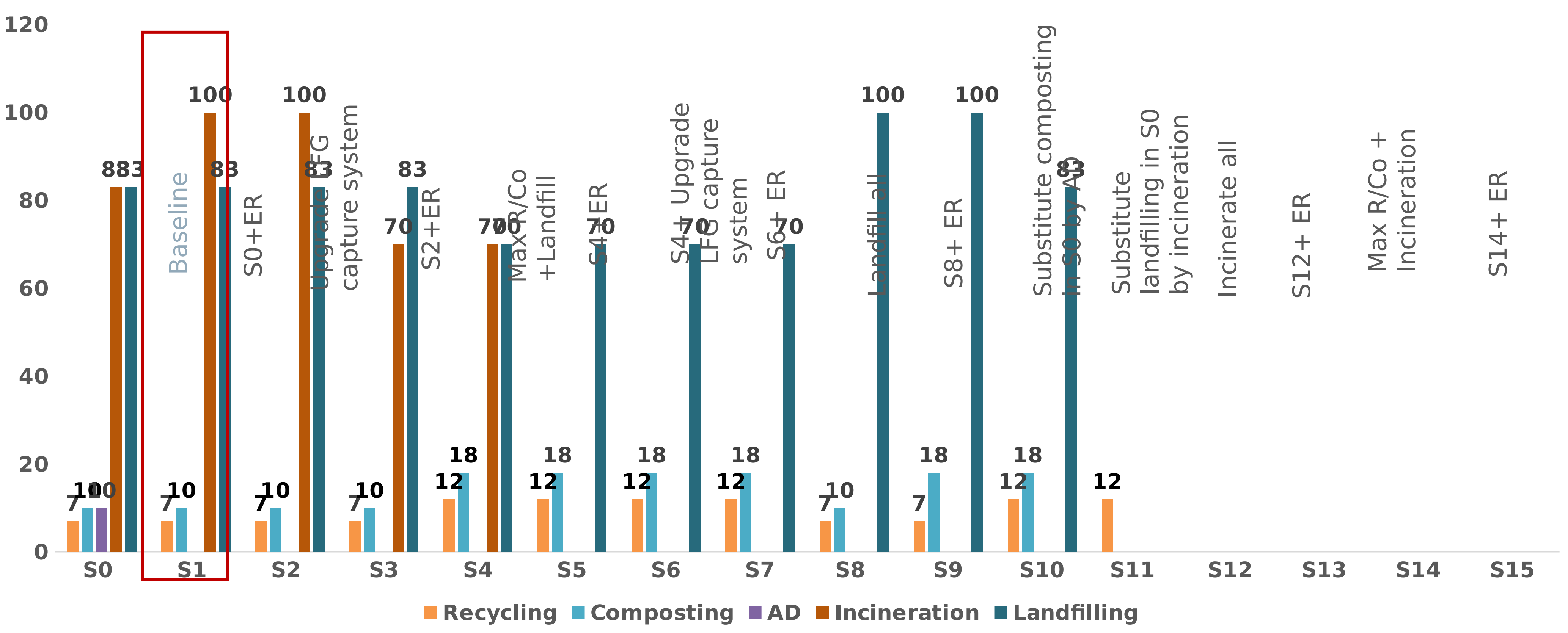
1- Study area

2- Scenario definition

Alternative scenarios tested for policy and economic analysis



Simulation Model

A. Maalouf, M. El-Fadel   Resources, Conservation & Recycling 133 (2018) 263–277

