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Sustainable Utilization of Seaweeds

Hassan I. El Shimi[1] and Soha S. Moustafa[2]

[1]Chemical Engineering Department, Faculty of Engineering, Cairo University (CUFE), Egypt

[2]Microbiology Department, Soils, Water and Enviroment Research Institute (SWERI), Agricultural Research Center (ARC), Egypt

Dubai, UAE in April 26th, 2016

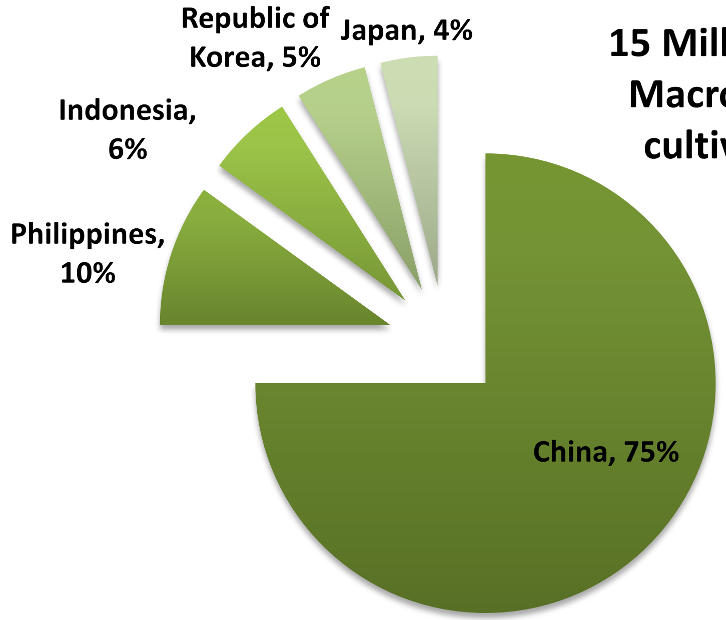
Agenda

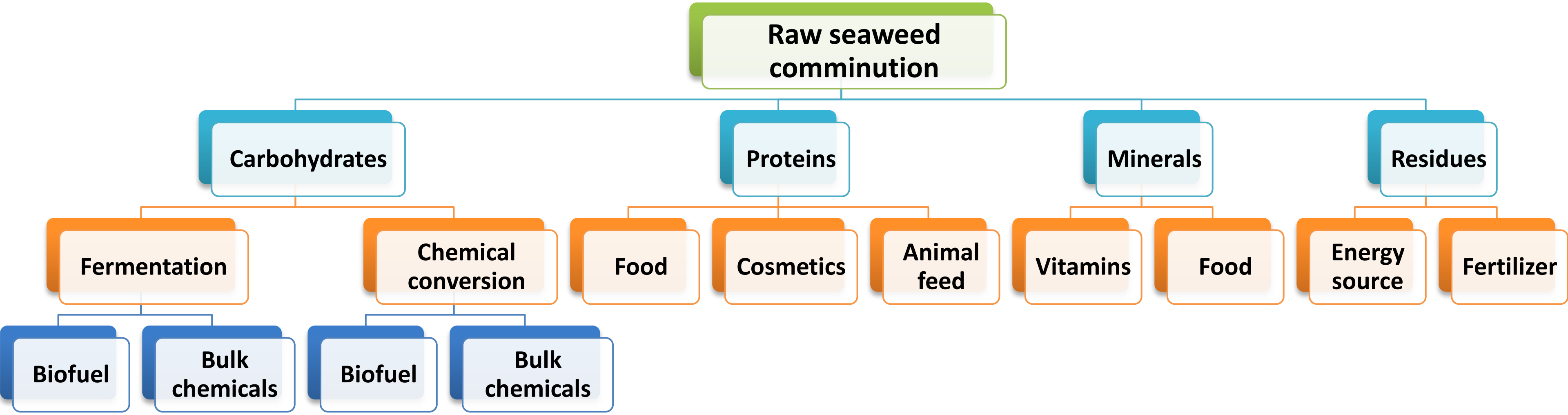
- Introduction to Seaweed “Macroalgae”
- Potentials of Seaweeds
- Nutritional value of Macroalgae
- Energy extraction from seaweed
- Bio refinery and Utilization Paths for Macro algae
- Conclusions
- References

Introduction

- Algae are unicellular and multi-cellular aquatic “plants” and possess chlorophyll without true stems and roots.
- Algae are divided by size into Macroalgae “Seaweed” and Microalgae; microscopic single cell organisms (1µm-100µm).

15 Million Tons of Macroalgae are cultivated per year





- Considerable amounts of algae are accumulated on Seas offshores which resist the ships motion and polluting the people's bodies upon swimming **(Seawater Pollution)**, so it must be removed.
- For **Sustainable Environment**, utilization of marine will be beneficial in energy or cosmetics sectors.

