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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

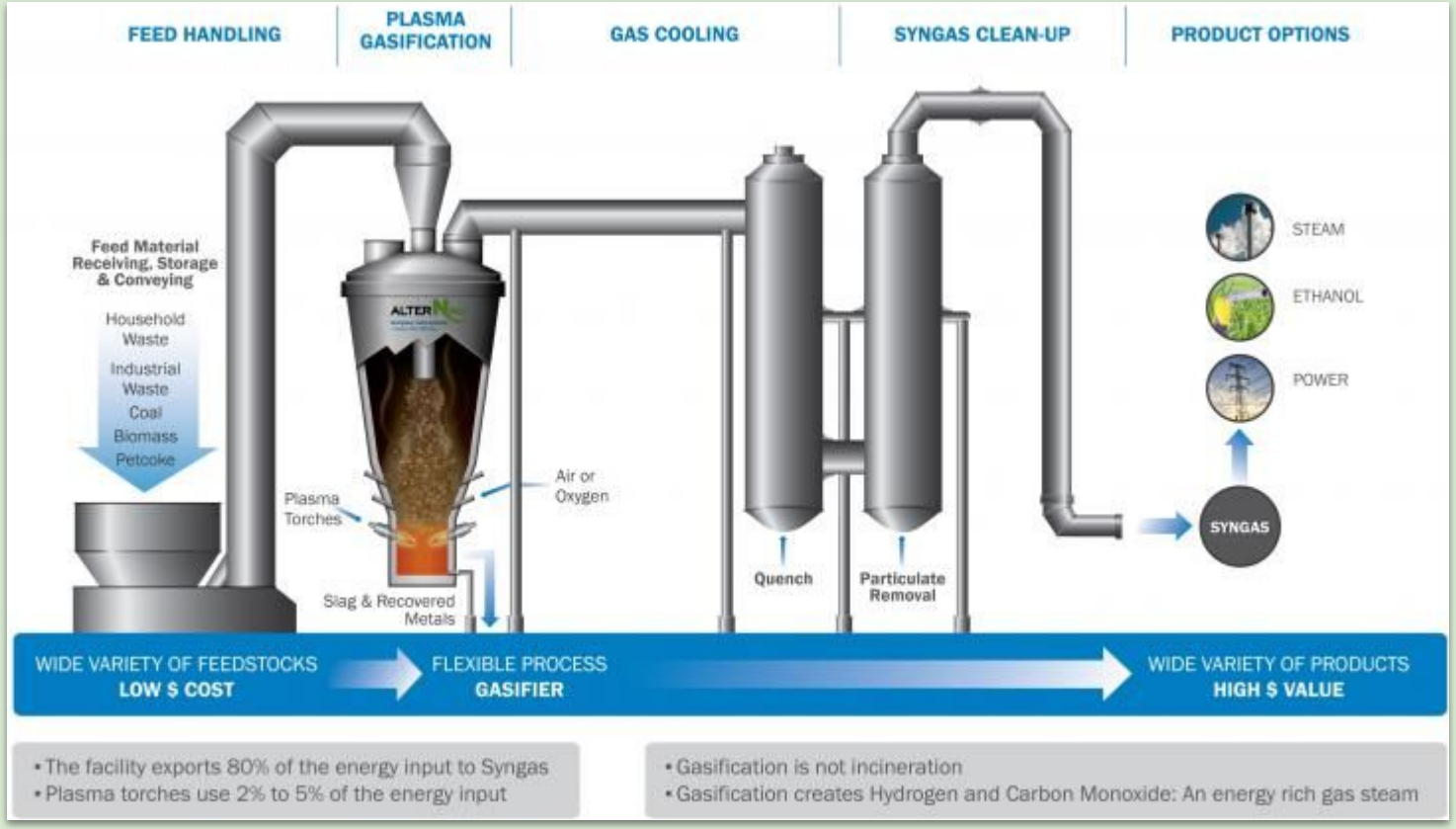
Plasma Gasification

“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

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

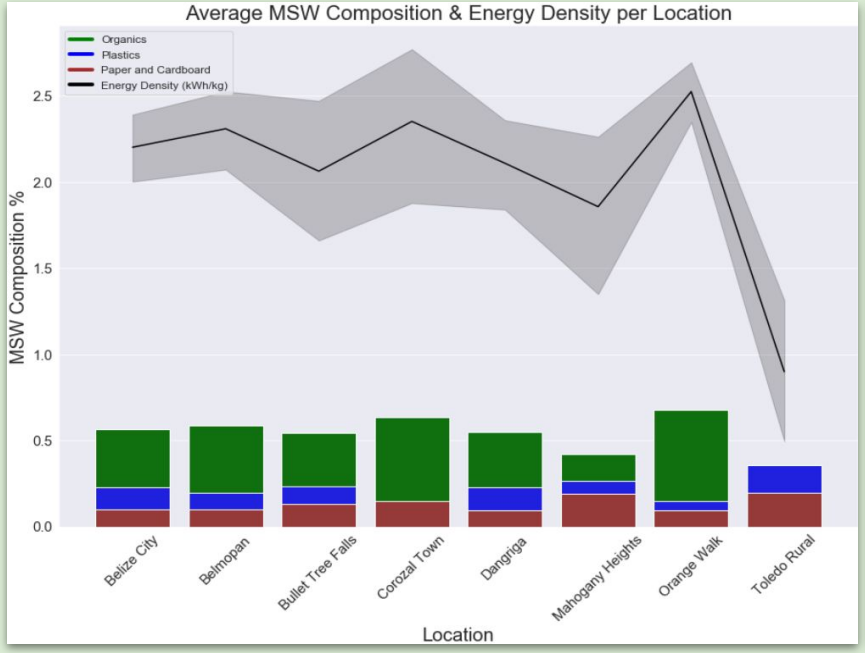