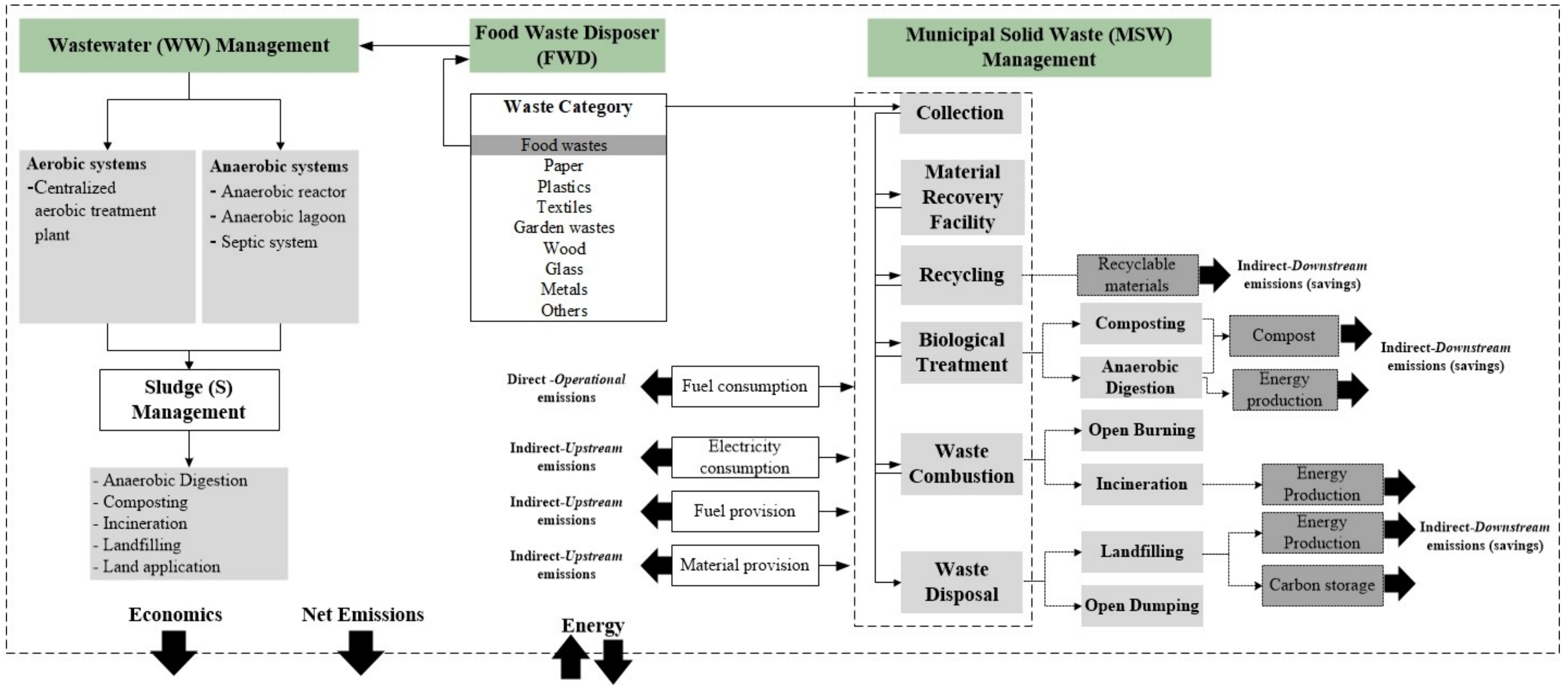


Fig. 1. Model framework.

Estimates

- **Direct and indirect GHG emissions from various processes**
- **Economic and environmental externalities, as well as energy produced or consumed across various stages**
- **Potential carbon credit**

