

# MSW to Energy

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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

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# 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

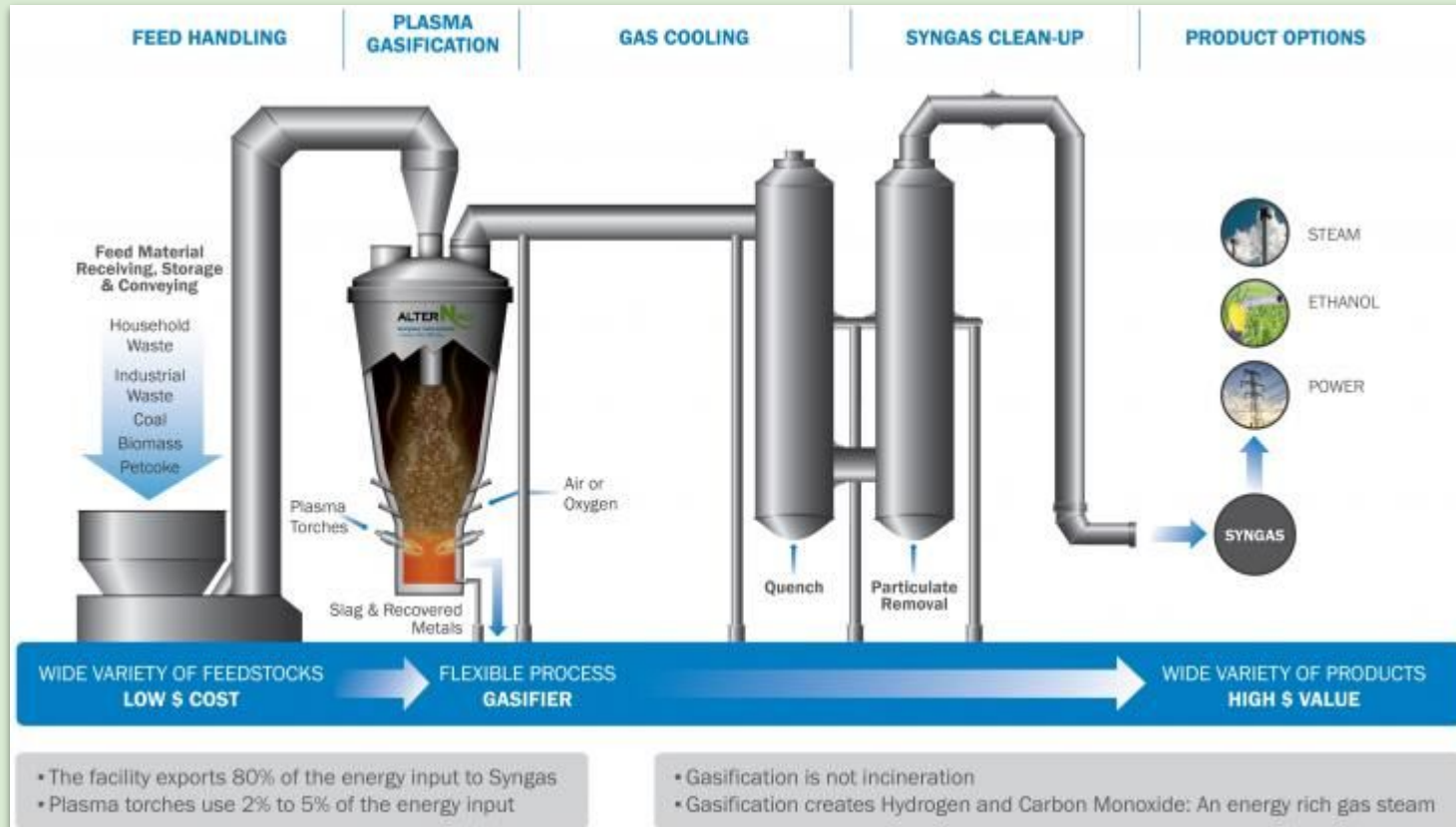
- An internationally adopted process with substantial increases in efficiencies over the years

## ❖ Products:

- ‘Syngas’ - Mostly Carbon Monoxide (CO) and Hydrogen (H<sub>2</sub>):
  - Local Clean Energy
  - Chemical Products (Ethanol, Methanol, Biodiesel, etc..)
- Vitrified Slag or Biochar:
  - Environmentally safe aggregate substitute or fertilizer



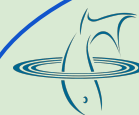
# Typical Plasma Gasification Process



# Exploring the Data

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# 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