3 Key Questions

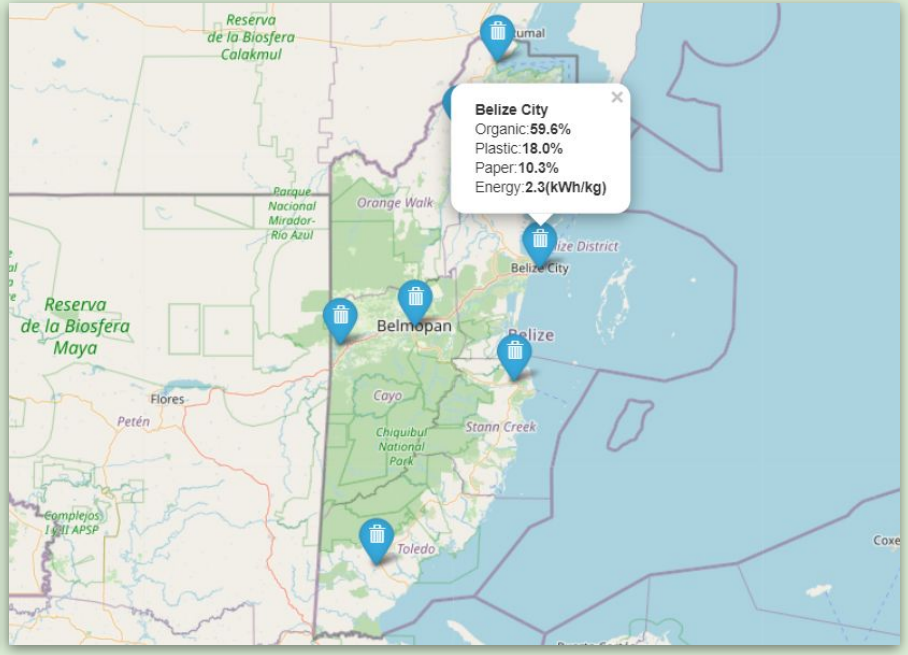
1. What typical MSW compositions can we determine for each household, region, country?

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

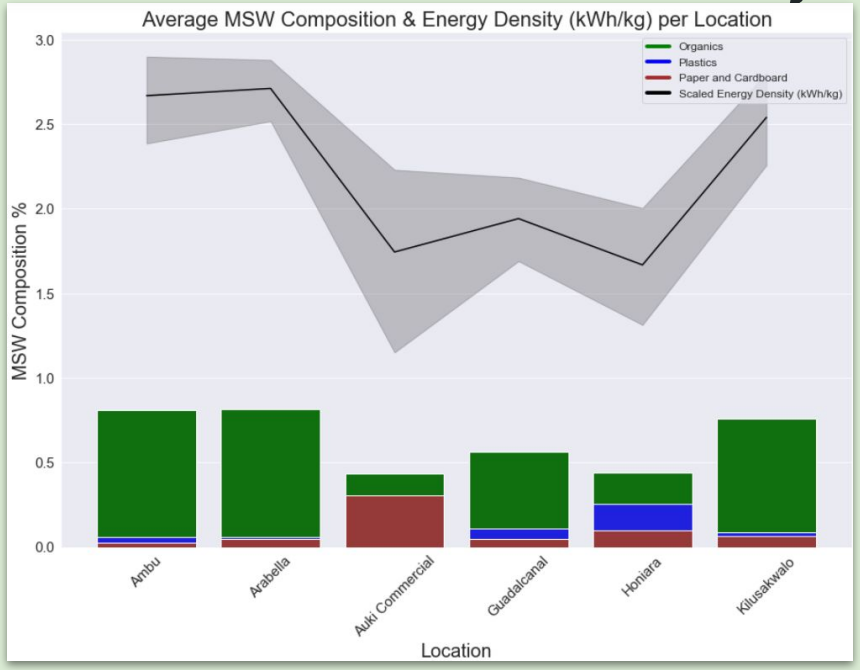
Typical Composition wt %	IQR
Organics	31 - 75%
Plastics	10 - 30%
Paper and Cardboard	2 - 16%