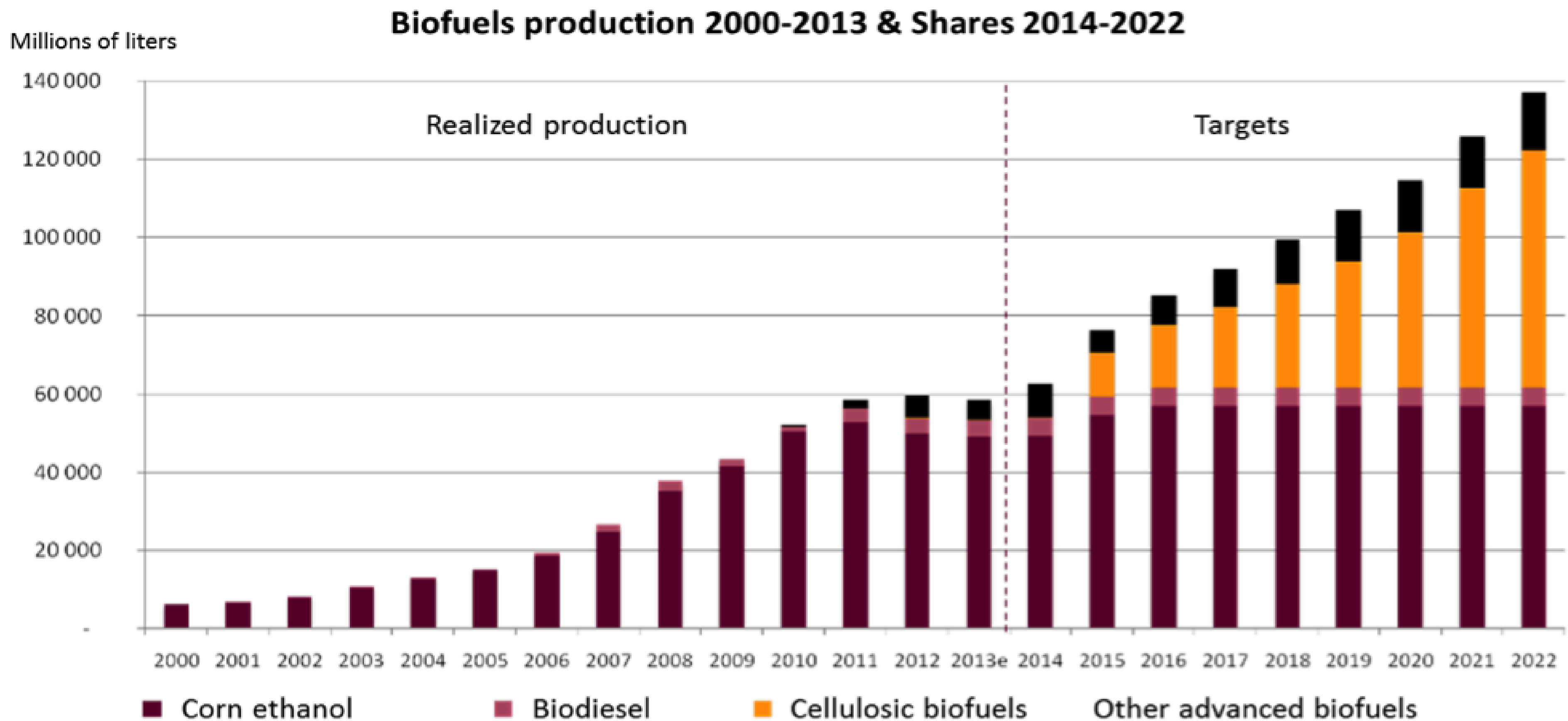
Chemical Constituents of Common Seaweed

	Ascophyllum nodosum	*Laminaria digitata*	*Alaria esculenta*	*Palmaria palmata*	*Porphyra yezoensis*	*Ulva species*
Type	Brown	Brown	Brown	Red	Red	Green
Water (%)	70-85	73-90	73-86	79-88	nd	78
Ash	15-25	21-35	14-32	15-30	7.8	13-22
Total carbohydrates	-	-	-	-	44.4	42-46
Alginic acid	15-30	20-45	21-42	0	0	0
Xylans	0	0	0	29-45	0	0
Laminaran	0-10	0-18	0-34	0	0	0
Mannitol	5-10	4-16	4-13	0	0	0
Fucoidan	4-10	2-4	nd	0	0	0
Floridoside	0	0	0	2-20	nd	0
Other carbohydrates	c. 10	1-2	1-2	nd	nd	nd
Protein	5-10	8-15	9-18	8-25	43.6	15-25
Fat	2-7	1-2	1-2	0.3-0.8	2.1	0.6-0.7
Tannins	2-10	c. 1	0.5-6.0	nd	nd	nd
Potassium	2-3	1.3-3.8	nd	7-9	2.4	o.7
Sodium	3-4	0.9-2.2	nd	2.0-2.5	0.6	3.3
Magnesium	0.5-0.9	0.5-0.8	nd	0.4-0.5	nd	nd
Iodine	0.01-0.1	0.3-1.1	0.05	0.01-0.1	nd	nd

Algae as sustainable future source for biofuel

- Algae don not require agricultural land for cultivation as terrestrial crops investigated for biofuel production.
- Many species grown on brackish and saline water (1kg biomass requiring $1m^3$ wastewater) avoiding food competition which required fresh water.
- The biomass yield of algae per unit area is higher than that of terrestrial crops; e.g. brown seaweeds having yield of 13.1kg dry biomass compared to 10kg for sugarcane.
- Algae convert CO_2 to biofuel (biodiesel, bioethanol and bio butanol) and other chemical feedstocks so, they described as **potential sunlight-driven cell factories.**

Algae as sustainable future source for biofuel



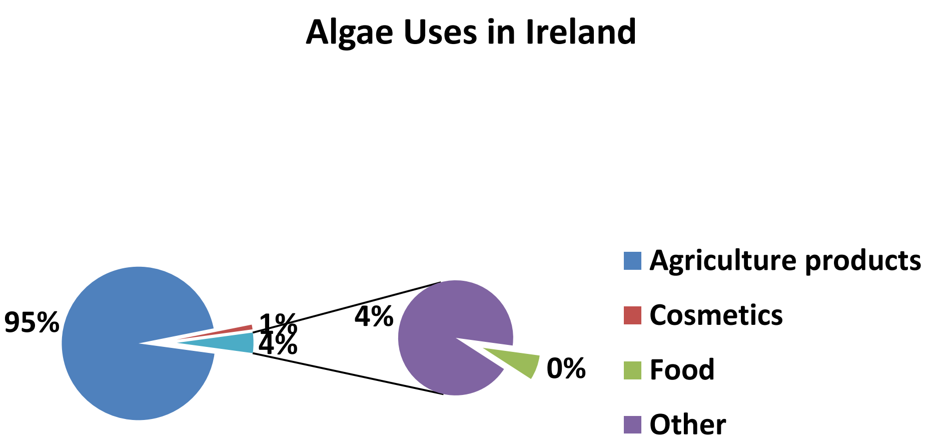
NB: Shares for biodiesel have not yet been fixed for the period 2014-2022, the shares used are those proposed for 2014 and 2015.
Sources: United States Environmental Protection Agency, United States Energy Information Administration

Algae Business (AB)

- Up to now, no economically-viable commercial scale fuel production from micro- or macroalgae; because of the lower Energy Return on Investment (EROI) compared to petroleum products.
- Considering full spectrum of products that might be extracted from algal biomass in addition to biofuels, in so-called **"Bio refineries"** could enhancing the algae business.
- Today the global utilization of (non-fuel) products obtained from macroalgae is a multi-billion dollar industry, and Asia is the main market.

Algae Business (AB)

- Current uses of seaweeds include human foods, fertilizers, cosmetics ingredients and phycocolloids.
- Worldwide 221 species of macroalgae are known to be exploited by humankind, in which 66% of the species used as food with 86000 tons production rate.
- *Luminaria* (reclassified as *Saccharine* for some species), *Undrain*, *Porphyria*, *Euphemia*, and *Gracilaria*, representing 76% of the total tonnage for cultured macroalgae.



Health Benefits of Seaweed

Dietary Fiber 1%

Carbo-hydrate s 2%

Nutrients

Protein 12%

Calories 2%

Vitamin C 65%

Vitamin A 100%

Vitamins

Minerals

Mn 49%
Fe 10%

Cu 13%
K 10%

Minerals & Vitamins rich

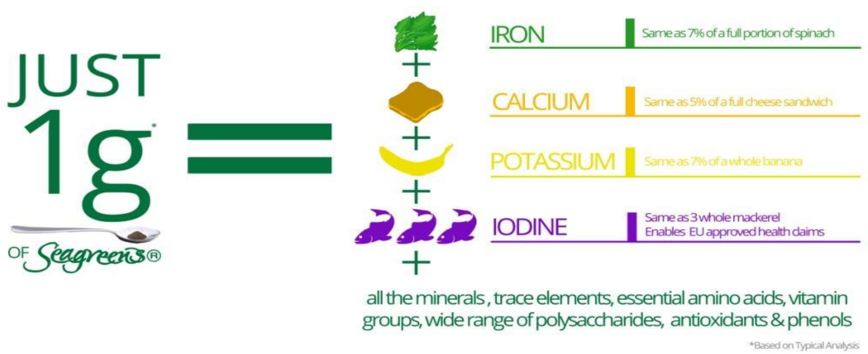
Mood balancing properties for women

Helps to strengthen eyes and hair

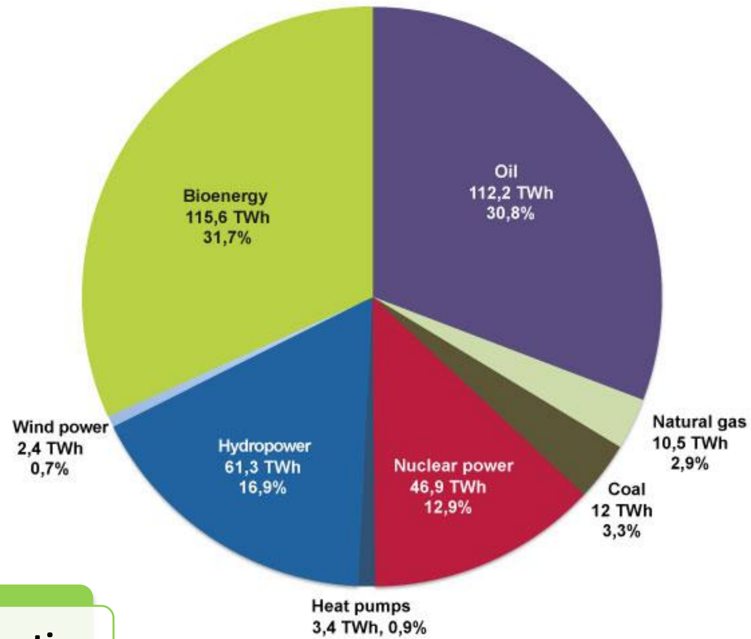
Used in soups, salads & eat it on its own