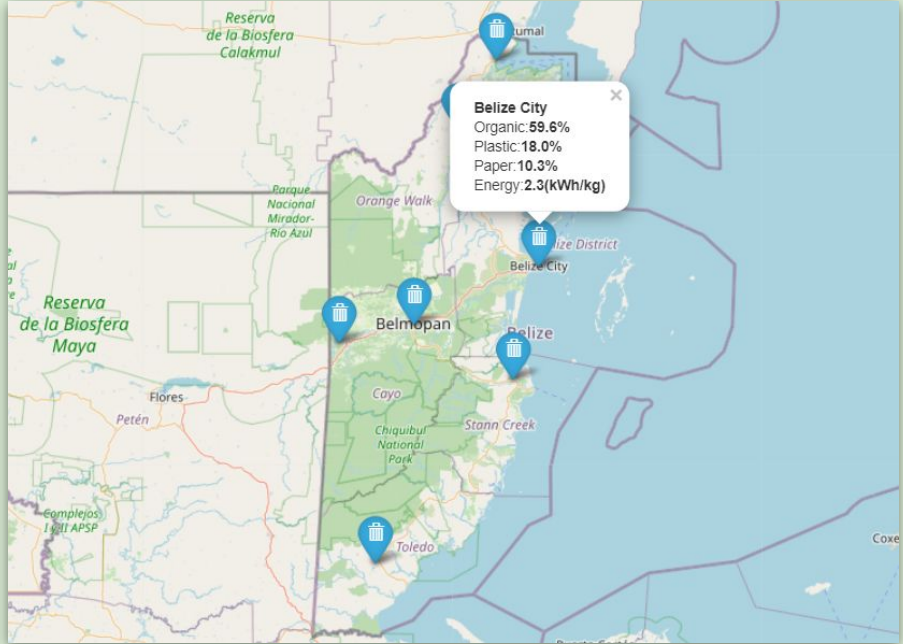
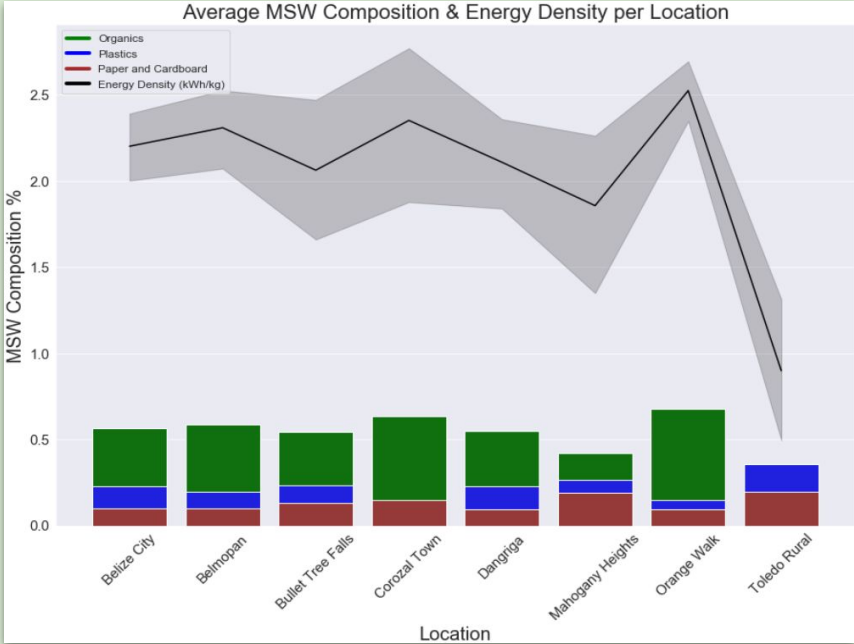
	Collection Locations	Total Households	Total MSW Measured
Belize	8	223	931 kg
Solomon Islands	7	311	2023 kg
Vanuatu	5	269	1670 kg