(Maalouf and El-Fadel,

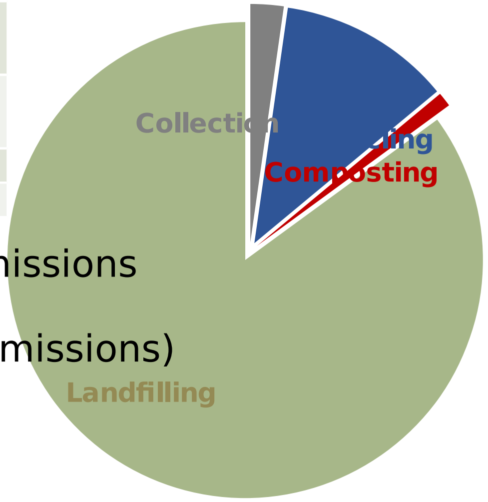
Emissions Under Baseline Conditions

1- Baseline condition

2- Scenario analysis

Category	Collection	Recycling	Composting	Incineration	Landfilling
Waste (M Tons)	1.069	0.071	0.111	0	0.887
Overall Direct emissions	0.019		0.100	0	1.383
Waste degradation	-		0.090	0	1.326
Fuel consumption	0.019		0.010	0	0.057
Overall Indirect emissions	0.003		0.023	0	-0.188
Upstream emissions	0.003		0.023	0	0.014
Electricity consumption	-		0.022	0	0.006
Fuel provision	0.003		0.001	0	0.008
Downstream emissions	-		0	0	-0.202
Electricity production	-	-	-	0	0
Carbon storage	-	-	0	-	-0.202
Total GWF S0	0.022	-2.655	0.123	0	1.196

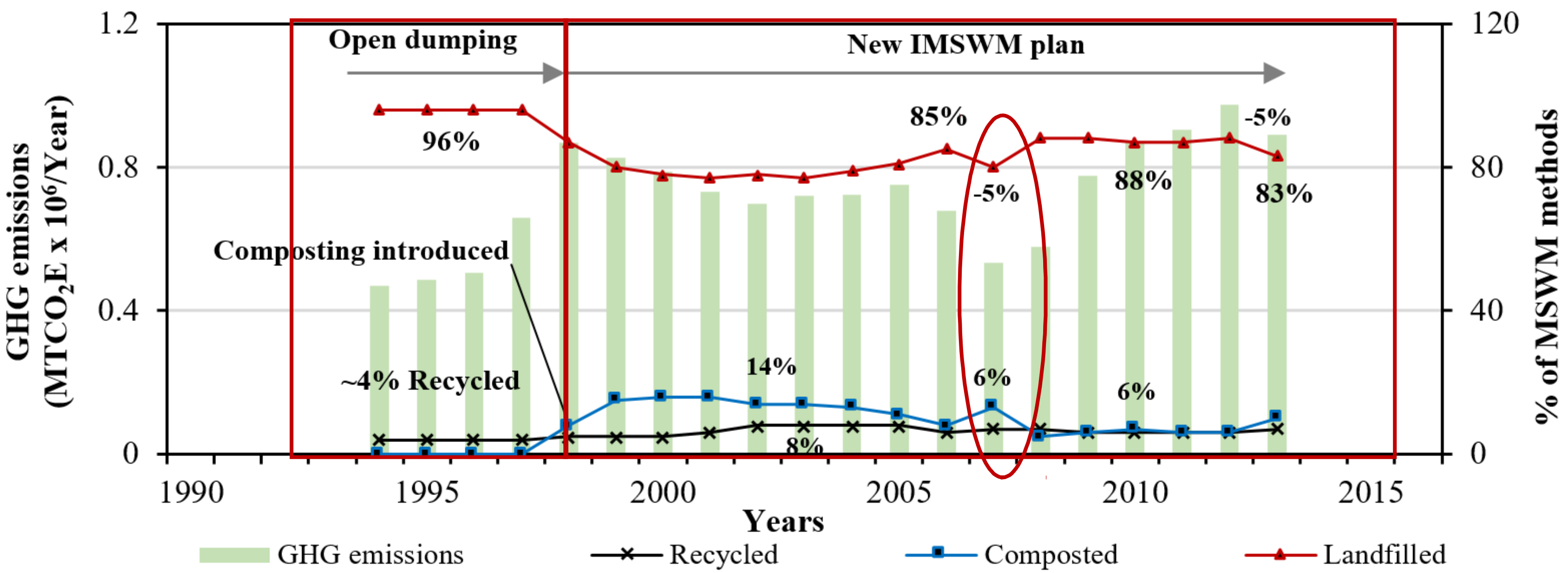
- **Direct emissions** constitute the **largest contributor (96%)** to total emissions
- **Indirect emissions** were **less significant** (accounted for **4%** of total emissions)