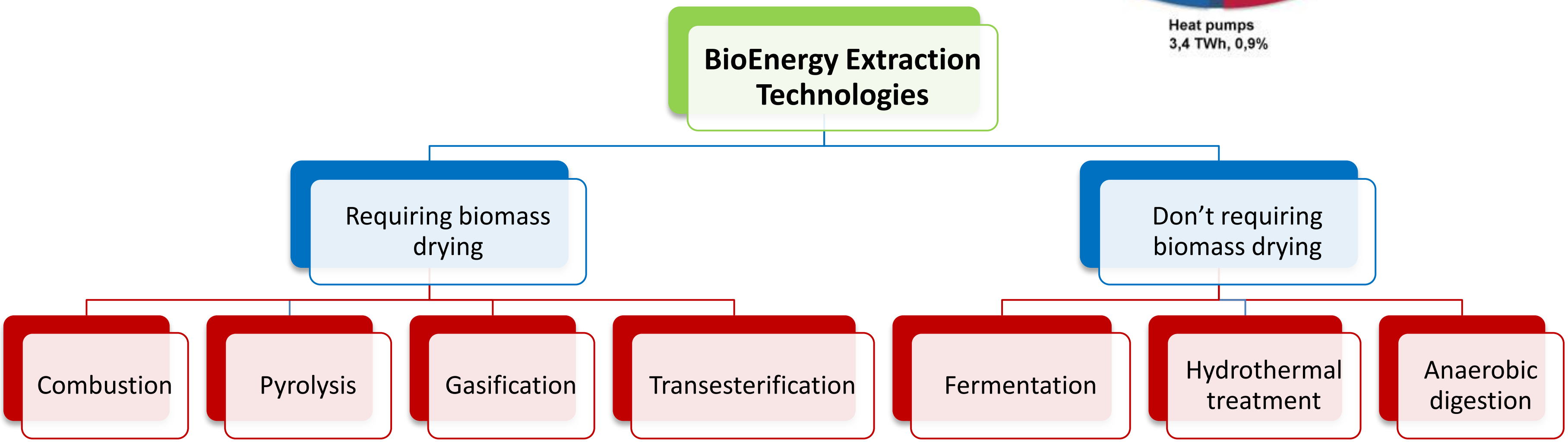
Aids in reducing accumulation of fats and aids in weight loss

Helps to prevent colon cancer and helps to detoxify and cleans body



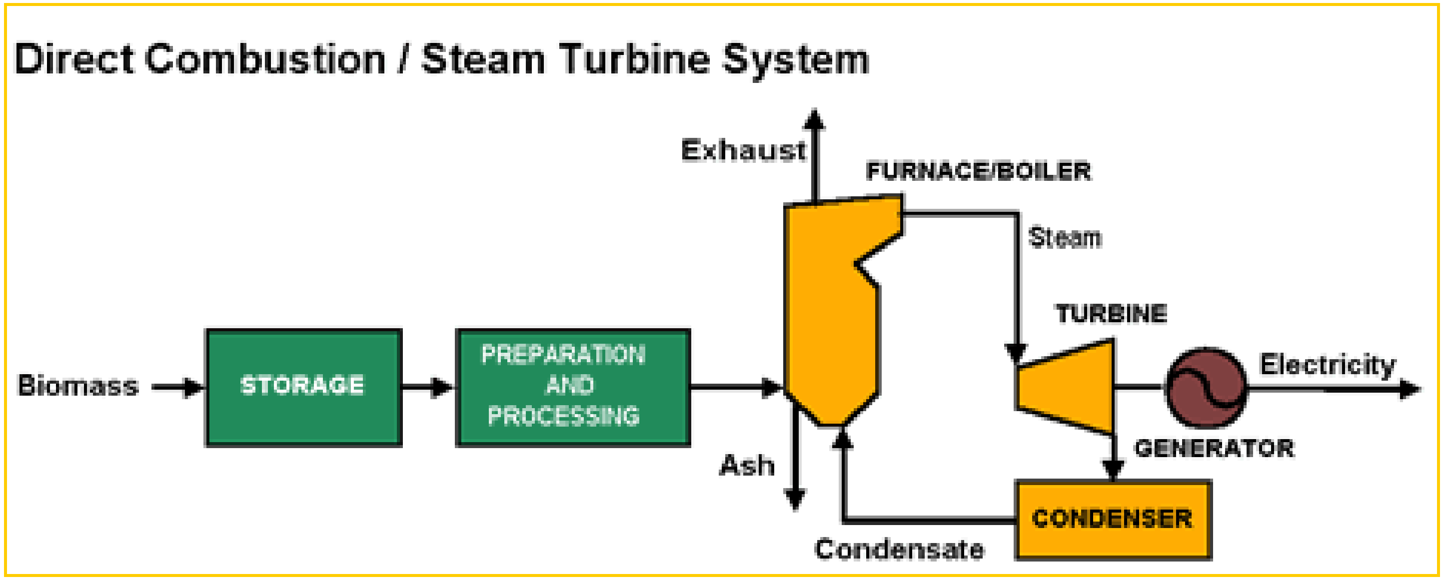
BioEnergy Extraction from Macroalgae





Direct Combustion

- Historically, direct combustion of biomass is carried out to generate heat or steam for household and industrial uses or electricity production, but it isn't yet applied for macroalgae due to the low thermal value (14-16 MJ/kg).
- Seaweed moisture content may reduce the heat available by 20%, and CANNOT be exceed 50% for direct combustion fuel.
- Macroalgae e.g. *Laminaria* has ash or residues up to 33% after firing which is too high compared to 0.5-2% for wood. This algal ash lead to boilers fouling and detrimentally impacts on the overall process efficiency.



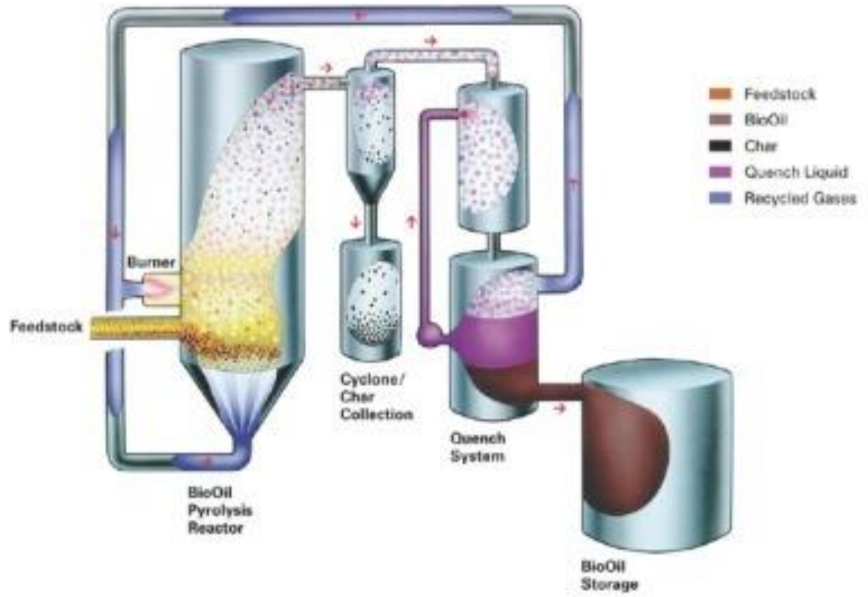
Direct Combustion

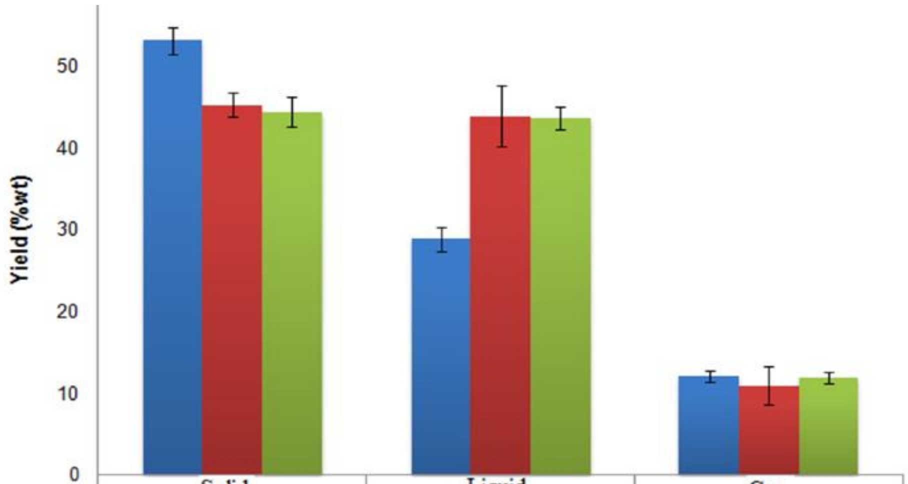
- High Sulphur content (1-2.5%) and N_2 (1-5%) contents of Seaweed will also hinder its utilization as a direct combustion fuel.
- Fluidized bed boilers are suggested to fire marine biomass, and the particle size has to be ground down to <0.18 mm in order to minimize “heat-transfer resistance”.

