

MSW to Energy

Plasma Gasification Feedstock Analysis - Belize, Solomon Islands, & Vanuatu

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Overview

- Introduction of Plasma Gasification Technology
- Exploring the Feedstock Data
- Predictive Modeling & Future Work
- Spotlight: Belize City



Plasma Gasification Technology

Plasma Gasification

“The conversion of carbonaceous material into a gaseous product for the production of energy products and by-products in an oxygen starved environment”

Plasma gasification converts all MSW except metals and glass, no sorting required!

❖ Proven Technology

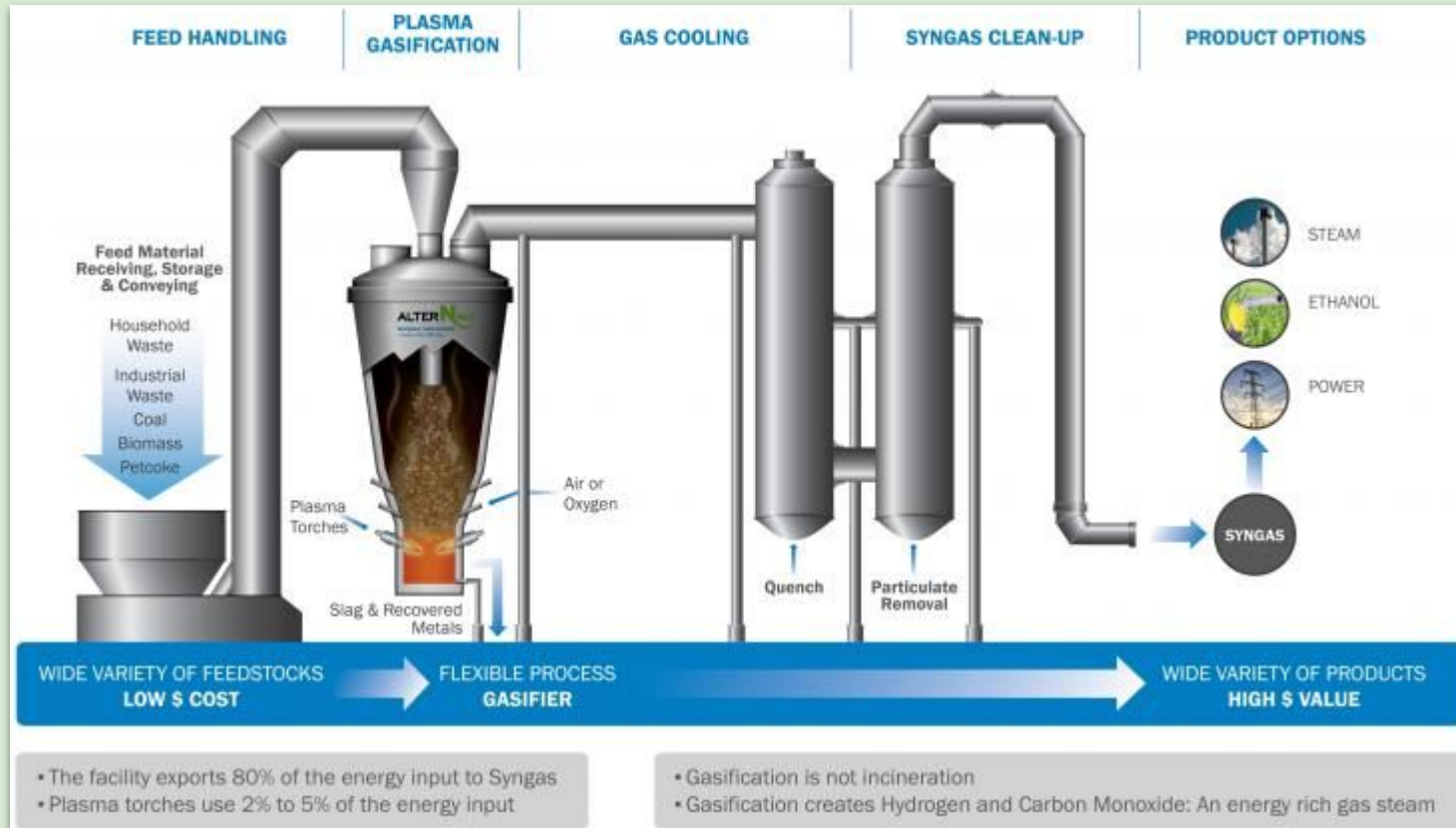
- An internationally adopted process with substantially increased efficiencies over the years

