



Feasibility of Anaerobic Digestion as an Option for Biodegradable and Sewage Sludge Waste Management in the Kingdom of Bahrain

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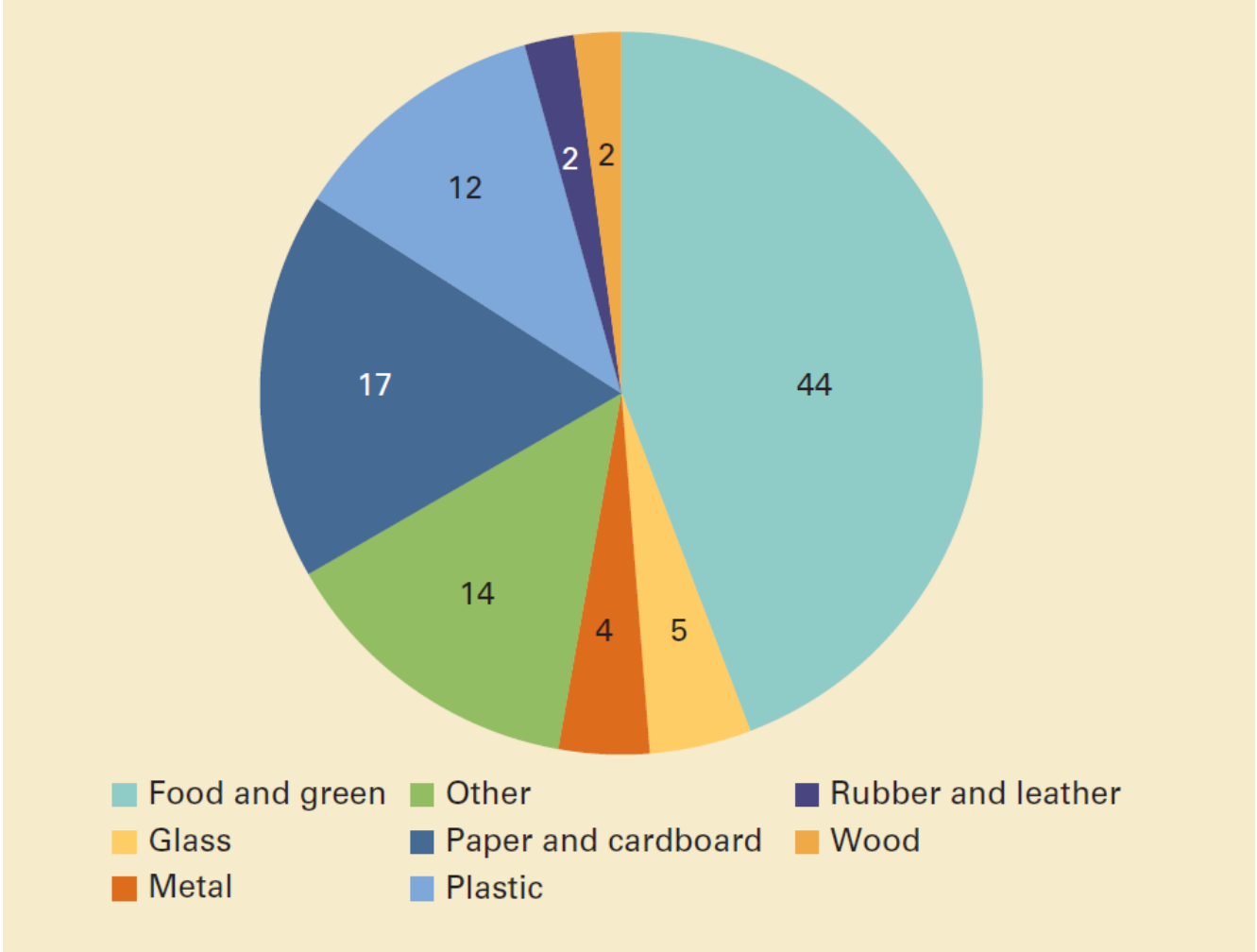
Kingdom of Bahrain

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Introduction

- Solid Waste Management (SWM) represents a main challenge to the developing countries.
- Dumping of biodegradable waste including sewage sludge resulted from wastewater treatment plants into the landfill results in methane emission, which is a greenhouse gas 25 times more potent than carbon dioxide.
- The study aims to explore the feasibility of Anaerobic Digestion (AD) technology to manage the biodegradable and sewage sludge waste in the Kingdom of Bahrain.
- AD leads to produces biogas, an important and promising renewable energy resource for the country.
- Cost-Benefit Analysis (CBA) used. The contribution in reduction of the landfill methane emission was estimated.