Co-combustion of seaweed in coal-fired plants is attractive option to improve the process economics and generate electricity, but that requires local heat demand.

Pyrolysis

- Thermal conversion (destruction) of organic biomass in absence of air producing biogas, biooil and char.
- By temperature and process time, pyrolysis is classified as slow (<400°C for days) , fast (=500°C for min.) and flash (>500°C for sec.).
- Fast and flash pyrolysis has potential of commercial biofuel production from seaweed as bio-oil is the main product (70-80%).
- Bio-oil composition depends on biomass type and pyrolysis protocol.

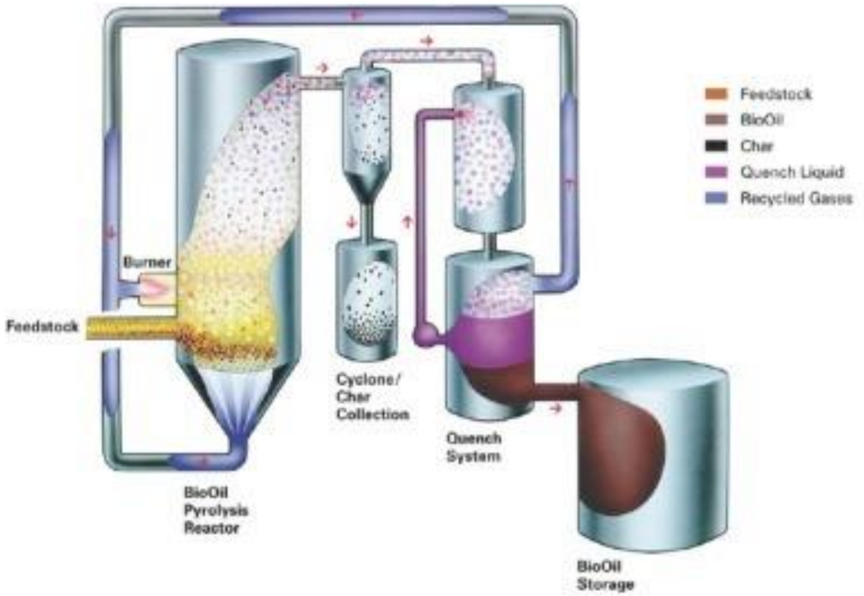


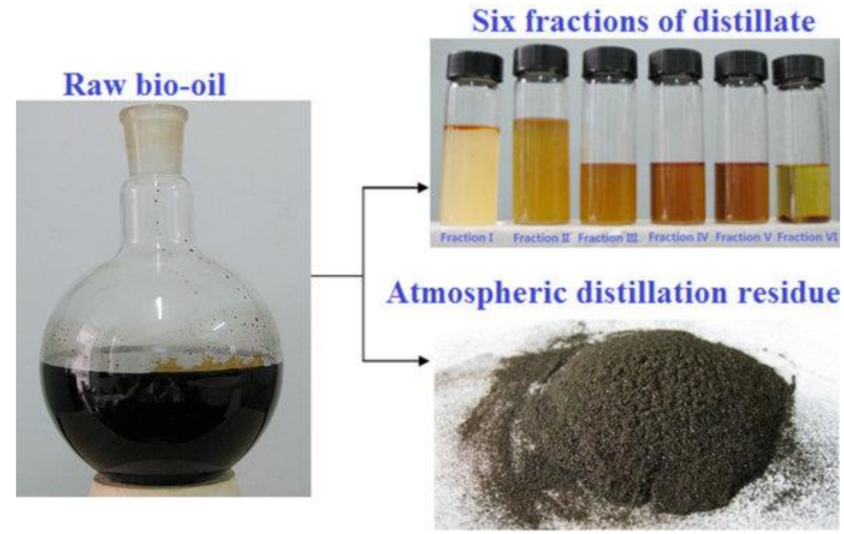


	Solid	Liquid	Gas
400°C	53.1	28.8	12.0
500°C	45.2	43.9	10.9
600°C	44.4	43.6	11.8

Pyrolysis

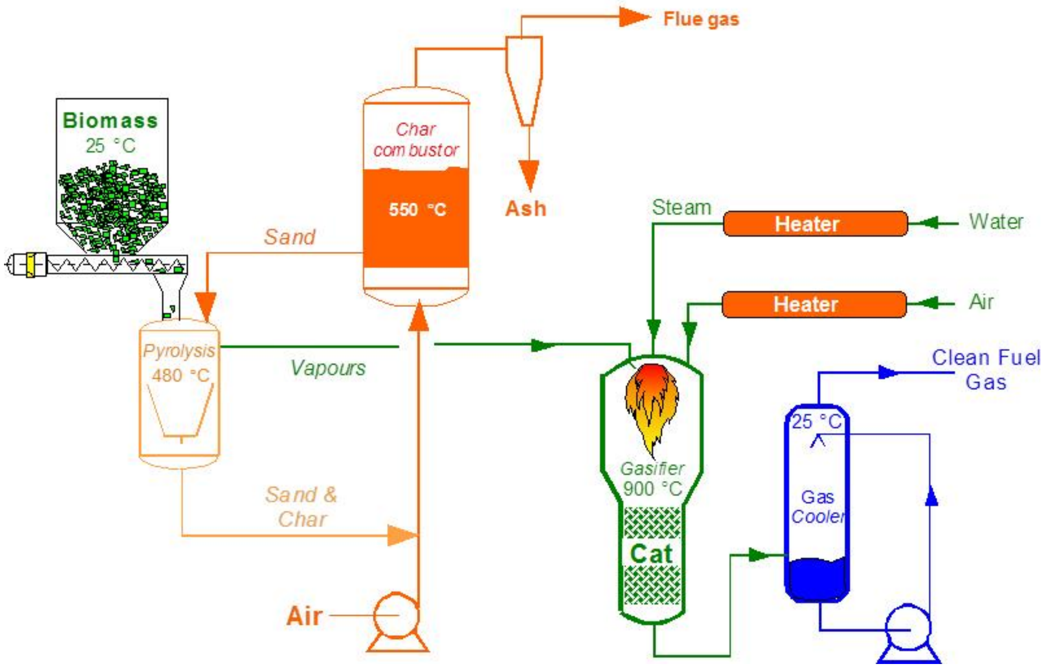
- Algal bio-oil is complex mixtures of highly oxygenated organic compounds, polar, viscous and corrosive, so it is unstable and unsuitable for use in conventional fuel engines unless refined.
- Bio-oil refining has possibility of chemical and food products.
- Pyrolysis in presence of solvents liberates biofuels with different properties, e.g. *Enteromorpha prolifera* at 300ºC with VGO gives Hydrocarbons, while in presence of Ethanol gives Oxygenated Products.
- Better bio-oil quality is obtained from pyrolysis of *Chlorella with yield 55% as HHV of Chlorella and its bio-Oil was 23.6 and 39.7 MJ/kg dry weight.*





Gasification

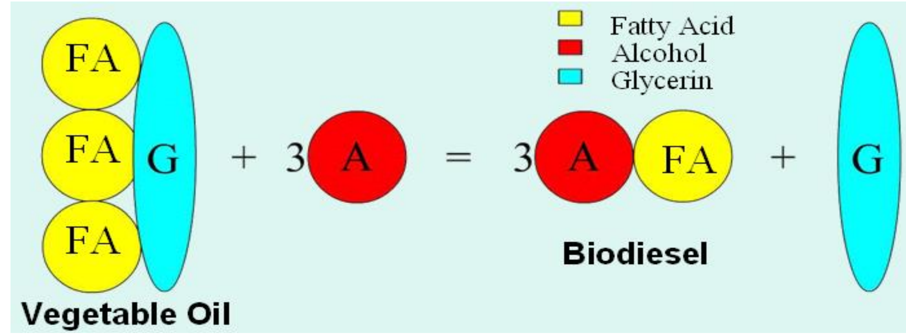
- Thermal conversion (partial oxidation) of biomass at elevated temperatures (800-1000ºC) into combustible gas mix (Syngas) with CV of 6MJ/m³. It composed of H_2 (30-40%), CO (20-30%), CH_4 (10-15%) and C_2H_4 (1%).
- Syngas can be burnt to produce heat or electricity in combined gas turbine systems, or as feedstock for CH_3OH and H_2 production as a transport fuel but, it is still non-economic.