❖ Products:

- ‘Syngas’ - Mostly Carbon Monoxide (CO) and Hydrogen (H₂):
 - Local Clean Energy
 - Chemical Products (Ethanol, Methanol, Biodiesel, etc..)
- Vitrified Slag or Biochar:
 - Environmentally safe aggregate substitute or fertilizer

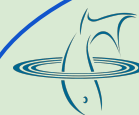


Typical Plasma Gasification Process



Exploring the Data

Data Summary



Cefas



apwc ASIA PACIFIC
WASTE CONSULTANTS

Original Data

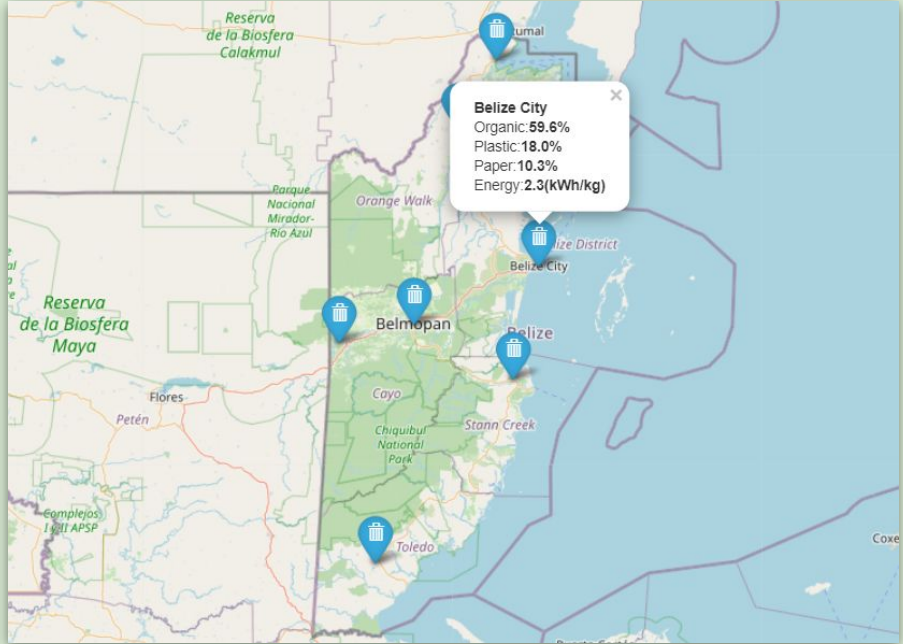
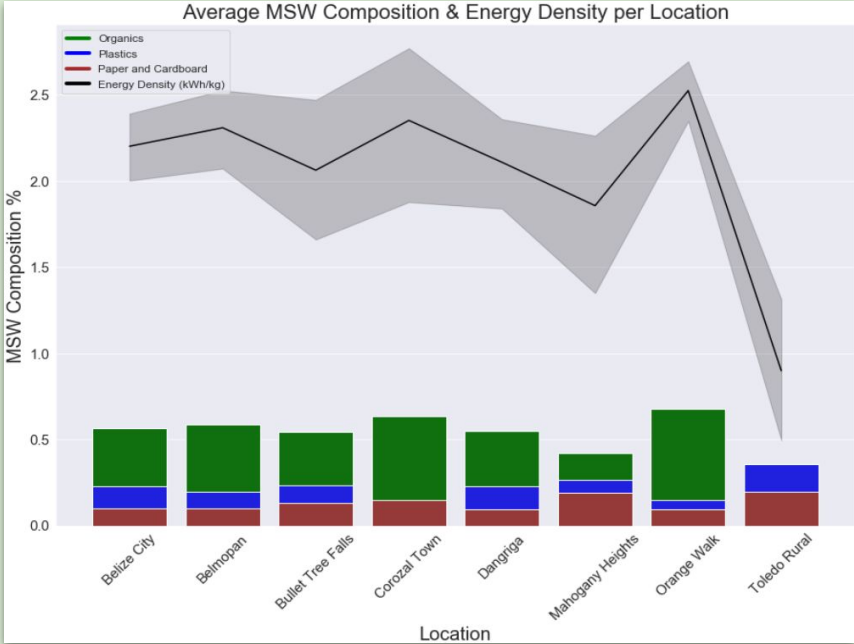
- ❖ Collected to support local **ocean waste reduction efforts**
- ❖ Comprised of two dataset types:
 - **Quantitative datasets** provided weighed & itemized MSW lists for each household
 - **Qualitative interviews** with each household to inquire about habits and help improve MSW management strategies