Global Waste Composition Percentages



1 NO POVERTY



2 ZERO HUNGER



3 GOOD HEALTH AND WELL-BEING



4 QUALITY EDUCATION



5 GENDER EQUALITY




6 CLEAN WATER AND SANITATION



7 AFFORDABLE AND CLEAN ENERGY



8 DECENT WORK AND ECONOMIC GROWTH



9 INDUSTRY, INNOVATION AND INFRASTRUCTURE



10 REDUCED INEQUALITIES



11 SUSTAINABLE CITIES AND COMMUNITIES



THE GLOBAL GOALS
For Sustainable Development

12 RESPONSIBLE CONSUMPTION AND PRODUCTION



13 CLIMATE ACTION



14 LIFE BELOW WATER



15 LIFE ON LAND

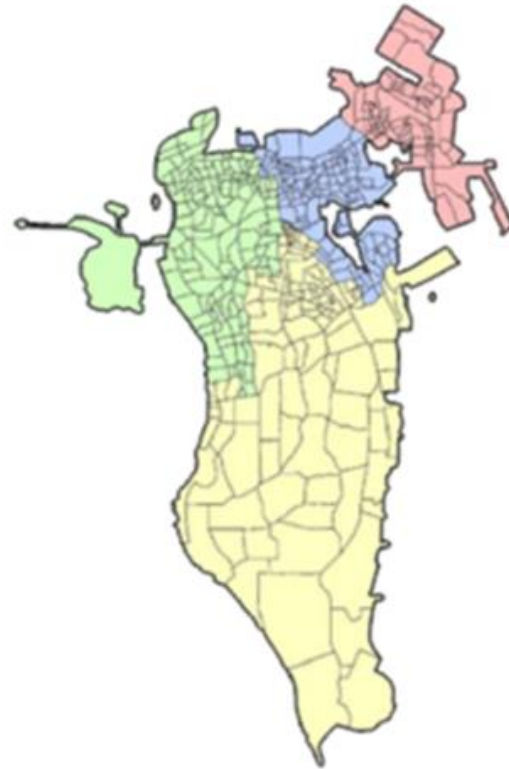


16 PEACE AND JUSTICE STRONG INSTITUTIONS







17 PARTNERSHIPS FOR THE GOALS





Legend

	Capital Governorate
	Muharraq Governorate
	Northern Governorate
	Southern Governorate

Bahrain Population → 1,742,424 (growth rate 7.4%)

Bahrain Area → 760 Km²

Landfill Area → 3 Km² (0.4 %)



Bahrain map with Main Governorates

Sewage sludge

- Chemically, wastewater is composed of organic (70%) and inorganic (30%) compounds as well as various gases.
 - Organic compounds consist primarily of carbohydrates (25 %), proteins (65 %) and fats (10 %).
 - Inorganic components may consist of heavy metals, nitrogen, phosphorus, pH, sulphur, chlorides, alkalinity, toxic compounds, et
- Sewage sludge is a product of wastewater treatment.
- Contains numerous known and unknown hazardous materials from different sources including :
 - household, medical, chemical, and industrial waste;
 - chemicals and metals that leach from the sewer pipes themselves;
 - materials that are created in the wastewater treatment plant as a result of the combination of chemicals and organic compounds present.

Cont.

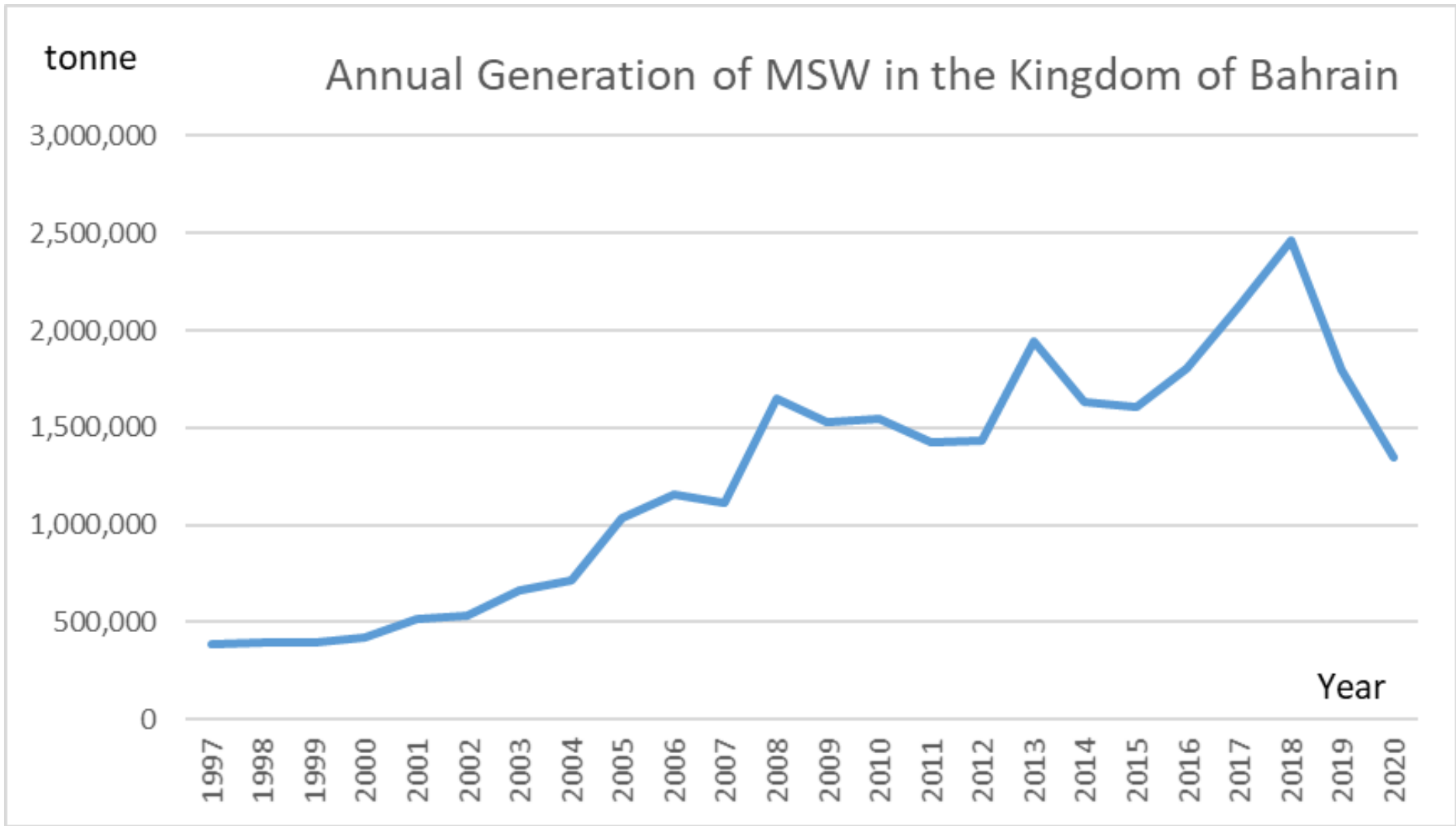
- In Bahrain there is one major STP which is Tubli Treatment Plant and 15 Minor Treatment Plants in which all of them uses activated sludge treatment process, but differs in the final disinfection process.
- Some of them are only up to secondary treatment like Askar and Jau STPs and all the remaining up to the tertiary treatment that mainly involve chlorination in the disinfection process in accompanying with other disinfection process like Ozonation in the case of Tubli STP or UV like the case in Muharraq STP.