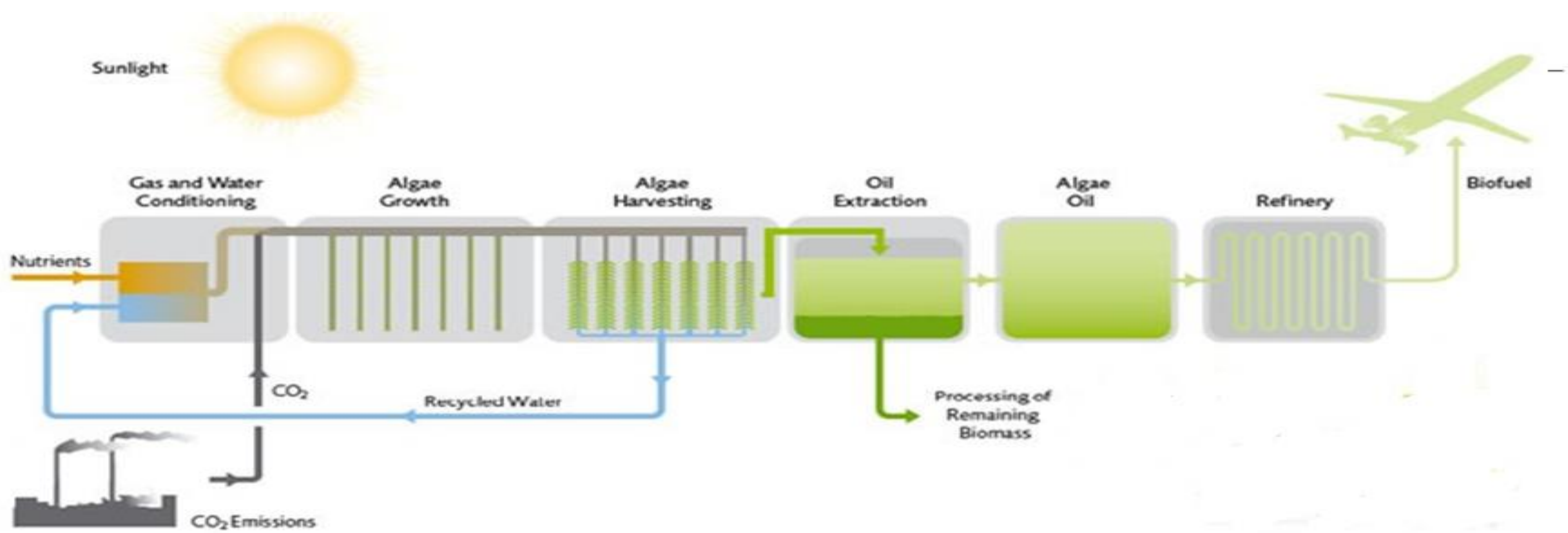
Syngas from macroalgae gasification can be converted catalytically into Hydrocarbons through **Fischer-Tropsch Synthesis (FTS)**

Transesterification

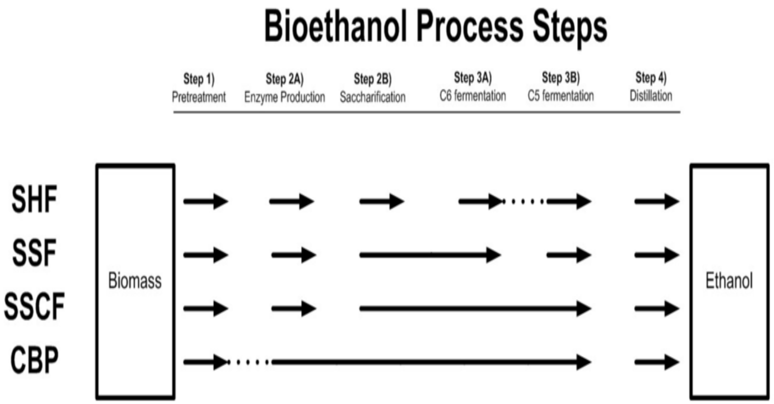
- It is a reaction between the algal lipids and alcohol (e.g. methanol) in presence of catalyst to yield fatty acid alkyl esters (biodiesel) and crude glycerol.
- This is usually achieved for Microalgae NOT Macroalgae.

