WPI

Algae Biofuel Enhancement Project

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Abstract

Fossil fuels are a limited resource that will eventually be depleted; an alternative must be found and implemented in order to supply the world's energy needs.[11] The high cost of growing algae with Photobioreactors (PBR) decreases it's attractiveness as a possible alternative to fossil fuels leaving room for improvement.[3] Overall, algae biofuels offer a clean, natural form of energy that can be helpful to the environment and to humanity.[6][8] Algae growth removes CO2, cleans wastewater, and is able to grow extremely fast.[2][4] If no alternative to fossil fuels is used, CO2 levels will continue to rise exacerbating global warming.[11] To find the right system, we propose using a universal scale of comparative values that will shift the industry in the right direction.

Background

PBR systems are the most efficient way of extracting algae and the most diverse when it comes to algae strain choice.[2][4] Since the entire system is closed it allows the use of almost any algae and can grow the algae at a very fast rate. [1][9] The cost prevents the growth of algae biofuel as a whole.[3] With hundreds of PBR systems known today the possibility of creating new and more advanced systems promises a great outlook for the future of algae biofuel.[11] Therefore, our dependency on oil will simply shift from fossil fuels to algae-based renewables.

Algae Biodiesel

High oil prices and advances in biotech over the past decade have refueled the algae biofuel race.

The process

1. After initial growth, algae is deprived of nutrients to produce a greater oil yield

2. Extraction of oil — A press produces 70-75% of their oils from the plant

3. Solvents used to separate sugar from oil; solvents then evaporate

4. Oil is ready — Can be used as oil directly in diesel engines or refined further into fuel

Sunlight
CO2
Water
Screw press
Algae
Oil

Yield of various plant oils
(Gallons per hectare)