Wastewater

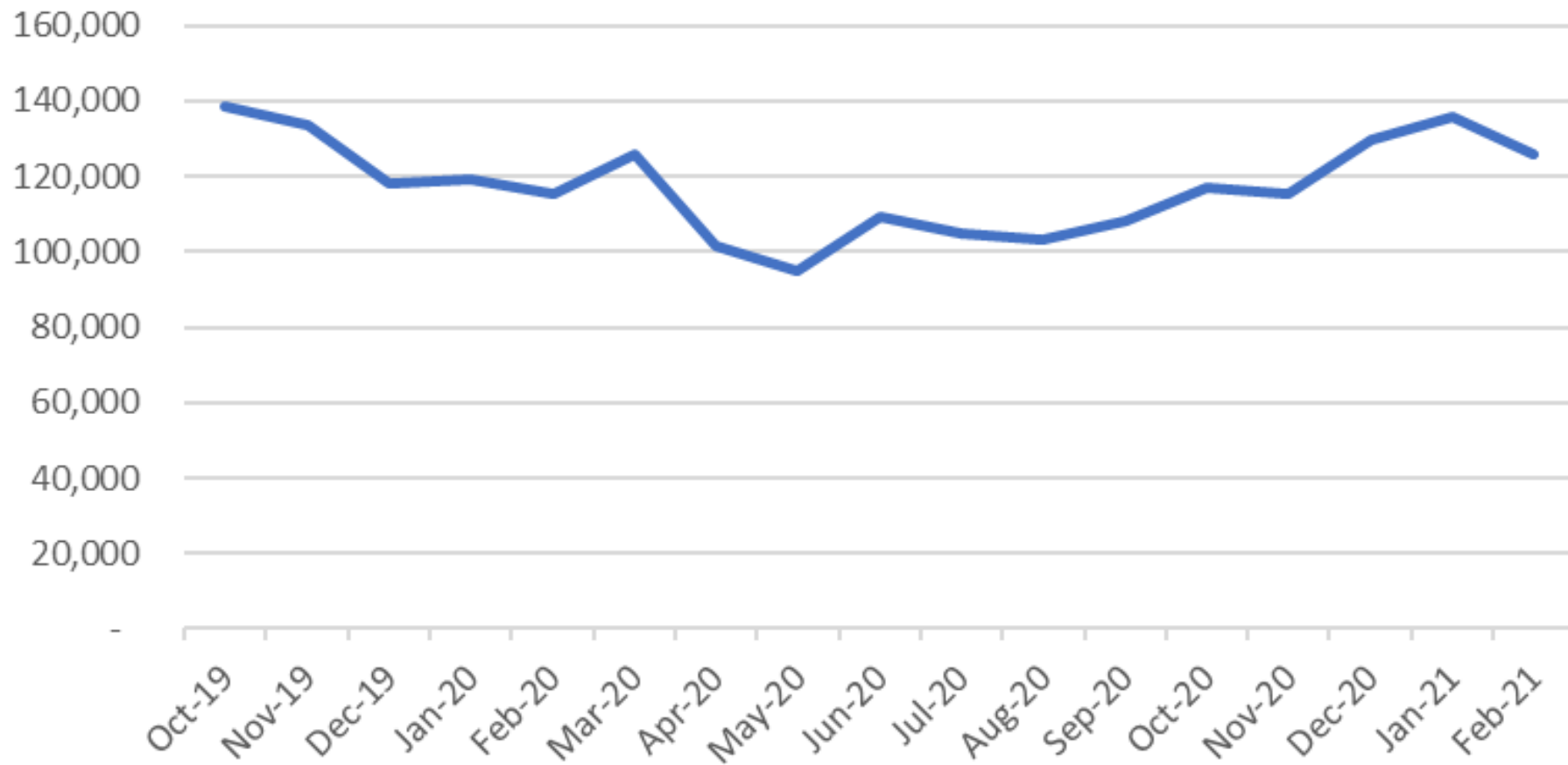
Treatment Plants in Bahrain

- 57 ton/day of sewage sludge is produced from 233,556cm/day
- (every 10,000cm produced 2.4 ton of sewage sludge in Bahrain)
- Annually, 20,750 ton of sewage sludge is produced in Bahrain

Secondary and Tertiary Treatments plants information in Bahrain					
NO.	STP	Capacity m3/day	Daily flow m3/day	Daily secondary treated m3/day	Daily tertiary treated waters m3/day
1	TUBLI	200,000	311,184	93,036	109,000
2	MADINAT SALMAN	39,680	14,793	14,793	14,247
3	SITRA	15,929	14,763	N/A	14,729
4	MA'AMIR	1,555	1,488	N/A	1,458
5	HIDD	1,108	2,025	N/A	1,985
6	S. ALBA	824	903	-	885
7	ASKAR	695	810	794	N/A
8	RIYADH ASKAR	871	415	-	407
9	AL DOUR	132	130	N/A	127
10	BUR AL DUR	2,000	458	-	449
11	JAU	701	707	693	N/A
12	UOB	107	129	N/A	140
13	JEDDAH	23	28	N/A	28
14	JASRAH	604	770	N/A	755
15	HAMALA	1,057	1,043	N/A	1,022
16	Muharraq	100,000	88324	N/A	88324
Total		365,285	437,970	109,316	233,556