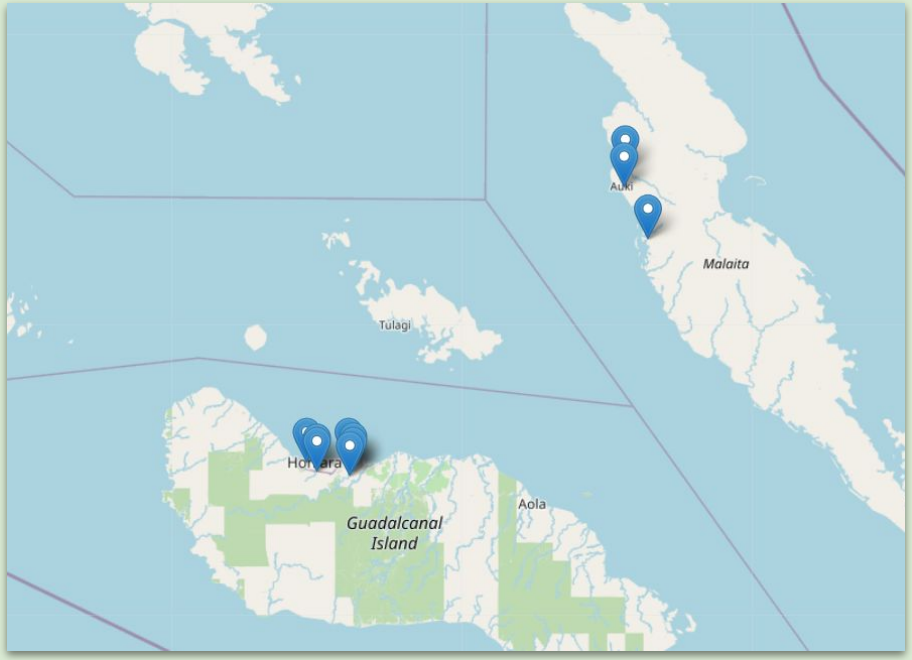
Top 5 Waste Items:

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:

