

Supplementary Materials: Life Cycle Sustainability Assessment

In this section, the two approaches to represent the LCSA results into a single score are represented below.

S1: Approach 1: The Ranking and Scoring System

Here the impact categories were ranked 1-4 with 4 being the best and 1 being the worst for the WtE system for the LCA and LCC. To avoid any bias, an average is taken for impact categories for each WtE system and then average is also taken to get a single score. This also applied to the LCC. From there scores of LCA and LCC are added to the scores of sLCA that was previously obtained to get the overall sustainability score. A sample calculation is given below:

For LCA, by using one of the WtE system as an example in this AD (Lagos) , all the scores for each impact category are summed and averaged by dividing by number of impact categories to get the LCA score for AD (Lagos), this shown as follows:

$$\text{LCA score for AD (Lagos)} = \frac{4+4+4+2+4+4}{6} = 3.67$$

This is added to the LCA score of the other WtE systems and averaged to get the LCA score for WtE (Lagos):

$$\text{LCA score for WtE (Lagos)} = \frac{3.67+3.17+1.83+1.33}{4} = 2.5$$

A similar step was taken for LCC whereby the LCC values for each WtE are ranked and assigned score which are summed up and averaged by dividing by number of WtE systems considered to get the LCC score for WtE (Lagos):

$$\text{LCC score for WtE (Lagos)} = \frac{4+1+2+3}{4} = 2.5$$

Adding LCA and LCC scores to sLCA score and averaging it, the sustainability score for WtE (Lagos) is given as:

$$\text{Sustainability score for WtE (Lagos)} = \frac{2.5+2.5+3.97}{3} = 2.99$$

This also done for Abuja and the results given in Tables S.1 and S2 below

Table S1. Overall Sustainability of WtE in Abuja using a Scoring and Ranking Approach

LCA Abuja	AD	Incineration	Gasification	LFGTE
ADP	4	3	1	2
GWP	4	3	2	1
HTP	4	3	1	2
POCP	2	4	3	1
AP	4	3	2	1
EP	4	3	2	1
Total Score	22	19	11	8
Average Score	3.67	3.17	1.83	1.33
Average Score for WtE				2.5
LCC Abuja	AD	Incineration	Gasification	LFGTE
	1	4	2	3
Average Score for WtE				2.5

sLCA Abuja	
Average Score for WtE	3.23
Overall Sustainability Score	8.23
Average Sustainability Score	2.74

Table S2. Overall Sustainability of WtE in Lagos using a Scoring and Ranking Approach

LCA Lagos	AD	Incineration	Gasification	LFGTE
ADP	4	3	1	2
GWP	4	3	2	1
HTP	4	3	1	2
POCP	2	4	3	1
AP	4	3	2	1
EP	4	3	2	1
Total Score	22	19	11	8
Average Score	3.67	3.17	1.83	1.33
Average Score for WtE		2.5		
LCC Lagos	AD	Incineration	Gasification	LFGTE
	1	4	2	3
Average Score for WtE		2.5		
sLCA Lagos				
Average Score for WtE		3.23		
Overall Sustainability Score		8.97		
Average Sustainability Score		2.99		

S2: Approach 2: The Muti Attribute Value Theory

In this approach, equal weights of 0.33 are assigned to three dimensions (environmental, economic, and social) as follows :

$$\text{Weight of Dimension} = \frac{1}{3} = 0.33$$

This was then followed by standardising the impact categories by assuming the score of the best performance to be 1, then the other scores are obtained by the proportion of the best sustainability performance for the WtE system. An example of this is done using Abiotic Depletion Potential (ADP) where AD has the least ADP with a value of 0.6 MJ and, standardising gives it a score of 1 when standardised making it the best in that category as such the other scores are obtained by the proportion of the best sustainability performance for the WtE system as show below:

$$\text{AD: } = \frac{0.6}{0.6} = 1$$

$$\text{Incineration: } \frac{0.6}{2.86} = 0.2097$$

$$\text{Gasification: } \frac{0.6}{6.98} = 0.8595$$

$$\text{LFGTE: } \frac{0.6}{3.63} = 0.1648$$

This is done for all the other impact categories and for all WtE systems, there after the values are summed up and averaged to get the LCA score for each WtE system. The scores are then summed up and multiplied by the weight of the dimension to get the LCA score of WtE (Lagos) as shown below:

$$\begin{aligned}\text{LCA score for WtE (Lagos)} &= (0.8874+0.6590+0.4532+0.1817) \times 0.33 \\ &= 0.7199\end{aligned}$$

This is also done for the LCC where incineration with lowest LCC value was standardised to having the value of 1 making the option with best performance, while scores of the other WtE were obtained as follows:

$$\text{AD: } \frac{214.1}{467.35} = 0.4581$$

$$\text{Incineration: } \frac{214.1}{214.1} = 1$$

$$\text{Gasification: } \frac{214.1}{411.04} = 0.5209$$

$$\text{LFGTE: } \frac{214.1}{240.53} = 0.8901$$

$$\begin{aligned}\text{LCC score for WtE (Lagos)} &= (0.4581+1 +0.5209+0.8901) \times 0.33 \\ &= 0.94680\end{aligned}$$