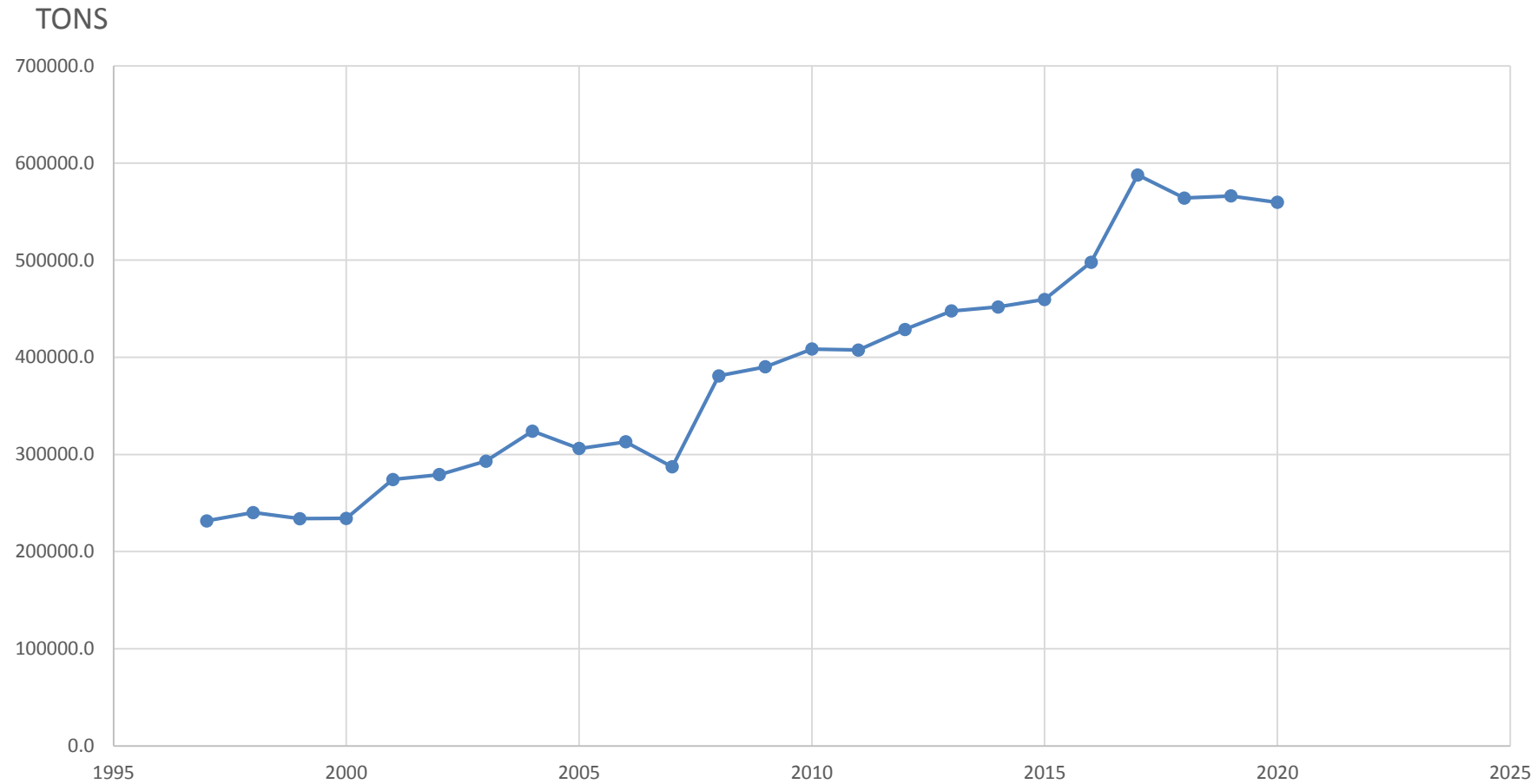


Total Monthly MSW During the Pandemic



MSW Composition

MSW	2018	2019	2020
Dead Animals	8,031	11,971	
Building Waste	831,609	322,472	
Commercial Waste	347,827	333,093	289,142
Construction Waste for Recycling		355,690	339,762
Domestic Waste	563,915	566,125	559,593
Garden Waste	124,324	126,107	78,429
Industrial Waste	81,577	81,175	27,318
Buhair Waste	509,449		
Bulky Waste			41,526
Tyres			8,416
Total	2,466,732	1,796,633	1,344,186