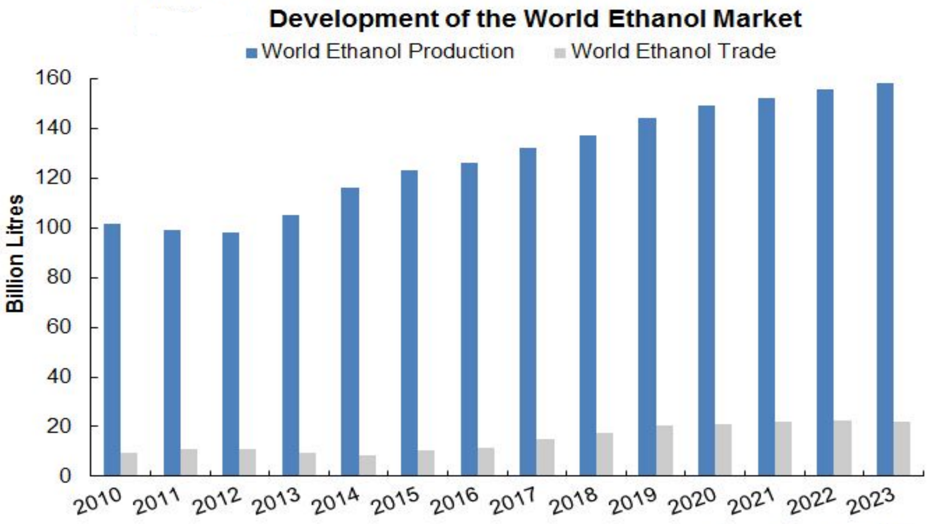


Microalgae → In-Situ Transesterification → Biodiesel Upgrading → Petrochemicals

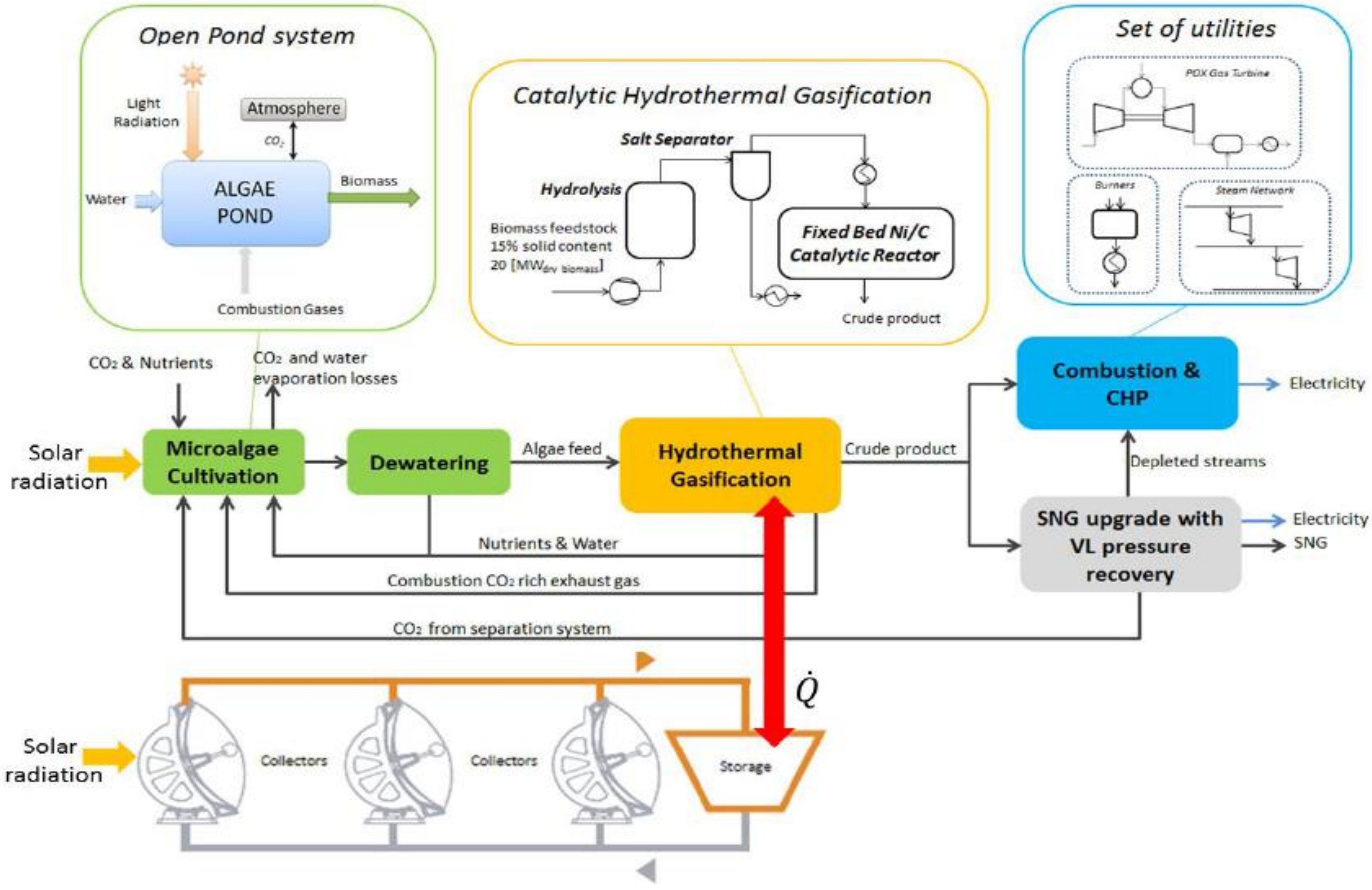


Fermentation



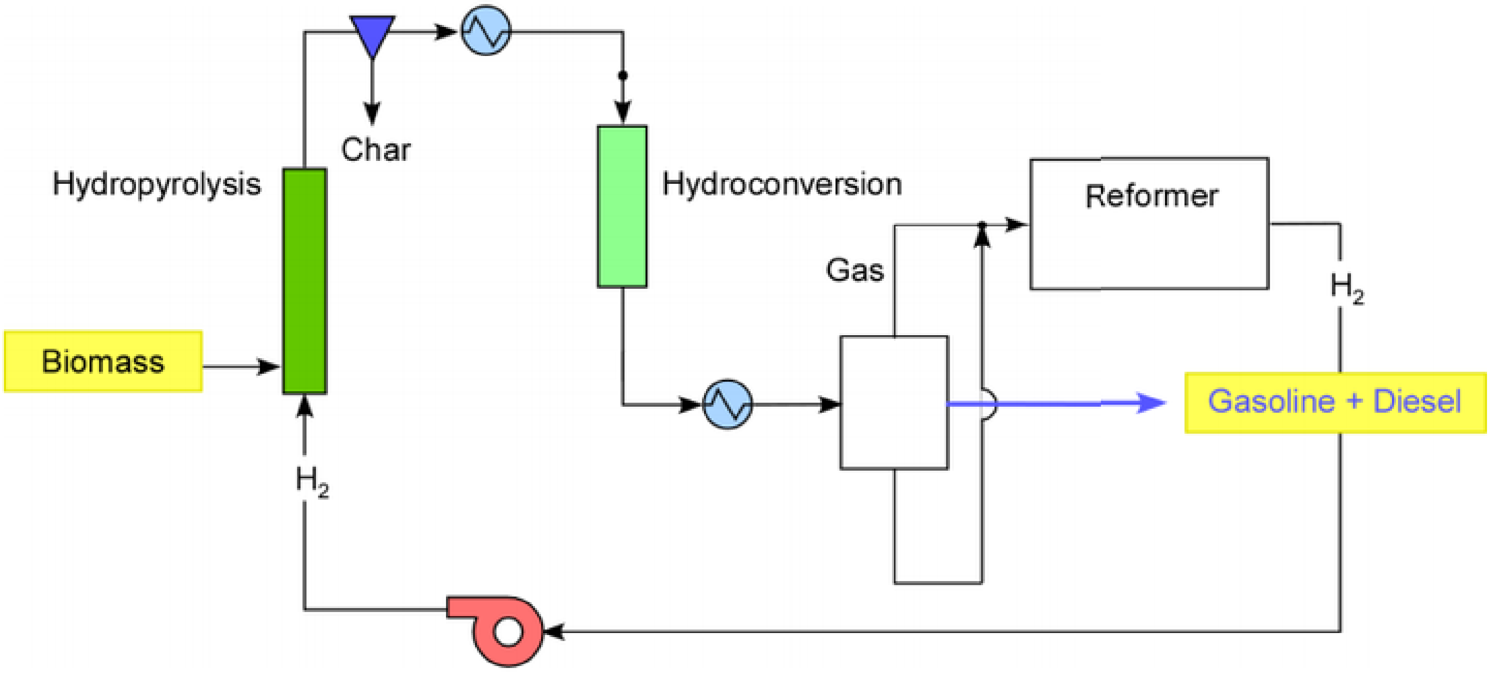


Hydrothermal Treatment