	Collection Locations	Total Households	Total MSW Measured
Belize	8	223	931 kg
Solomon Islands	7	311	2023 kg
Vanuatu	5	269	1670 kg

3 Key Questions

- 1.** What typical MSW compositions can we determine for each household, region, country?
- 2.** What information about MSW energy density, and total energy output can we derive from these data?
- 3.** Which MSW items are most prevalent in each household, region, country, and why?

Feedstock Analysis: Belize



Household Averages:
Mean Energy Density:

2.04 kWh/kg

Median Total MSW Energy:

8.9 kWh

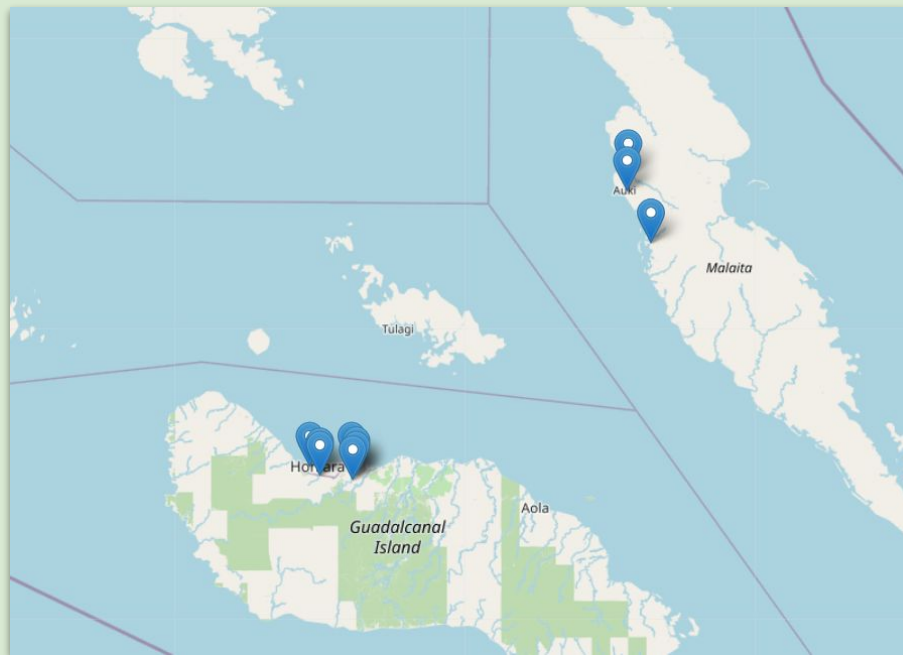
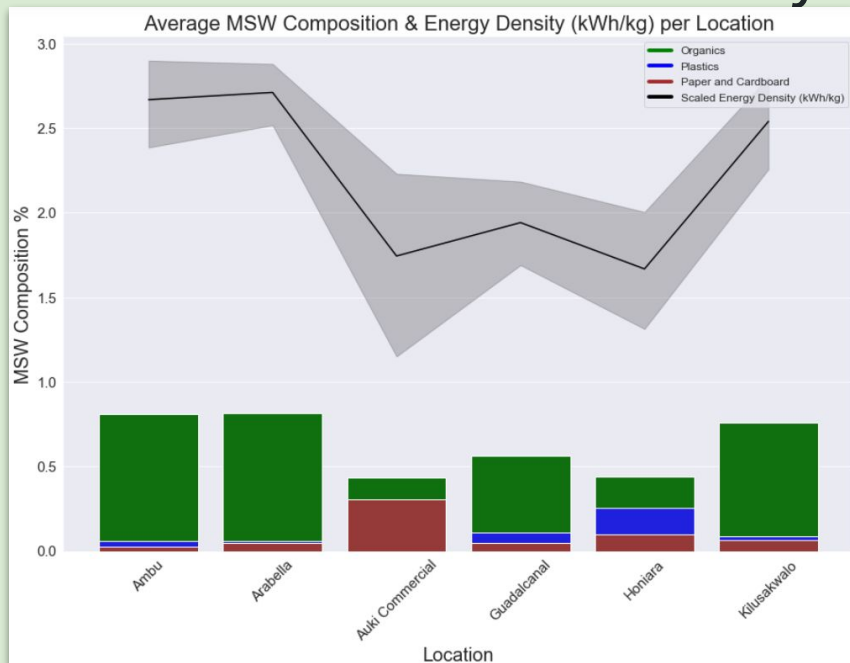
Typical Composition wt %	IQR
Organics	31 - 75%
Plastics	10 - 30%
Paper and Cardboard	2 - 16%