The annual generation rate of the household (domestic) waste in Bahrain in the last two decades

Biodegradable Waste in 2019

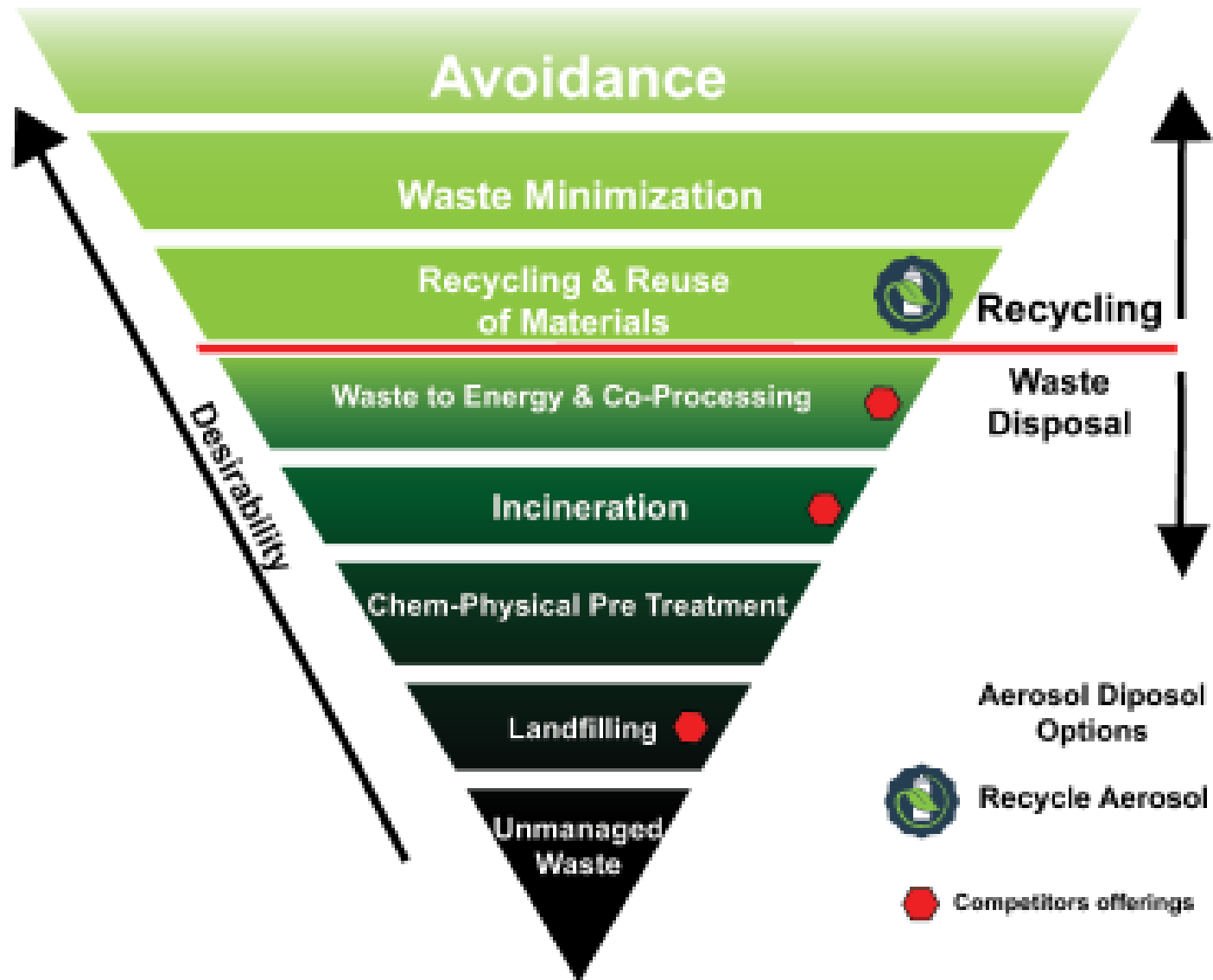
Biodegradable Waste	ton/year
Total Domestic Biodegradable Waste (food, papers, green)	221,942
Total Garden Waste	125,216
Dead Animals	10,001
Total Commercial Biodegradable Waste	136,184
Total Industrial Biodegradable Waste	21,158
Total WWTP Sludge	20,750
Total Biodegradable Waste in Bahrain	535,251