## **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**

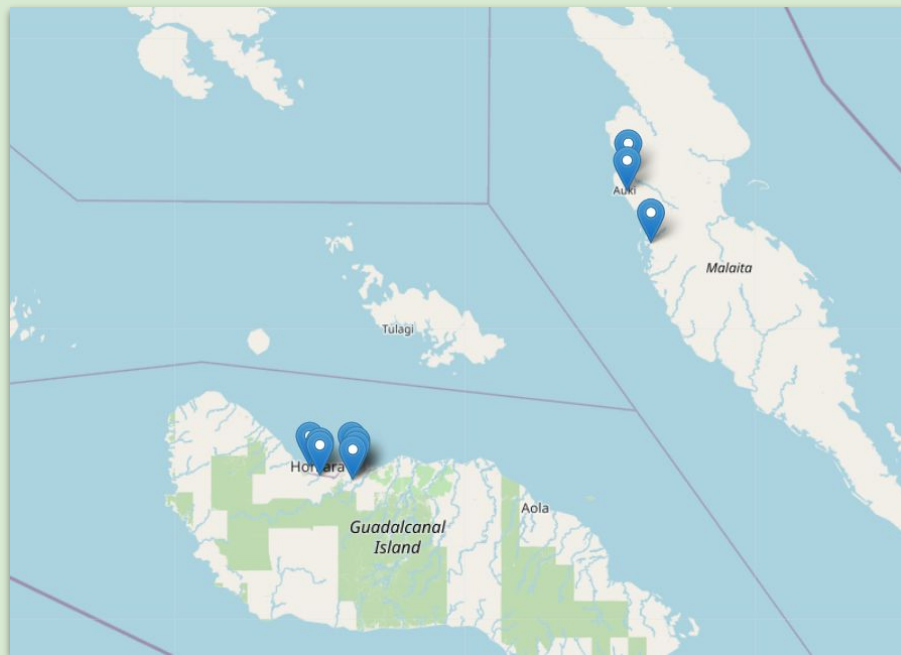
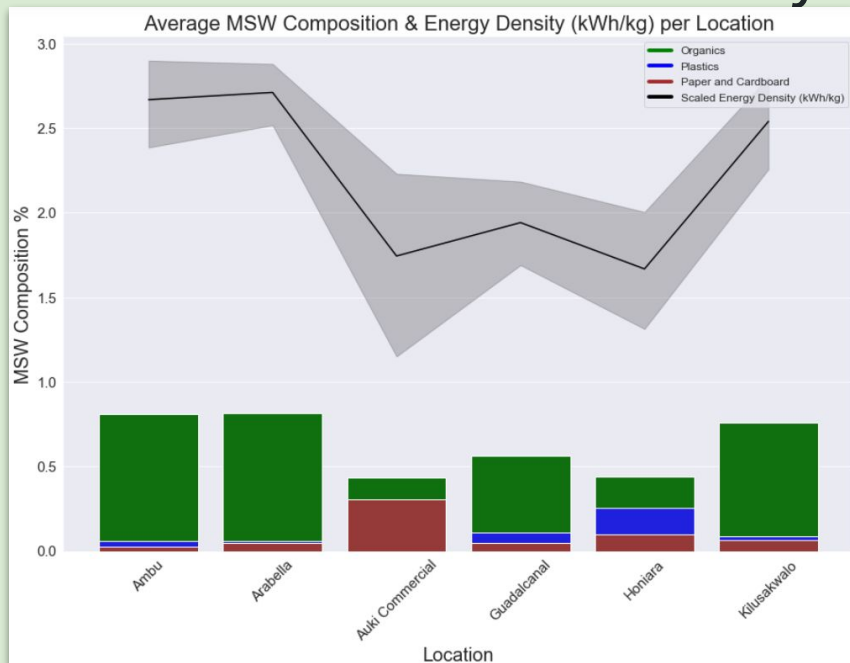
Typical Composition wt %	IQR
Organics	31 - 75%
Plastics	10 - 30%
Paper and Cardboard	2 - 16%