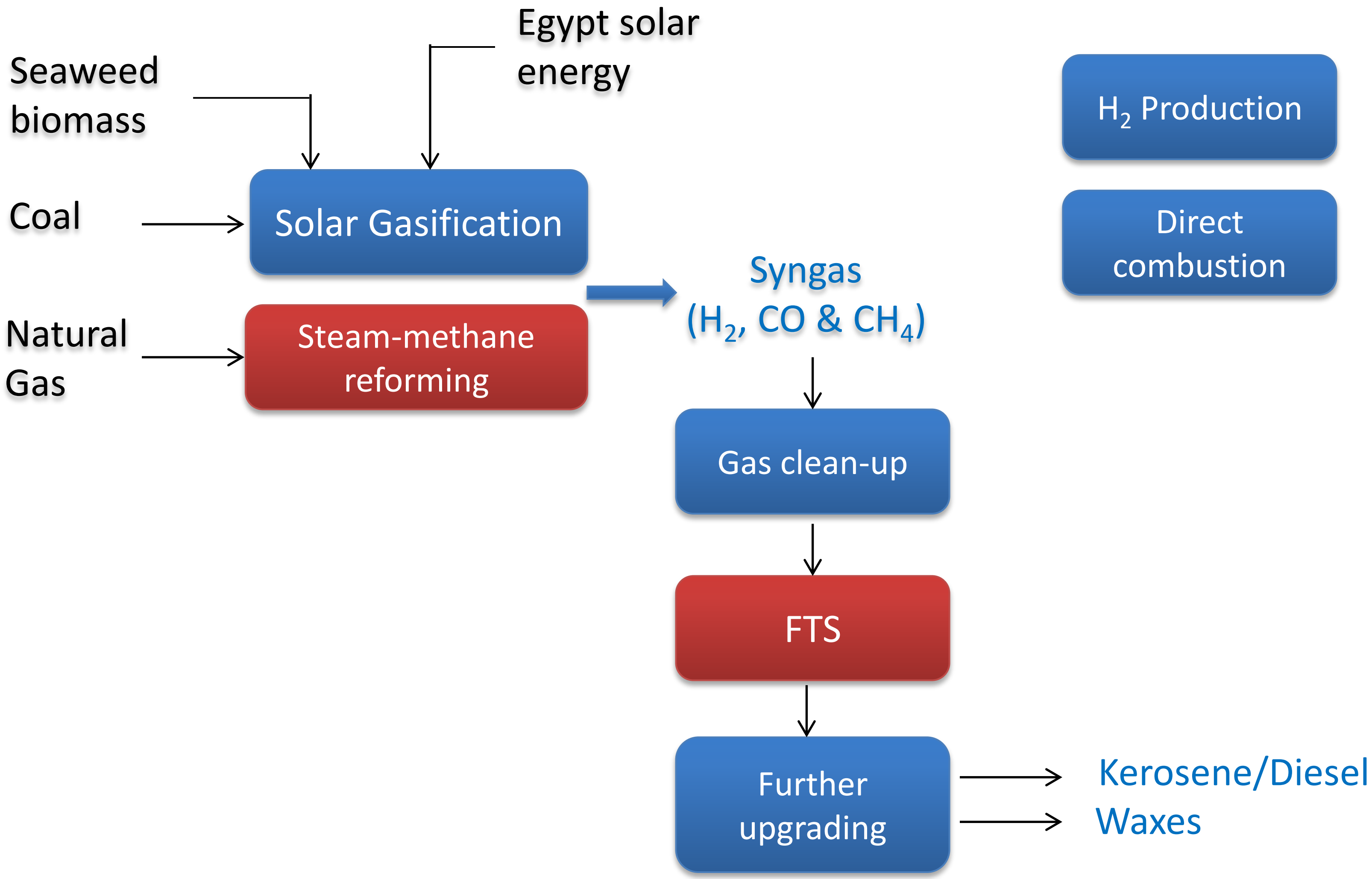


Integrated Hydro pyrolysis

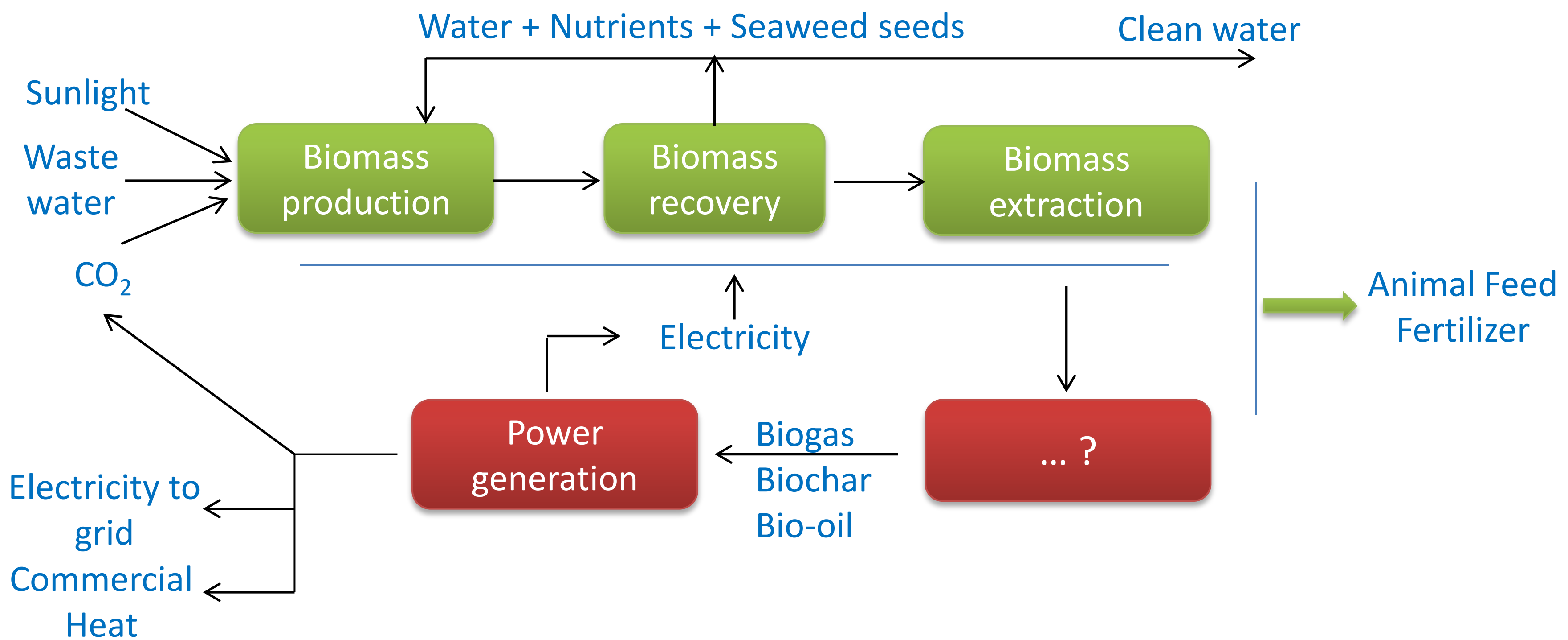
Directly make desired products.
Run all steps at moderate H_2 pressure (100-500psi).
Utilize C1-C3 gas to make all H_2 required,
Avoid making "bad stuff" made in pyrolysis.



