A Life Cycle Assessment of a Self-Sustainable Renewable Energy Ecosystem

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Introduction

The sustainability of aviation directly depends on the availability of environmentally responsible fuel. With the growing gap between production and demand, increasing prices, and concentration of known fuel reserves in politically unstable regions; biofuels are considered a viable alternative to securing the future of aviation. Biofuels are a renewable energy source, which could be customized to meet specific fuel needs, including jet fuel which requires high performance characteristics. NASA GRC has initiated a pilot program to develop in-house capabilities to study two principal sources of biofuels: sea water algae, and arid land halophytes (salt-tolerant plants). This study will perform a life cycle assessment (LCA) of the research facility in order to determine if the overall impact of the GreenLab is influential and financially beneficial.

NASA's GreenLab Research Facility Practices

Qualifications to be eXtreme Green:

- Sustainable
- +
- Alternative
- +
- Renewable

The Big Three Rule: Criteria for plant selection

1) **No Food Crops**
   Corn, soybeans, sugarcane, etc…
2) **No Arable Land**
   Competes with food crops
   47% of land is non-arable
3) **No Fresh Water**
   Competes with human consumption

→ **Halophytes & Algae**
Beach Sand
Saltwater

97.5% of the Earth's water is saline
Of the 2.5% fresh water, <1% is accessible for direct human uses

Biofuel Sources

Halophytes:

- High-lipid content
- Salt-tolerant
- Easy to cultivate
- Food-fuel feedstock


Seashore mallow


Micro-Algae Systems


Salicornia virginica


Salicornia bigelovii


Salicornia europaea


Salicornia subterminalis

➔ **Identified four optimal halophytes species out of 26 potential candidates worldwide.**

Climatic Adaptation

Halophyte species were gradually acclimated to the varying salinity values.

Use the wastes of fresh water mollies for plant nutrients.

No Chemical Fertilizers

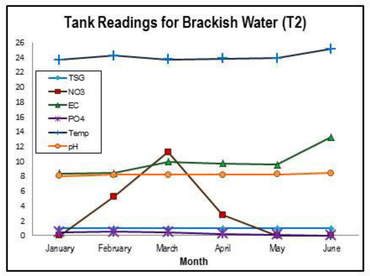
Brackish Water – "Brazil"

Salinity: 1.005 TSG

Halophytes:

- Seashore mallow
- *Salicornia europaea*
- Red & black mangroves
- *Salicornia virginica*
- *Lena camelina*

Algae bloom



Chaetomorpha sp. Macro-Algae

- Absorbs excess nutrients like NO_3^- and PO_4^{3-}
- Same consistency of plastic ~> biodegradable plastic

Testing growth parameters:

- Control
- Excess CO_2
- Direct lighting
- Indirect lighting
  - Mass weighed weekly

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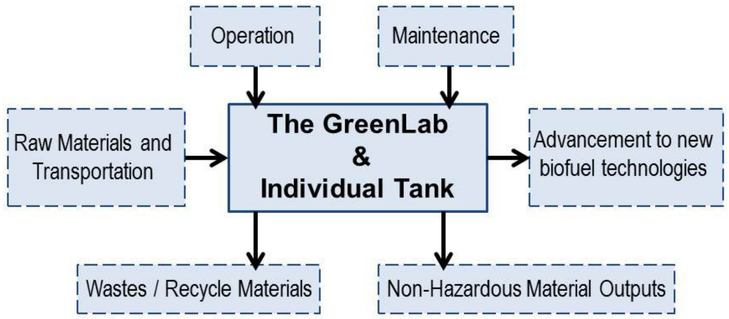
Life Cycle Assessment (LCA)



Financial Benefits:

- NASA FY 2013 budget estimate: = $19.96 B
  - For Science = $ 5.51 B (0.0018%)
  - For Aeronautics = $ 1.65B (0.0061%)
    - For Aeronautics and Green Aviation: $20 million/yr
    - Non-NASA cost: $625,000 to remove / 1.2 million to relocate

  Only $100,000/yr to keep GreenLab running
- Foreign oil- $114 billion dollars/yr
  - 40% Biofuels supplements ~> $46 billion/yr

GreenLab Benefits:

- GreenLab tours to ~ 1,500 students/year (K-12th grade)
- STEM Degrees:
  - Growth in STEM jobs 3 times more than other occupations
  - Earn 26% more than non-STEM workers
    - $550/credit hour ~ $66,000/STEM Degree
    - Average STEM earnings = $80,000/yr
  - Inspire 20% of the students, improve economy by ~ 4 million dollars in a year.

Conclusion

- Optimal parameters for algae growth
  - Direct light source
  - Dirt accumulation
- Benefits vs. Costs of the GreenLab
  - Remove foreign dependency and improve economy
  - Advancing STEM education
    - In 3 years ~ 4,000 people visit the GreenLab
    - 40 summer interns
    - 5 university professors
    - Green Explorer Educators (2nd – 12th grade) ~ 3,100
  - Costs to remove or relocate > costs to run the GreenLab

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