Food Waste in Bahrain

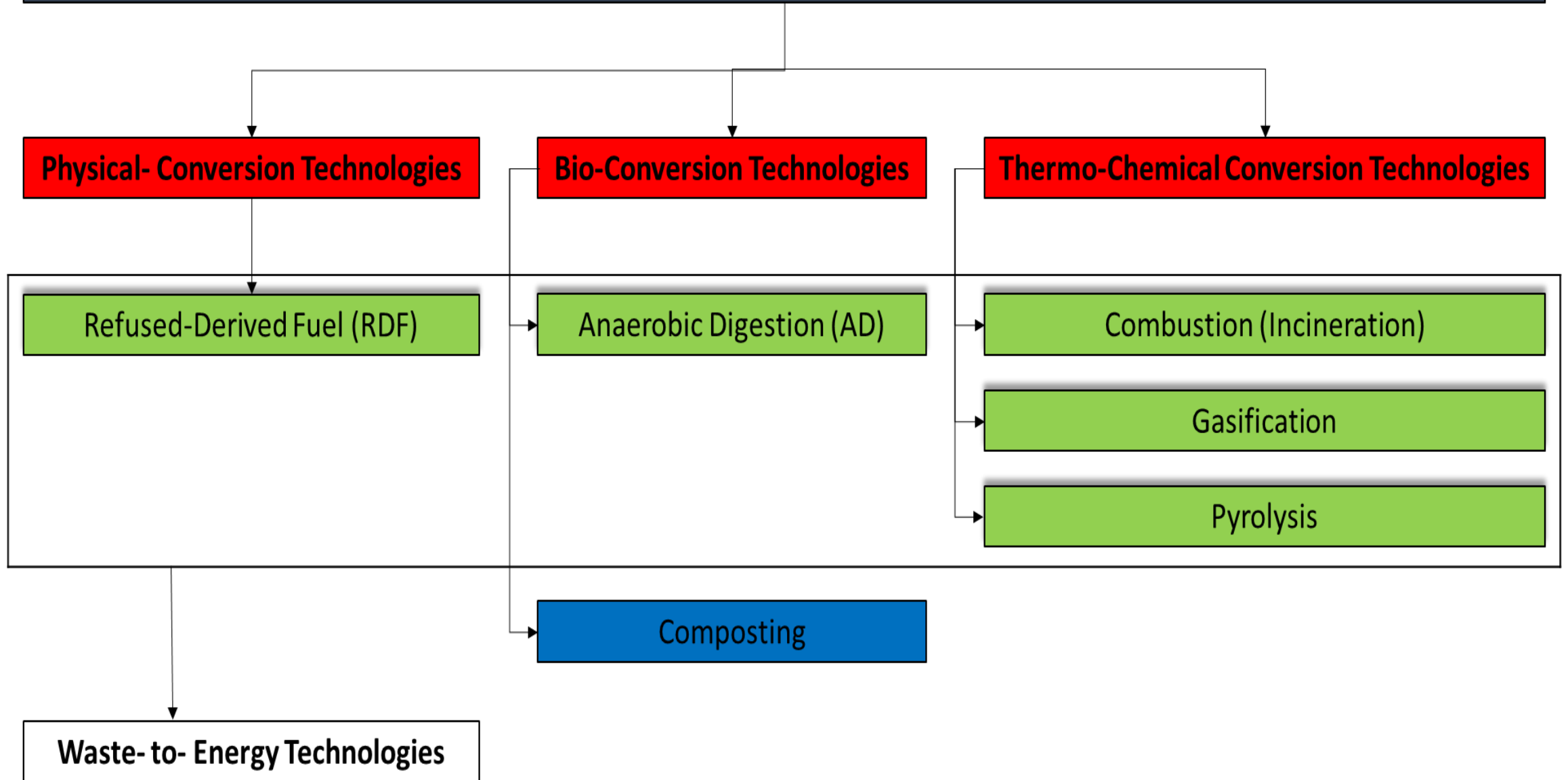
- As per the most recent report: the UNEP Food Waste Index Report 2021, Bahrain has the top highest food waste per capita among Arab countries, with an annual rate of 132kg/capita
- Therefore, food waste portion of domestic waste is equal 230,000 ton/year!
- While total Domestic Waste in 2020 is 559,593 ton (➔ food waste is 41% of domestic waste in 2020)!