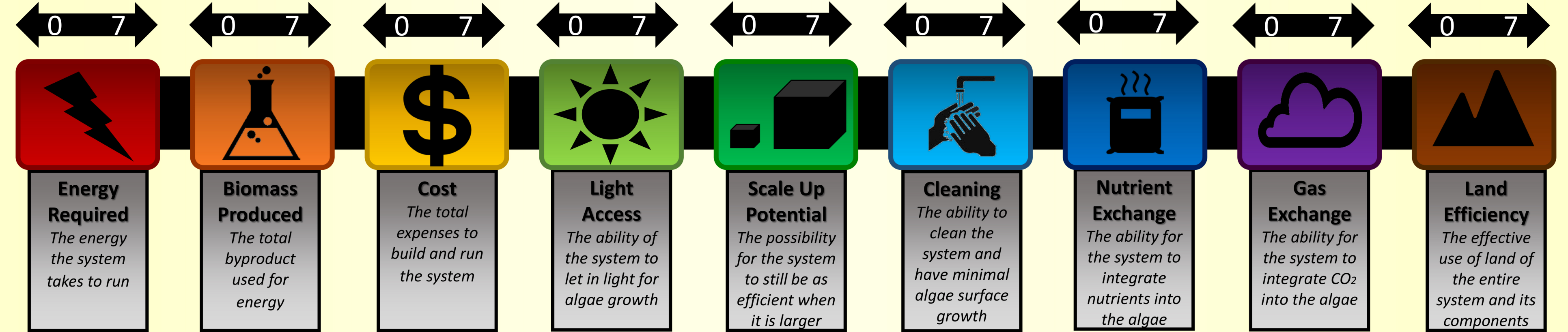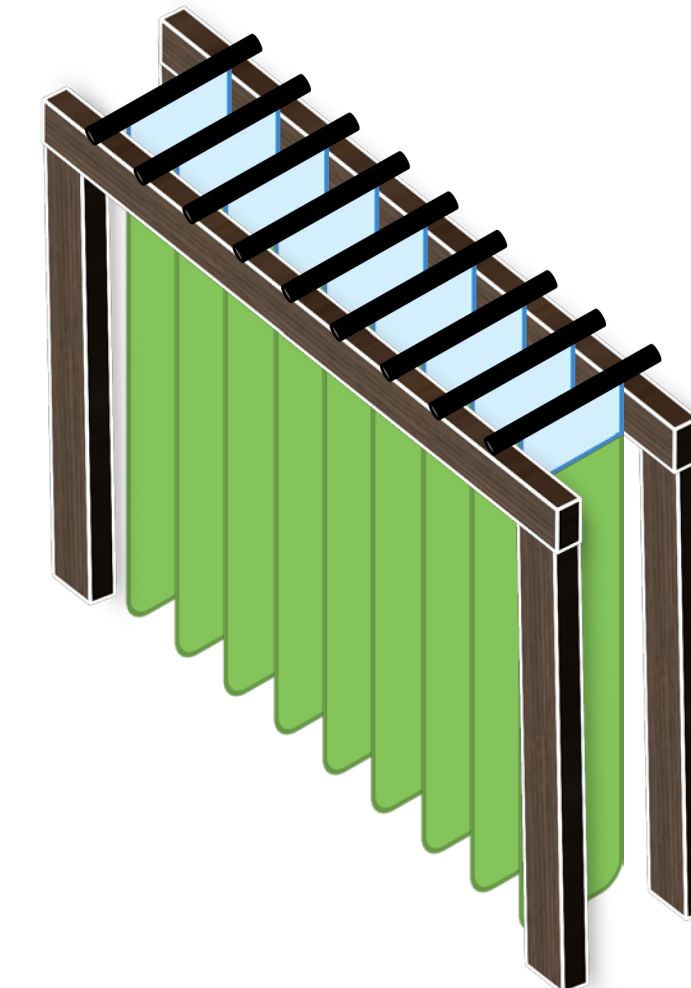|	
Soy	118
Safflower	206
Sunflower	251
Castor	373
Coconut	605
Palm	1,572
Algae	26,417
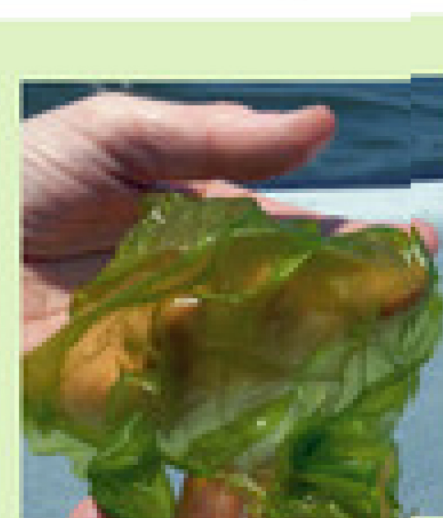
About algae
- Among the fastest growing plants; about 50% of their weight is oil
- Contains no sulfur; non toxic; highly biodegradable
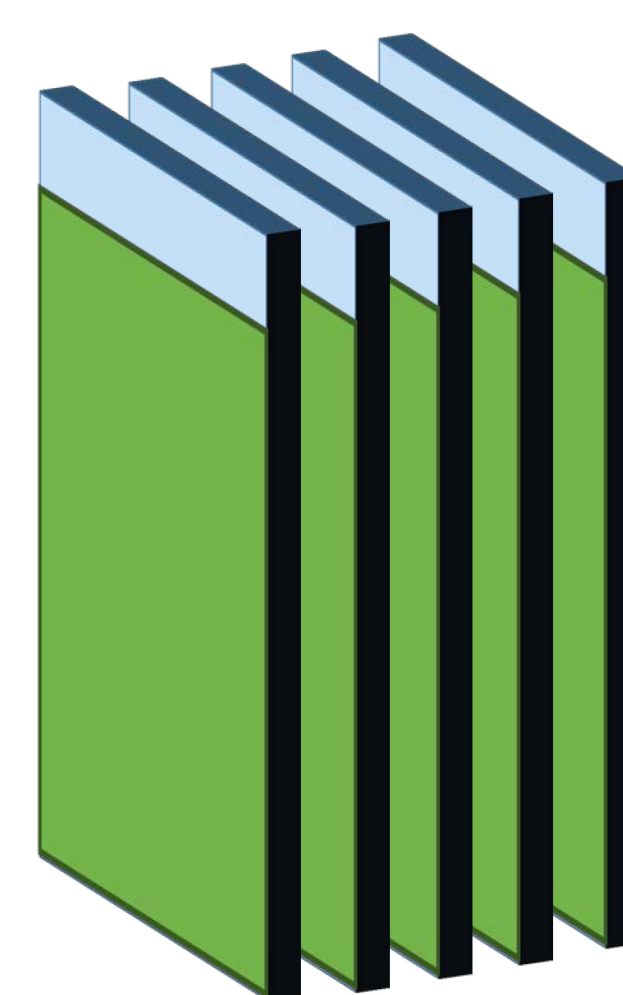- Algae fuel is also known as algal fuel or oilgae
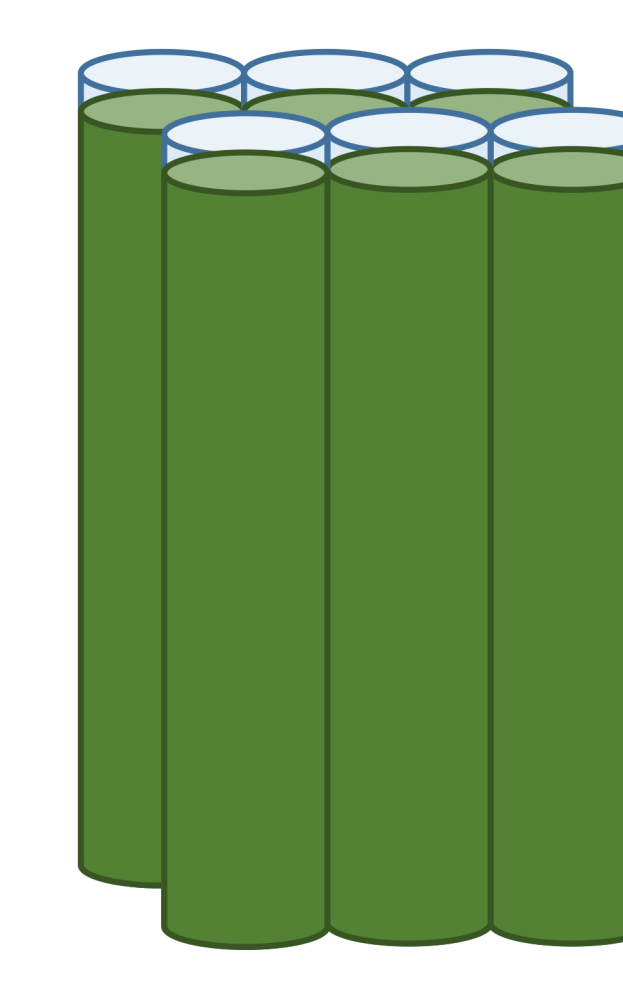
The ABEP Percentile Scale