For sLCA, the score obtained was multiplied by the assigned weight as follows:

$$\begin{aligned}\text{sLCA score for WtE (Lagos)} &= (3.97) \times 0.33 \\ &= 1.3101\end{aligned}$$

The overall sustainability score for WtE score (Lagos) was evaluated as

$$\begin{aligned}\text{Sustainability Score for WtE (Lagos)} &= 0.7199 +0.94680+1.3101 \\ &= 2.977\end{aligned}$$

The same was done for WtE (Abuja) with the results given in Tables S3 and S4

Table S3. The Overall Sustainability Performance of WtE (Lagos)

Dimension		Weight of the dimensions				
LCA		0.33				
LCC		0.33				
sLCA		0.33				
LCA Lagos						
Impact Categories		Unit	AD	Incineration	Gasification	LFGTE
ADP		(MJ)	0.6	2.86	6.98	3.64
GWP		(Kg CO2 eq)	0.506	0.74	0.94	8.7
HTP		(Kg 1,4 DB eq)	0.0054	0.0092	0.0213	0.015
POCP		(Kg C2H4 eq)	0.00011	0.0000357	0.0000506	0.00186
AP		(Kg SO2 eq)	0.00056	0.00083	0.0011	0.00237
EP		(Kg PO4 eq)	0.000143	0.000179	0.000228	0.000568
Standardising by dividing with best option (the one with lowest impact)			AD	Incineration	Gasification	LFGTE
ADP			1	0.20979021	0.085959885	0.1648352
GWP			1	0.683783784	0.538297872	0.0581609
HTP			1	0.586956522	0.253521127	0.36
POCP			0.324545	1	0.705533597	0.0191935
AP			1	0.674698795	0.509090909	0.2362869
EP			1	0.798882682	0.627192982	0.2517606
Total Value			5.324545	3.954111992	2.719596373	1.0902371
Average Value			0.887424	0.659018665	0.453266062	1.0902371
Summing up the scenario scores to get the overall LCA score			2.181415			
Multiplying by the weights of the LCA dimension			0.719867			
LCA sustainability score			0.719867			
LCC Lagos		AD	INC	GASF	LFGTE	
LCC (U\$/t)		467.35	214.1	411.04	240.53	
Standardising by dividing with best option (the one with lowest impact)						
LCC Lagos		AD	INC	GASF	LFGTE	
LCC		0.458114903	1	0.520873881	0.890117657	

Summing up the scenario score to get the overall LCC score	2.869106441
Multiplying by the weights of the LCC dimension	0.946805125
LCC Sustainability Score	0.946805125
sLCA Lagos	
sLCA score	3.97
Multiplying by the weights of the sLCA dimension	1.3101
sLCA Sustainability Score	1.3101
Overall Sustainability Score	2.976772127

Table S4. The Overall Sustainability Performance of WtE (Abuja)

Dimension	Weight of the dimensions				
LCA	0.33				
LCC	0.33				
sLCA	0.33				
LCA Abuja					
Impact Categories	Unit	AD	Incineration	Gasification	LFGTE
ADP	(MJ)	0.62	3.17	6.4	4.59
GWP	(Kg CO2 eq)	0.507	0.8	0.86	9.5
HTP	(Kg 1,4 DB eq)	0.0055	0.0102	0.0195	0.019
POCP	(Kg C2H4 eq)	0.00011	0.0000396	0.0000464	0.00202
AP	(Kg SO2 eq)	0.000564	0.00089	0.00097	0.00299
EP	(Kg PO4 eq)	0.000144	0.000192	0.000209	0.000717

Standardising by dividing with best option (the one with lowest impact)		AD	Incineration	Gasification	LFGTE
ADP		1	0.195583596	0.096875	0.1350763
GWP		1	0.63375	0.589534884	0.0533684
HTP		1	0.539215686	0.282051282	0.2894737
POCP		0.36	1	0.853448276	0.019604
AP		1	0.633707865	0.581443299	0.1886288
EP		1	0.75	0.688995215	0.2008368
Total Value		5.36	3.752257148	3.092347956	0.8869879
Average Value		0.893333	0.62537619	0.515391326	0.1478313
Summing up the scenario scores to get the overall LCA score		2.181932			
Multiplying by the weights of the LCA dimension		0.720038			

LCA sustainability score		0.720038			
LCC Abuja	AD	INC	GASF	LFGTE	
LCC (U\$/t)	456.4	232.76	419.58	323.71	
Standardising by dividing with best option (the one with lowest impact)					
LCC Lagos	AD	INC	GASF	LFGTE	
LCC	0.509991236	1	0.554745221	0.719038646	
Summing up the scenario score to get the overall LCC score	2.783775103				

Multiplying by the weights of the LCC dimension	0.918645784
LCC Sustainability Score	0.918645784
sLCA Abuja	
sLCA score	3.23
Multiplying by the weights of the sLCA dimension	1.0659
sLCA Sustainability Score	1.0659
Overall Sustainability Score	2.704583399