Waste Management Hierarchy



Organic Household Waste (OHW) Management Technology Options



CBA of AD for the Kingdom of Bahrain

Total BDW	Biogas m3/ton	Total biogas yield (m3)	kWh/ton	Total Energy output (KWh)	Total Energy output (GWh)	Electricity cost (USD)	Benefit USD
535,251	450	240,862,950.00	398.5	213,297,523.50	213.30	0.02	4,265,950

Description	USD
Capital cost /ton	18
O&M cost/ton	14.4
Total Capital Cost	9,634,518
Total O&M Cost	7,707,614
Benefits/ Year	
Electricity	4,265,950
Fertiliser	642301
Direct saving by discontinuing waste dumping	8,473,705
Total Benefit/year	13,381,957
Net Profit	5,674,342

PERIOD	CASH FLOW
0	(9,634,518)
1	5,674,342
2	5,674,342
3	5,674,342
4	5,674,342
5	5,674,342
6	5,674,342
7	5,674,342
8	5,674,342
9	5,674,342
10	5,674,342
11	5,674,342
12	5,674,342
13	5,674,342
14	5,674,342
15	5,674,342
DISCOUNT RATE	10%
NPV	33,524,979
IRR	59%
PBP	1.7

Feasibility of AD by discontinuing dumping with Sensitivity Analysis

Sensitivity Analysis: Cash Flow with NPV, IRR and PBP of the AD Plant Project (discount rate 5%)

PERIOD	CASH FLOW
0	(9,634,518)
1	5,674,342
2	5,674,342
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10	5,674,342
11	5,674,342
12	5,674,342
13	5,674,342
14	5,674,342
15	5,674,342
DISCOUNT RATE	5%
NPV	49,263,212
IRR	59%
PBP	1.7

Sensitivity Analysis: Cash Flow with NPV, IRR and PBP of the AD Plant Project (discount rate 20%)

PERIOD	CASH FLOW
0	(9,634,518)
1	5,674,342
2	5,674,342
3	5,674,342
4	5,674,342
5	5,674,342
6	5,674,342
7	5,674,342
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10	5,674,342
11	5,674,342
12	5,674,342
13	5,674,342
14	5,674,342
15	5,674,342
DISCOUNT RATE	20%
NPV	16,895,713
IRR	59%
PBP	1.7

Feasibility of AD by continuing dumping with Sensitivity Analysis

Sensitivity Analysis: Cash Flow with NPV, IRR and PBP of the AD Plant Project when continuing dumping (discount rate 10%)

PERIOD	CASH FLOW
0	(9,634,518)
1	(2,799,362)
2	(2,799,362)
3	(2,799,362)
4	(2,799,362)
5	(2,799,362)
6	(2,799,362)
7	(2,799,362)
8	(2,799,362)
9	(2,799,362)
10	(2,799,362)
11	(2,799,362)
12	(2,799,362)
13	(2,799,362)
14	(2,799,362)
15	(2,799,362)
DISCOUNT RATE	10%
NPV	-30,926,688

Sensitivity Analysis: Cash Flow with NPV, IRR and PBP of the AD Plant Project when continuing dumping (discount rate 5%)

PERIOD	CASH FLOW
0	(9,634,518)
1	(2,799,362)
2	(2,799,362)
3	(2,799,362)
4	(2,799,362)
5	(2,799,362)
6	(2,799,362)
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9	(2,799,362)
10	(2,799,362)
11	(2,799,362)
12	(2,799,362)
13	(2,799,362)
14	(2,799,362)
15	(2,799,362)
DISCOUNT RATE	5%
NPV	-38,690,938

Sensitivity Analysis: Cash Flow with NPV, IRR and PBP of the AD Plant Project when continuing dumping (discount rate 20%)

PERIOD	CASH FLOW
0	(9,634,518)
1	(2,799,362)
2	(2,799,362)
3	(2,799,362)
4	(2,799,362)
5	(2,799,362)
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11	(2,799,362)
12	(2,799,362)
13	(2,799,362)
14	(2,799,362)
15	(2,799,362)
DISCOUNT RATE	20%
NPV	-22,722,858