Energy Required	Biomass Produced	Cost	Light Access	Scale Up Potential	Cleaning	Nutrient Exchange	Gas Exchange	Land Efficiency
The energy the system takes to run	The total biomass used for energy	The total expenses to build and run the system	The ability of the system to let in light for algae growth	The possibility for the system to still be as efficient when it is larger	The ability to clean the system and have minimal algae surface growth	The ability for the system to integrate nutrients into the algae	The ability for the system to integrate CO2 into the algae	The effective use of land of the entire system and its components

BAG CONTAINMENT
68 — 5, 7, 2, 5, 4, 7, 5, 4, 4

HORIZONTAL TUBULAR
65 — 4, 3, 5, 2, 5, 5, 6, 5, 5

PANEL
59 — 2, 4, 3, 3, 6, 5, 3, 5, 6

VERTICAL TUBULAR
51 — 7, 4, 5, 1, 4, 5, 6, 6, 7

AQUEOUS SYSTEM
62 — 4, 6, 4, 4, 5, 7, 4, 3, 3

HYBRID SYSTEM
73 — 4, 5, 6, 2, 7, 5, 7, 6, 4

Project Method

Research

- **PBR systems** [2][3][4][5][6][7][8][10]
  - We narrowed down hundreds of PBR systems to 6 types
    - *Bag Containment, Vertical Tubular, Horizontal Tubular, Panel Systems, Hybrid Systems, Aqueous Systems*
- **Algae strains** [9]
  - We looked at over 50 strains of marine and freshwater algae from the following algal groups:
    - *Diatoms, Green algae, Eustigmatophytes, Prymnesiophytes, Red algae*

Data Collection

- **PBR systems**
  - Energy Consumed, Biomass Volumetric Productivity, Cost, Light Harvesting Capability, Scale Up Potential, Cleaning, Nutrient Exchange, Gas Exchange
- **Algae Strain** [9]
  - Lipid productivity (mg/L/day)
  - Lipid content (% dry biomass weight)