Temporal variation of GHG emissions under baseline scenario from 1994 to 2013

1- Baseline condition

2- Scenario analysis

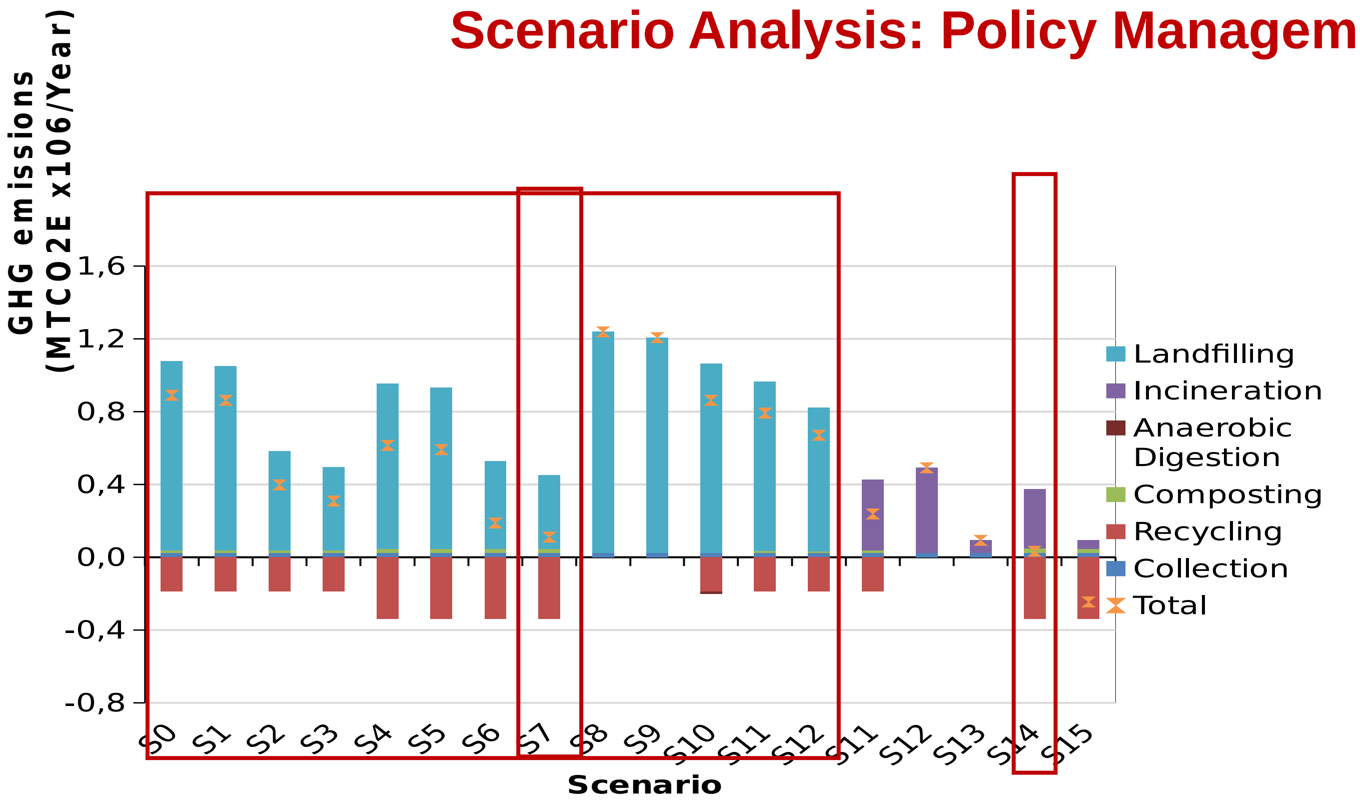


- **Prior to 1997**, a small fraction (~4%) of MSW was recovered for recycling and the majority of the waste (~96%) was disposed of at uncontrolled dumpsites
- **In 1997-2015,** a new integrated plan was adopted whereby the waste was diverted from dumpsites into a managed landfill
- Emissions remained stable **between 2002 and 2005** with improved performance on composting and recycling at 8% with a drop in 2006-2007