## 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:**

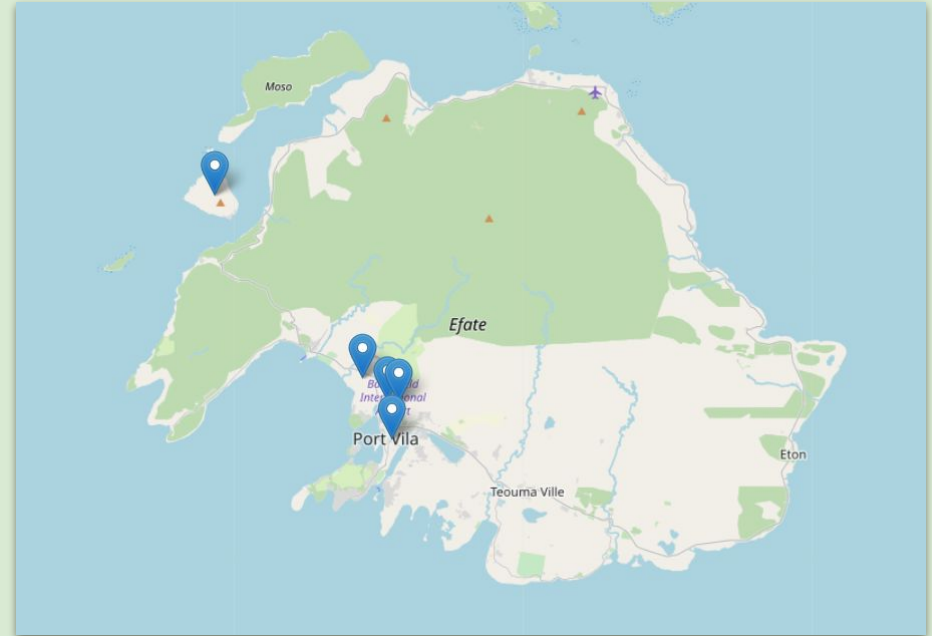
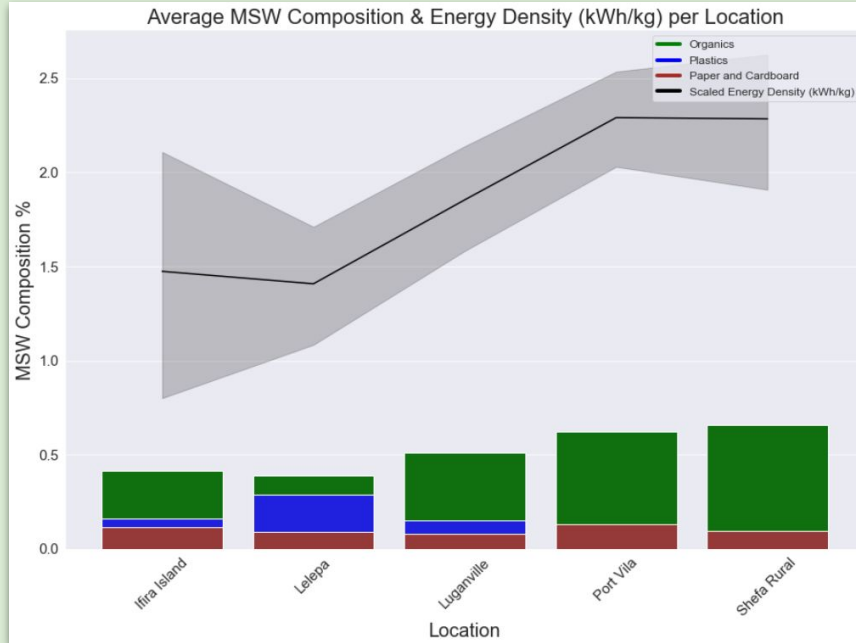
**11.75 kWh**

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

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# 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	<b>Total energy (kWh)</b> per household MSW sample.	Household MSW sample's <b>energy density (kWh/kg)</b> .
Purpose	This model will serve as the basis of a <b>user application</b> , 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 <b>feedstock analysis for developers of gasification facilities</b> . Improving on the robustness of this model will help developers to better understand the potential energy output, and therefore <b>projected revenues</b> , of a proposed facility.
Results	Top performing model is able to predict <b>total MSW energy within 0.7 kWh</b> .	Top performing model is able to predict <b>MSW energy density within 0.22 kWh/kg</b> .