Benefits of AD

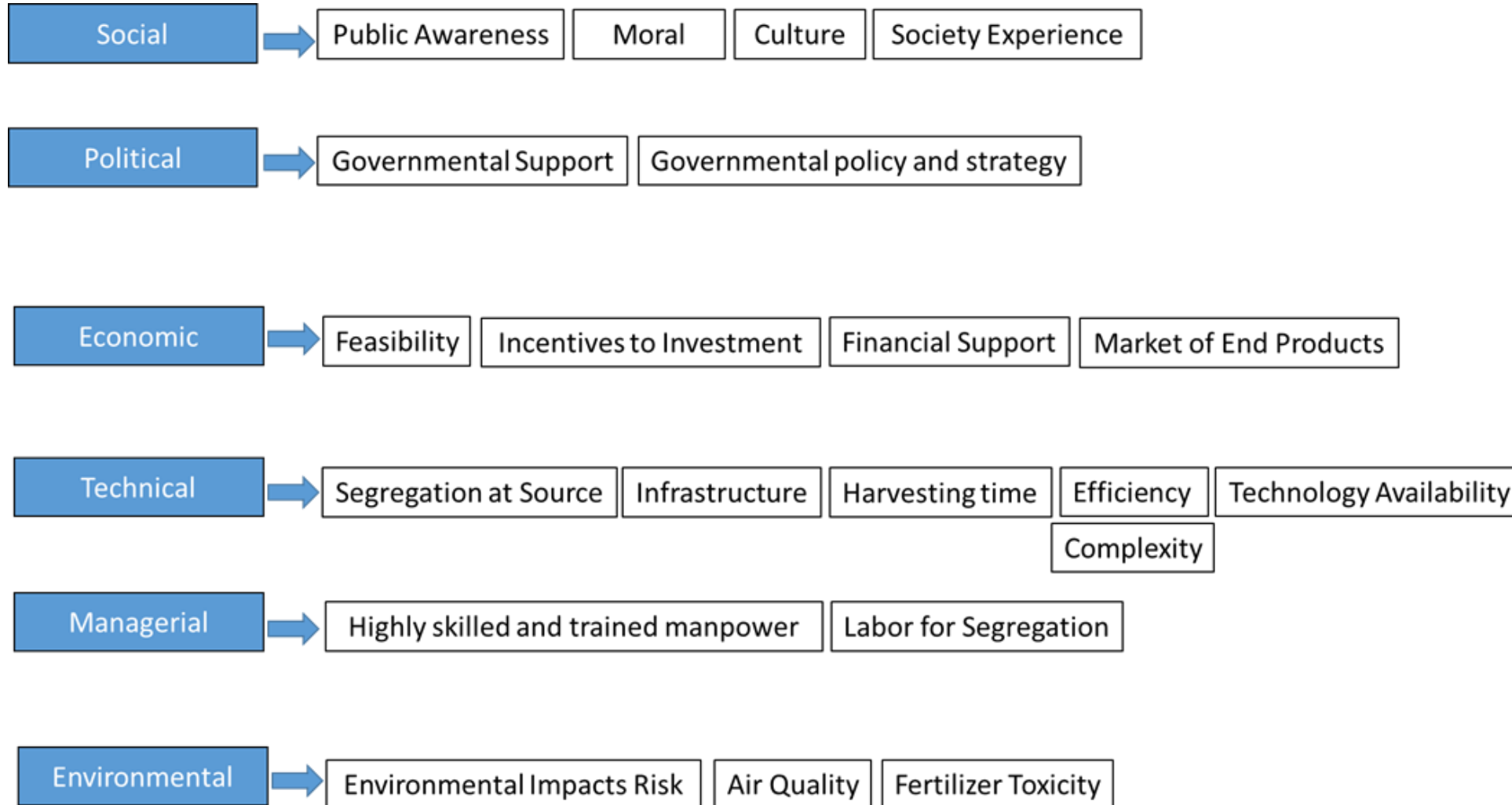
By recovering energy from the total biodegradable waste in the Kingdom of Bahrain using anaerobic digestion for bioenergy production:

- ✓ 213.3 GWh can be generated annually, equals 2% of current total power generation in Bahrain.
- ✓ BD 1.62M Electricity annual revenues
- ✓ Save 4.5M from waste dumping budget

Environmental Benefits

- ✓ Consequently, dumping of 535,251 tonne/year of biodegradable waste in the landfill results in 21410 ton CH₄/ year
(1 ton biodegradable waste results in 0.04 ton CH₄), which is equivalent to 535,251 ton CO₂ per year.
- ✓ Therefore, the AD project contribute to GHG emission reduction since the landfill methane has a global warming potential of approximately 25 times higher than that of CO₂

General Barriers to AD Technology Adoption



The Lack of:

- incentives to investment in green technologies
- national capacity building,
- market of the end products,
- centralization of WM responsibility
- coordination between all stakeholders
- sector privatization
- source segregation of waste

are the main barriers to AD adoption for biofuel production in Bahrain

CONCLUSION

- Cost-benefit analysis in this study gives an economic evidence to recommend AD to the decision makers as a feasible option to manage the biodegradable waste in the Kingdom of Bahrain including the sewage sludge, which can then be embedded into the national legal and policy frameworks
- AD Plant in Bahrain for the treatment of biodegradable waste going to the landfill annually, is expected to generate 213.3 GWh/year, with annual revenues of USD 4,265,950 from electricity sales.
- The second source of revenues from this project is expected from the sales of the fertilizer produces as another end product with the biofuel, with a sales revenues of USD 642,301 considering that each ton of organic waste produced 0.2ton of digestate, so this project is expected to produce 107,050 ton of digestate to be used as a fertilizer, with the international sale price of USD 6/ton.
- The direct saving earned by discontinuing biodegradable waste dumping of 535,251 ton/year in the landfill, is about USD8.47M which will be saved annually and increase the viability of the project.
- Moreover, 535,251 tonne/year of CO₂ -e can be reduced by discontinuing biodegradable waste dumping into the landfill after implementing the AD plant project, assuming the existing biodegradable generation rate in the Kingdom of Bahrain.



Thank you