Top 5 Waste Items:

1. Mixed Food - 361 kg
2. Other* - 99 kg
3. Nappies - 89 kg
4. Other Sanitary Waste - 48 kg
5. PET Bottles - 42 kg

*Other deemed non-combustible

Feedstock Analysis: Solomon Islands



Household Averages:
Mean Energy Density:

2.16 kWh/kg

Median Total MSW Energy:

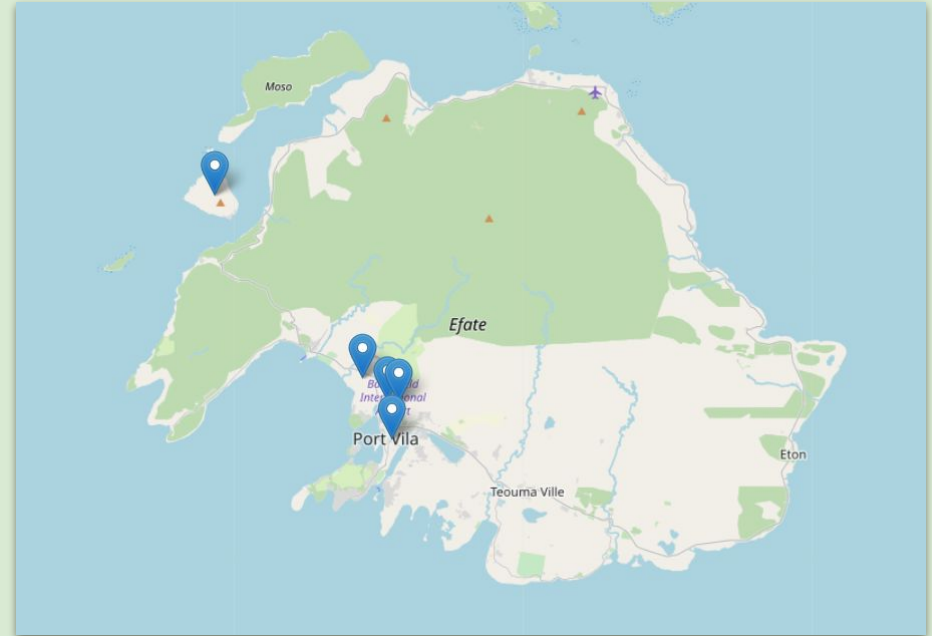
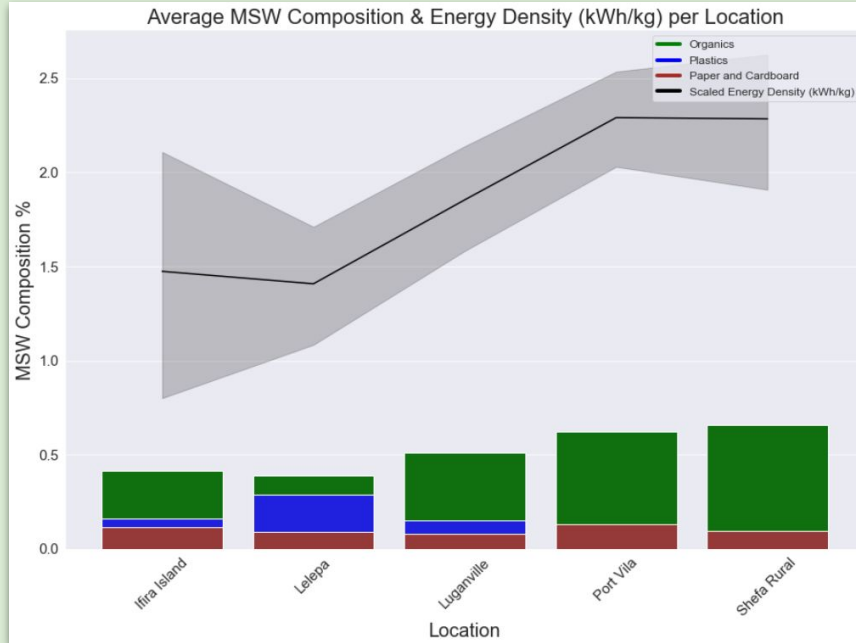
11.75 kWh