Conclusion

- **PBR System** [3][4][6][7][8][10]
  - The data we collected provided a huge gap between both qualitative and quantitative values
  - So we developed a comparative scaling system to easily understanding
    - ABEP Scale (63 total points scaled out of 100)
    - Eight categories (0-7)
- **Algae Strain**
  - Based on company's characteristics, we were able to narrow down which algae would be the most used [1]
    - Nannochloropsis sp. F&M-M28 [9]
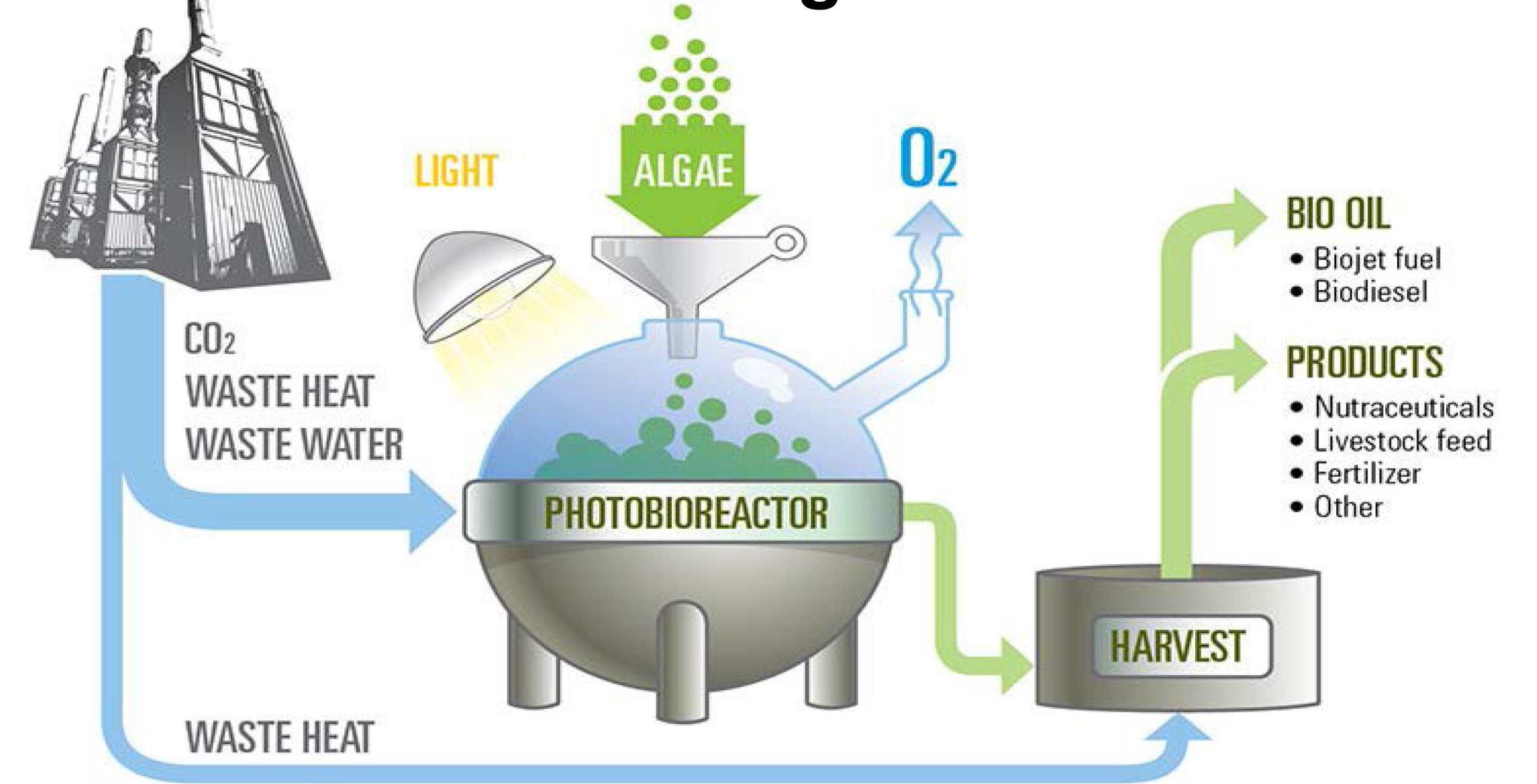
Implementation

- **ABEP Scale for PBRs** [11]
  - Integrate the scaling system or similar system into the U.S. Department of Energy
    - U.S. Energy Information Department

Conclusions

Creating a standard, like any measurement system, starts with getting the U.S. federal government involved. The U.S. government can ensure that all PBR system collects similar data to provide comprehensive analysis with comparable values. The project will then be successful when companies and investors use the government's report to make economic decisions. As a result, adequate investments can be made and the PBR industry can shift towards the system with the highest potential, and largest ABEP value.

Algae Growth Process

LIGHT
ALGAE
O2
CO2
WASTE HEAT
WASTE WATER
PHOTOBIOREACTOR
WASTE HEAT
HARVEST

BIO OIL
- Biojet fuel
- Biodiesel

PRODUCTS
- Nutraceuticals
- Livestock feed
- Fertilizer
- Other

References

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Acknowledgments

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