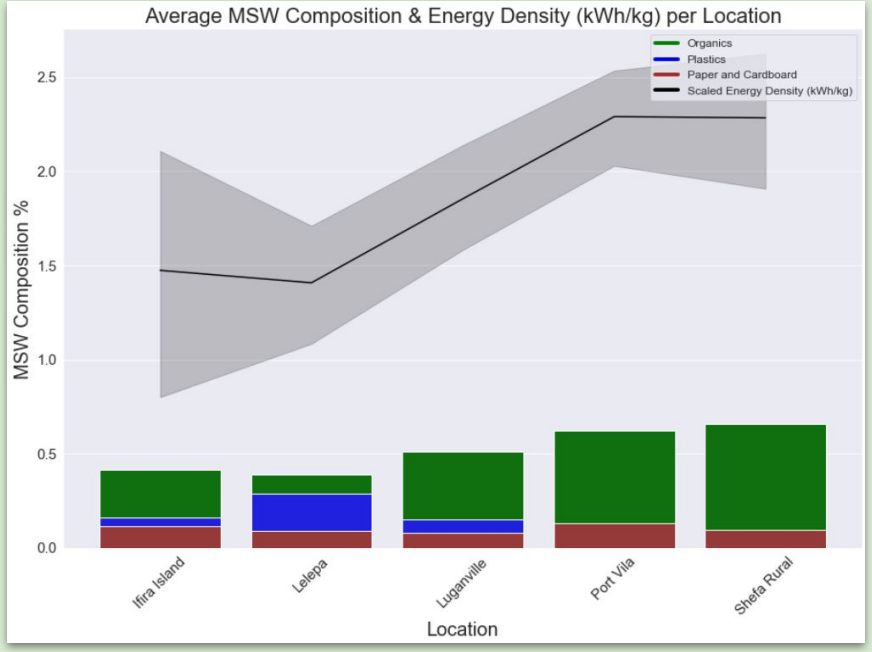
11.75 kWh

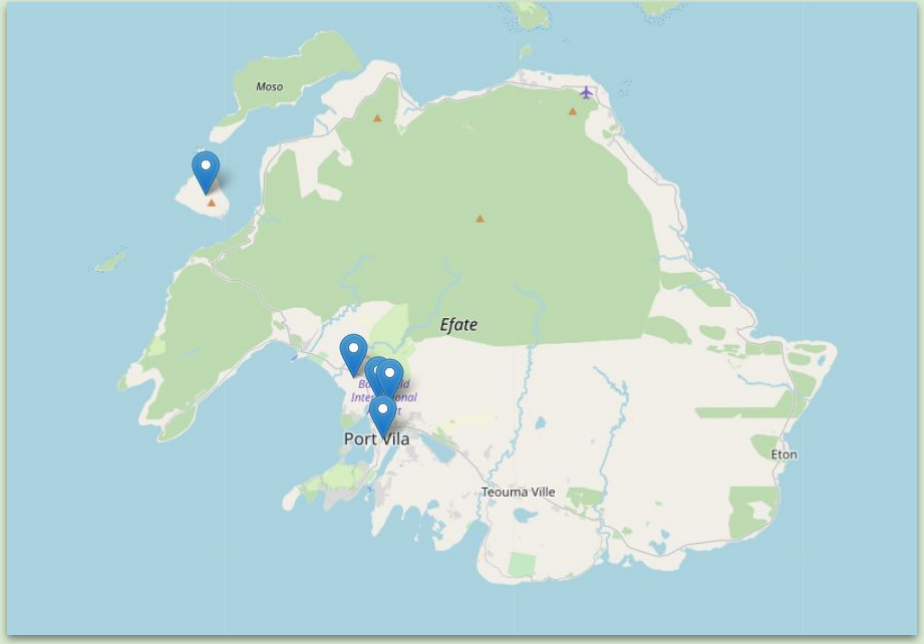
Typical Composition wt %	IQR
Organics	34 - 93%
Plastics	2 - 17%
Paper and Cardboard	0 - 8%

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. i**N**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