Typical Composition wt %	IQR
Organics	34 - 93%
Plastics	2 - 17%
Paper and Cardboard	0 - 8%

Top 5 Waste Items:

1. Other Organics - 657 kg
2. Mixed Food - 642 kg
3. Aluminium Cans - 174 kg
4. Steel Cans - 88 kg
5. Plastic Bags - 71 kg

Feedstock Analysis: Vanuatu



Household Averages:
Mean Energy Density:

1.88 kWh/kg

Median Total MSW Energy:

11.9 kWh

Typical Composition wt %	IQR
Organics	23 - 87%
Plastics	5 - 23%
Paper and Cardboard	1 - 12 %

Top 5 Waste Items:

1. Nappies - 502 kg
2. Mixed Food - 365 kg
3. Other Organics - 311 kg
4. Steel Cans - 119 kg
5. PET Bottles - 53 kg

Predictive Modeling & Future Work

Predictive Modeling

Regression Analysis Methodology - OSEMN

1. **O**btain: Import datasets and revise summary details.
2. **S**crub: Clean datasets of unnecessary, redundant, or missing values and features.
3. **E**xplore: Manipulate and reformat datasets to make calculations possible for labeling data.
4. **M**odel: Once in a format conducive for modeling, build out multiple models
5. **iN**terpret: Compare models across multiple performance metrics.

	Model 1	Model 2
Target	Total energy (kWh) per household MSW sample.	Household MSW sample's energy density (kWh/kg) .
Purpose	This model will serve as the basis of a user application , where input of MSW wt%, by specified item, will result in a predicted energy output. Electric utilities may utilize this as well as developers.	This model forms the basis of a feedstock analysis for developers of gasification facilities . Improving on the robustness of this model will help developers to better understand the potential energy output, and therefore projected revenues , of a proposed facility.
Results	Top performing model is able to predict total MSW energy within 0.7 kWh .	Top performing model is able to predict MSW energy density within 0.22 kWh/kg .

Model Comparisons

Model	Train-Test Split	Median Total Energy	RMSE	Median Energy Density	RMSE
Belize	172 / 31	8.9 kWh	+/- 0.78 kWh	2.04 kWh/kg	+/- 0.44 kWh/kg
Solomon Islands	160 / 29	11.75 kWh	+/- 1.3 kWh	2.16 kWh/kg	+/- 0.26 kWh/kg
Vanuatu	138 / 25	11.9 kWh	+/- 3.53 kWh	1.88 kWh/kg	+/- 0.50 kWh/kg
Combined Model	438 / 78	10.85 kWh	+/- 0.70 kWh	2.03 kWh/kg	+/- 0.22 kWh/kg