1- Baseline condition

2- Scenario analysis

Scenario Analysis: Policy Management



S0 **Existing baseline scenario**
S1 S0 + LFG energy recovery
S2 Upgrade LFG capture system
S3 S2 + LFG energy recovery
S4 Max recycling & composting + landfilling
S5 S4 + LFG energy recovery
S6 S4+ Upgrade LFG capture system
S7 S6+ LFG energy recovery
S8 Landfilling all waste
S9 S8 + LFG energy recovery
S10 Substitute composting in S0 by anaerobic digestion + energy recovery
S11 Substitute landfilling in S0 by incineration
S12 Incinerate all waste
S13 S12 + energy recovery
S14 Max recycling and composting + incineration
S15 S14 + energy recovery

- Scenarios with **landfilling (S0 to S12)** resulted in greater emissions in comparison with scenarios involving **incineration (S11 to S15)**
- **Maximizing waste recycling and composting** coupled with energy recovery from landfilling (S7) minimizes the overall emissions by 88% with respect to S0
- **Incineration (S14)** coupled with maximum recycling and composting, minimizes the overall emissions by 96% with respect to S0; with additional 32% emissions reduction from energy recovery (S15)

Scenario Analysis: Economic Implications

1- Baseline condition

2- Scenario analysis

Scenario	Description	Avoided emissions (%)	Cost variation (%)
S0	Existing baseline scenario	0	0
S1	S0 + LFG energy recovery	-3	-7
S2	Upgrade LFG capture system	-55	-7
S3	S2 + LFG energy recovery	-65	-19
S4	Max recycling & composting + landfilling	-31	-7
S5	S4 + LFG energy recovery	-34	-15
S6	S4+ Upgrade LFG capture system	-79	-16
S7	S6+ LFG energy recovery	-88	-26
S8	Landfilling all waste	39	16
S9	S8 + LFG energy recovery	36	4
S10	Substitute composting in S0 by anaerobic digestion + energy recovery	-3	10
S11	Substitute landfilling in S0 by incineration	-73	63
S12	Incinerate all waste	-45	89
S13	S12 + energy recovery	-90	39
S14	Max recycling and composting + incineration	-96	43
S15	S14 + energy recovery	-128	7

- **Maximizing waste recycling** and composting coupled with upgrading LFG collection for energy recovery from **landfilling** decreases the overall cost of MSW management most (-26% with carbon credit)
- Optimizing emissions reduction through **incineration (S14)** reduces emissions most (-96%) at the expense of an overall net cost increase by ~43% if carbon credit is considered

Major Conclusions

- Calculation of the **GHG inventory** in time series for the IWMS of the Greater Beirut area highlights the ability of this **tool** to inspire appropriate environmental policies aimed at reducing the climate change impacts of the waste sector
- The lower quantity of wastes treated in **landfills** and the greater quantity of LFG captured determined a reduction in total GHG emissions of the IWMS
- Optimizing **composting and recycling** coupled with upgrading LFG collected for energy recovery from **landfilling** reduced equivalent emissions by 88% at a corresponding savings 26% with carbon credit
- Optimizing **composting and recycling** coupled with **incineration** reduced equivalent emissions the most (96% savings) at a corresponding increased cost of 43 with carbon credit
- The results provide guidelines for policy and decision makers on the **economic viability** of investment in carbon credit to meet NDCs under the **Paris Agreement**

THANK YOU !!

Amani Maalouf, PhD

Postdoctoral Researcher
Environmental and Water Resources Engineering
American University of Beirut

Email: ahm22@mail.aub.edu