# 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

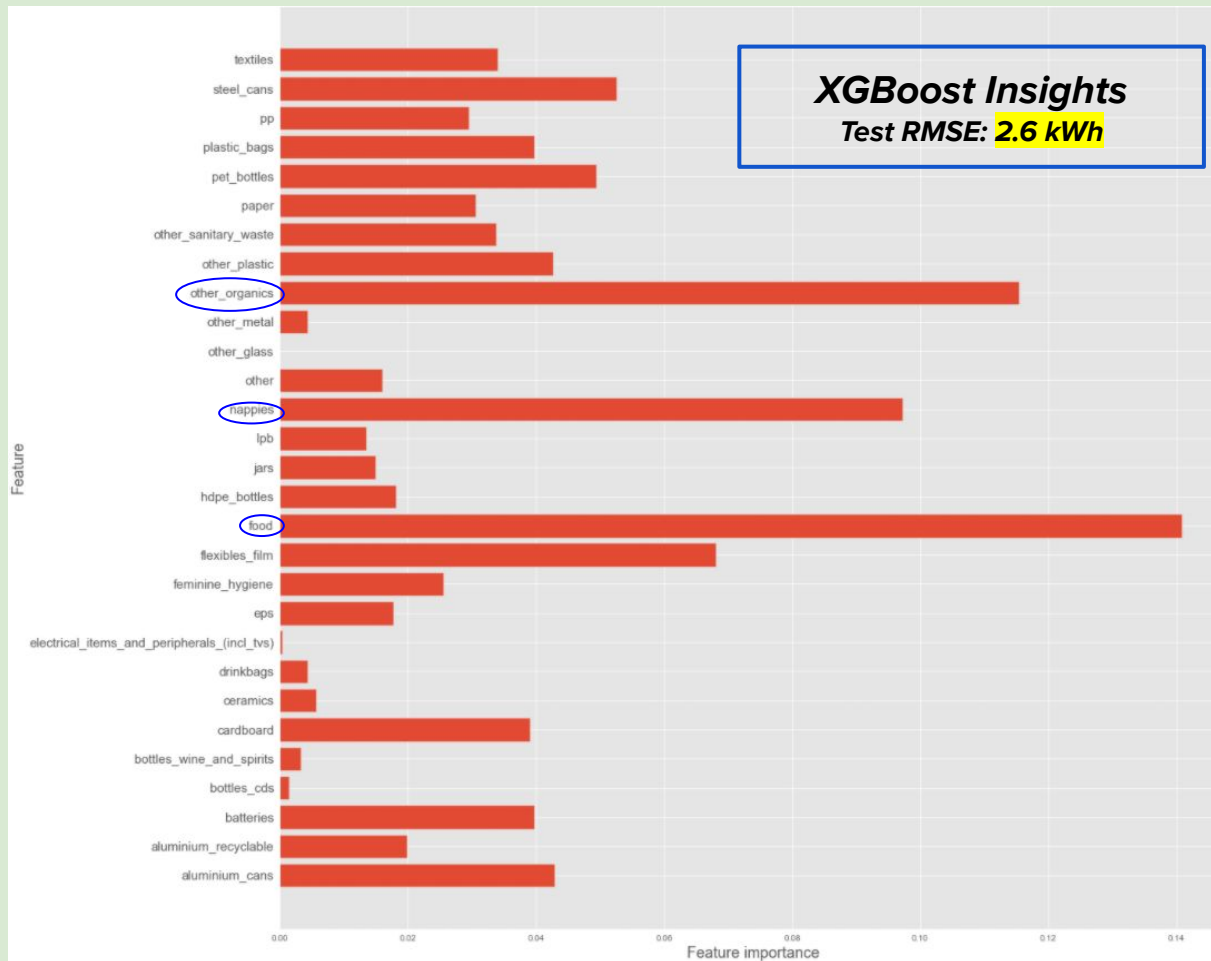
**Trainable Parameters:** 2092

**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.



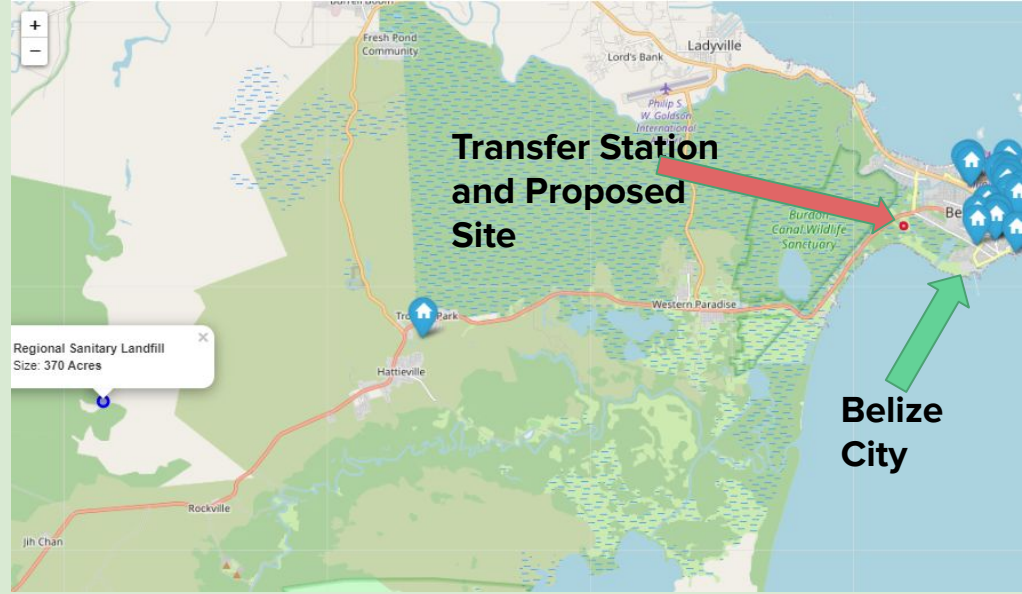
# Spotlight: Belize City

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# 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!

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