Final Model Type: Neural Network

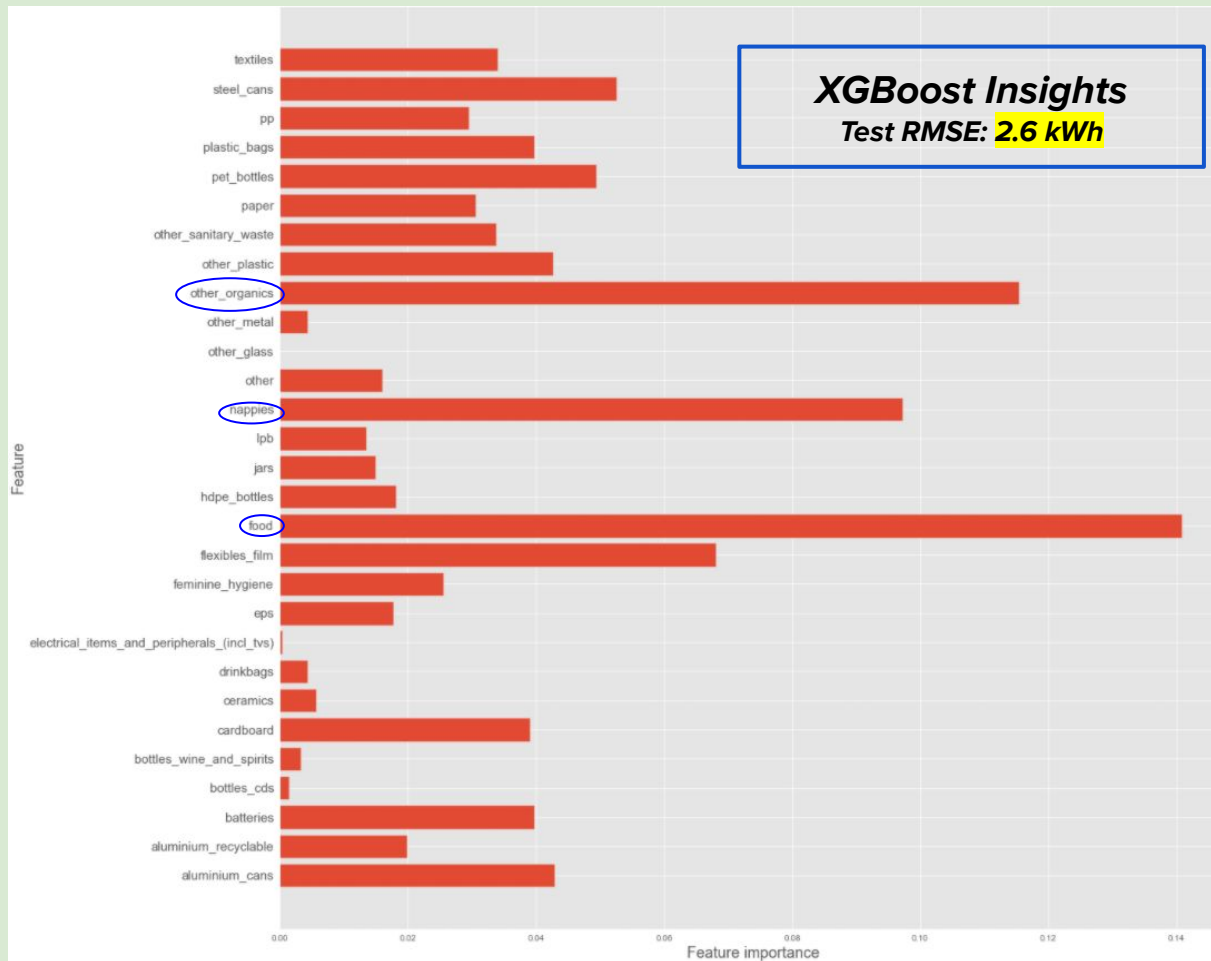
Trainable Parameters: 2092

Dense Layers: 3 (45, 15, 3)

- Final model **combines datasets** from all 3 case studies.
- **Maintains low RMSE scores** for both dependent variables despite increasing data.
- **Robust architecture** allows this model to work well with new information not previously seen.