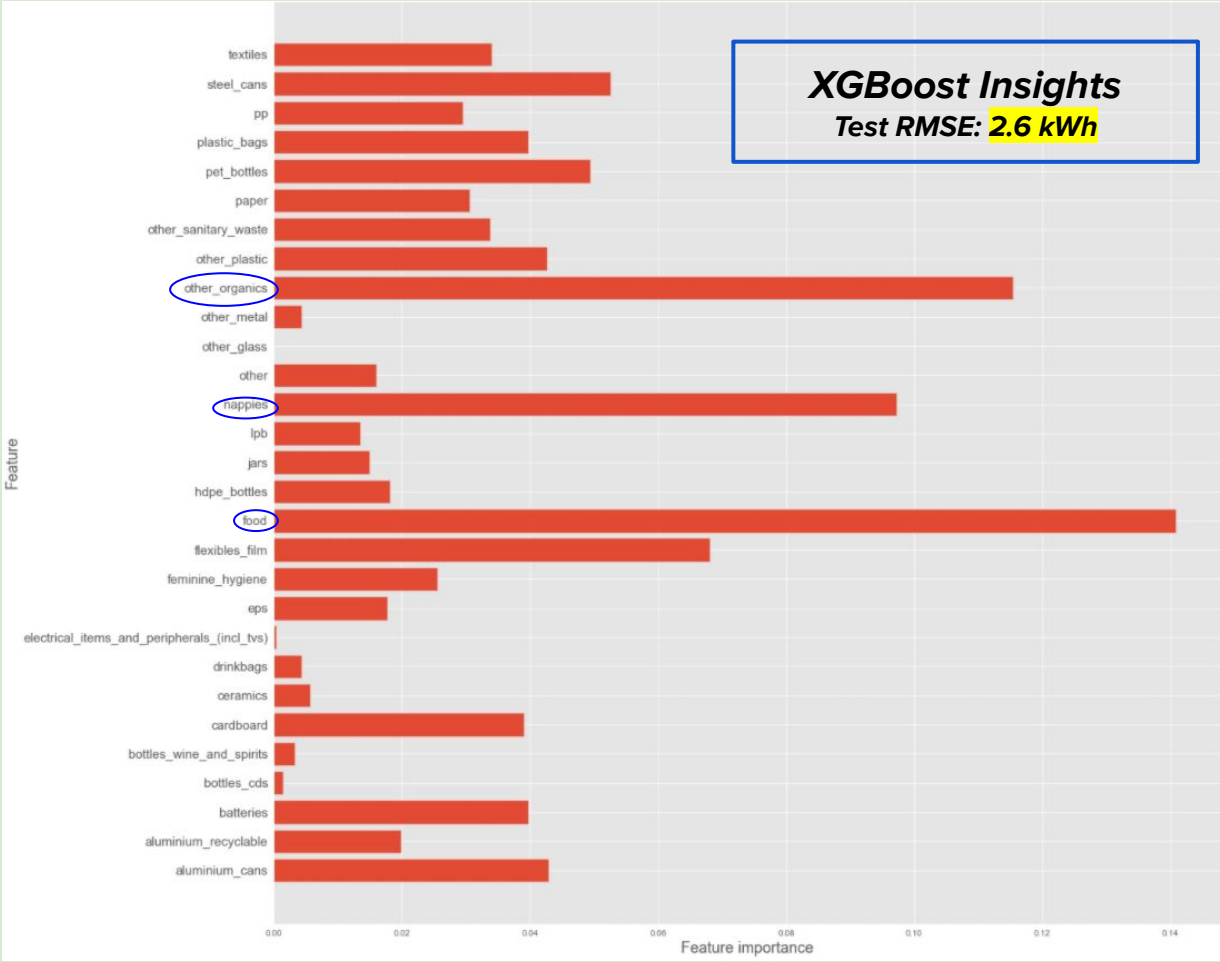
Trainable Parameters: 2092

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

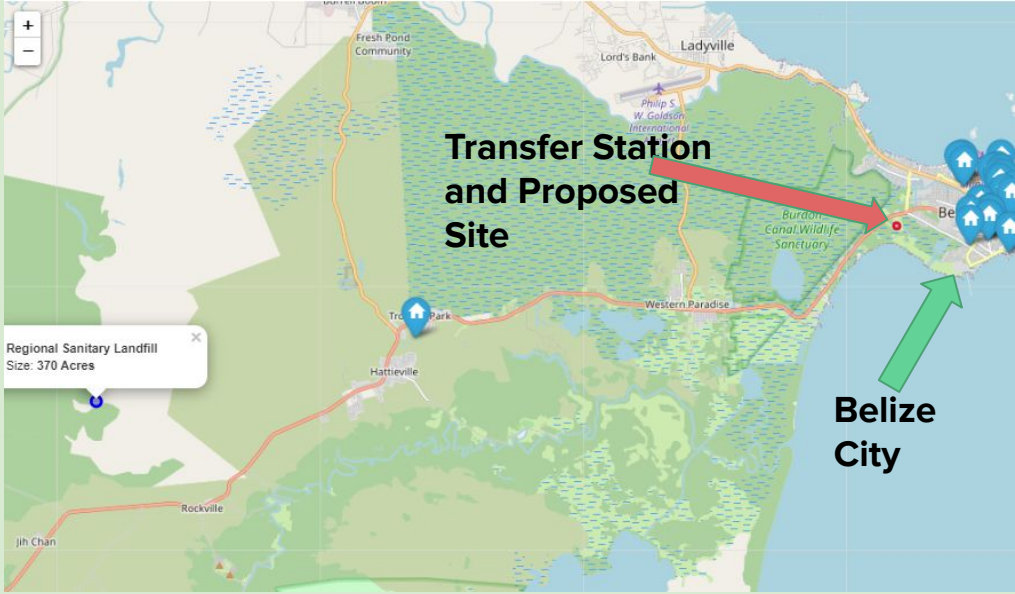
- Further data collection, improved **focus on energy related user and MSW details.**
- **Collaborate with domain experts** to improve on the list of waste items to better capture the variations of energy in waste
- **Cooperate with the Belize Solid Waste Management Authority** to better understand the 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 is a valuable source MSW feedstock reserves.**

Belize City: Gasification Facility

Location: **Mile 3 George Prince Highway**

Total Capacity: **2 MW**

Generating Technology: **Plasma Gasification**

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

Daily Capacity: **~100 tons/day**

Potential 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:**~U$9.5 Million**

Thank you!