Future Work

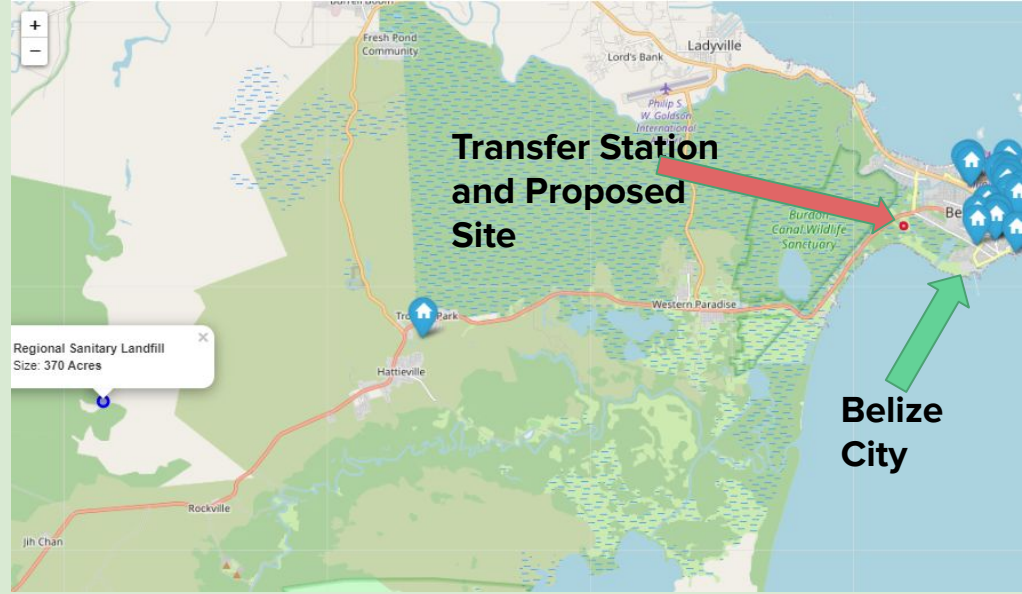
- Further data collection, improved **focus on energy related user and MSW details**.
- **Collaborate with domain experts** to improve on the list of waste items to better capture the variations of energy in waste
- **Cooperate with the Belize Solid Waste Management Authority** to better understand the public, their needs, as well a local government capacities.



Spotlight: Belize City

Belize: A Leader in Clean Energy

- Belize ranked **5th best country in Caribbean** for Foreign Direct Investment (FDI)
- 3 highly sought elements for global investors:
 1. **Stability:** Currency pinned 2:1 with USD since 1978.
 2. **Profitability:** Fiscal incentives, Commercial Free/Export Processing Zones, ease of repatriation of profits
 3. **Liveability:** English speaking country, subtropical climate, virgin rainforest, 'un-spoiled' beaches, friendly people



- ❖ **Belize Electric Limited (BEL)** is the primary distributor of electricity in Belize.
- ❖ Country electricity rates are **very sensitive to volatility of energy import prices**.
- ❖ Regional Sanitary Landfill has over **125,000 tons of buried MSW**, and may be a valuable source of **MSW feedstock reserves**.

Belize City: Gasification Facility

Location: **Mile 3, George Prince Highway**

Total Capacity: **2 MW Module**

Generating Technology: **Plasma Gasification**

Primary Fuel: **Local MSW @ ~1,632 kWh/ton**

Daily Capacity: **70 - 100+ tons/day***

Proposed PPA: **US\$0.20/kWh**

Annual Energy Revenue: **US\$12 Million**

Annual By-Product Revenue: **US\$100,000**

Total Capital Cost: **US\$30 Million***

Total Annual Costs: **US\$4 Million***

ROI: **< 50 months**

EBDITA: **US\$9.5 Million**

*Estimates based on similar sized facilities and Belize City MSW collection and transfer statistics.



Thank you!