Bio refinery and Utilization Approaches

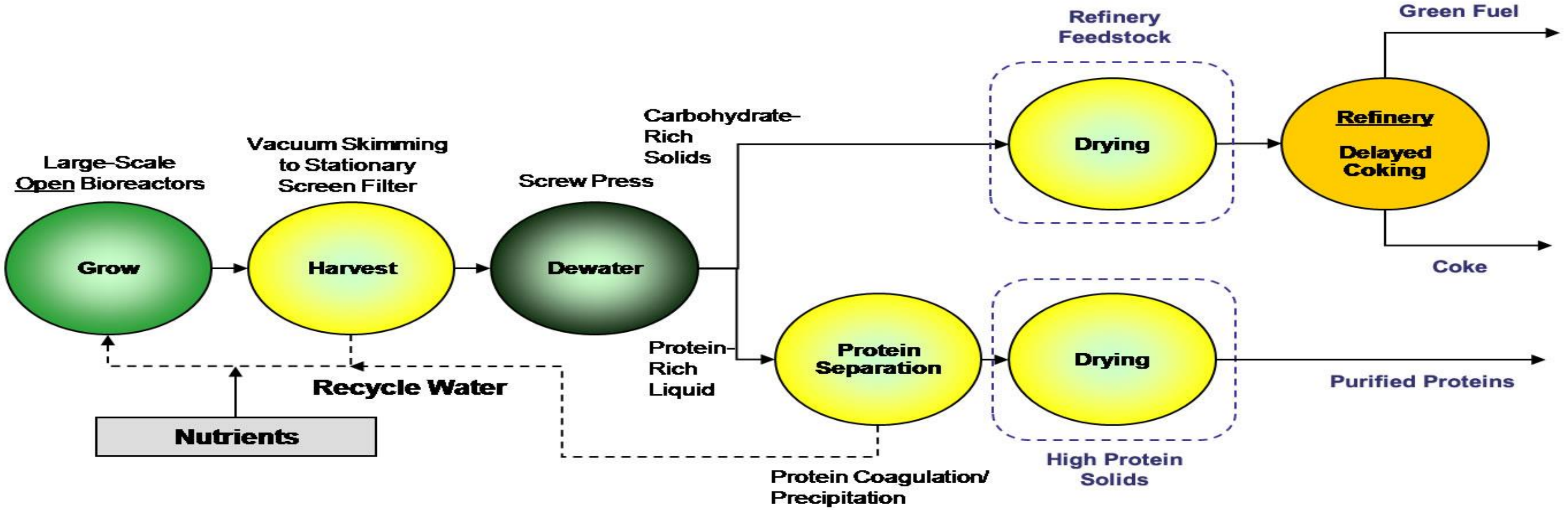


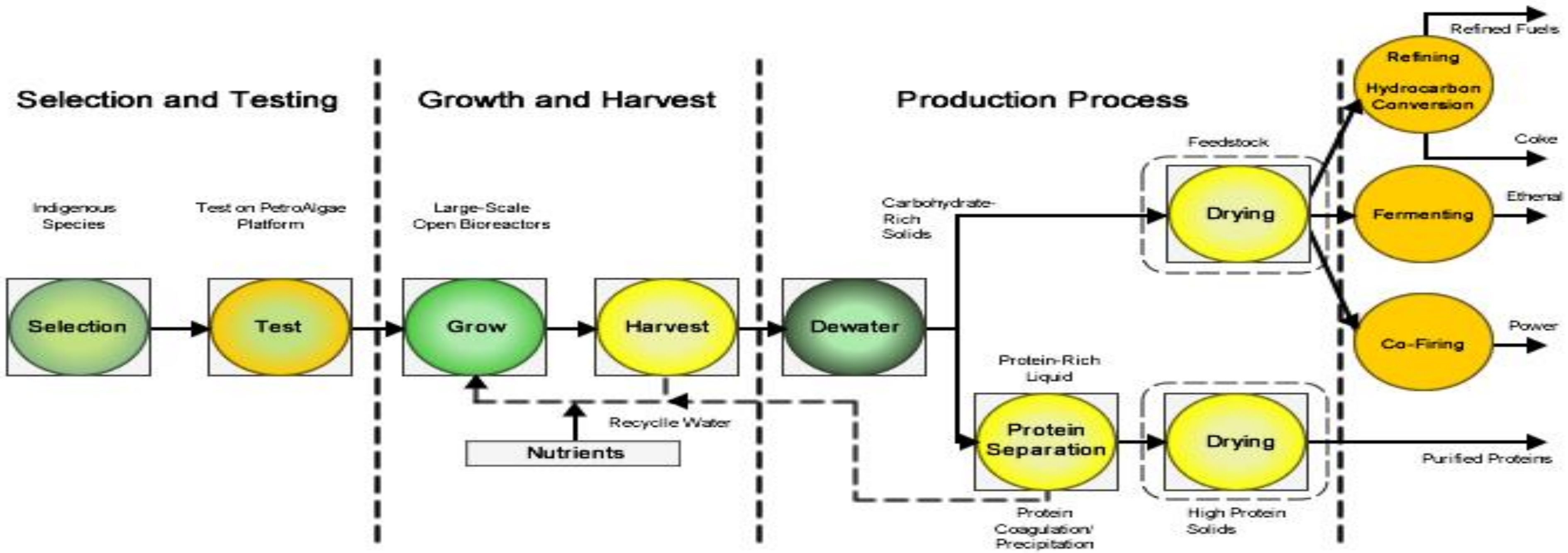
Bio refinery and Utilization Approaches



Integrated Uses of Algal Biomass

Bio refinery and Utilization Approaches

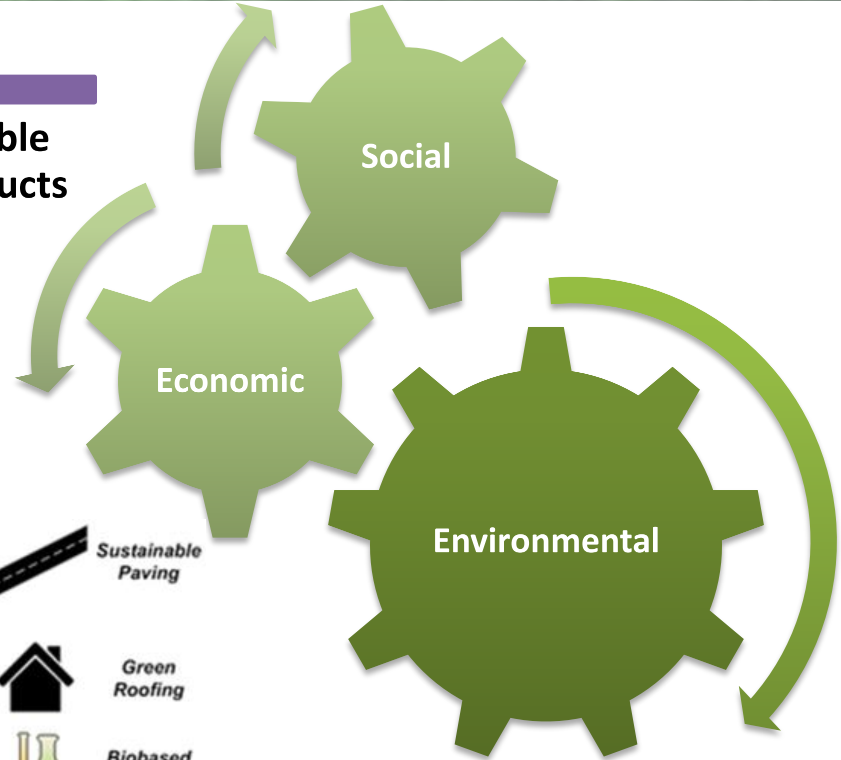


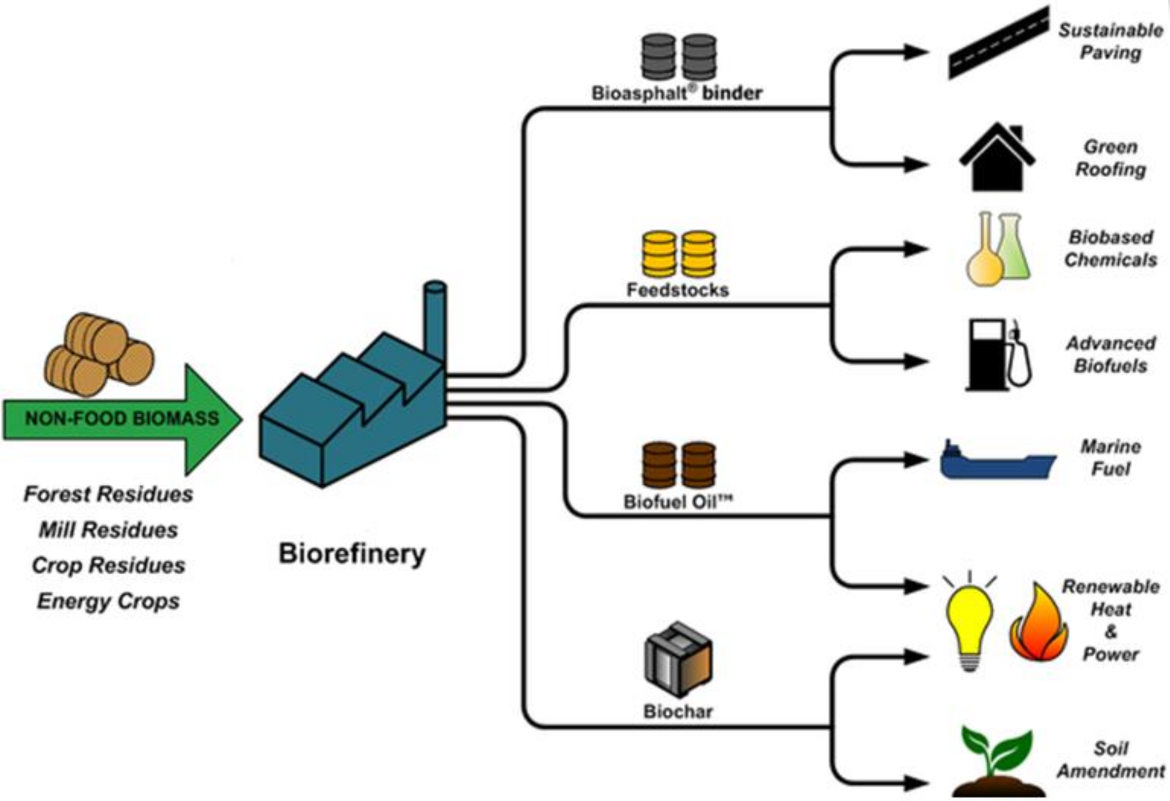


Sustainability

Sustainable Business Organizations participate in environmentally friendly or **green practices** in order to make certain that all processes, products and manufacturing activities sufficiently address **current environmental concerns** while still retaining a **profit**.

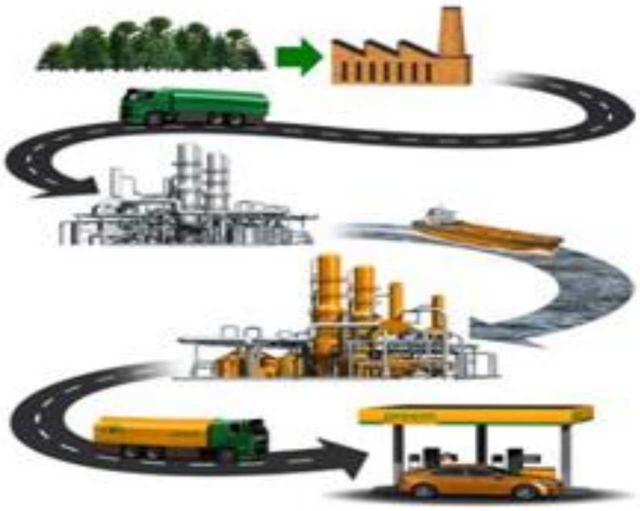
Marine Sustainable Bio Refinery

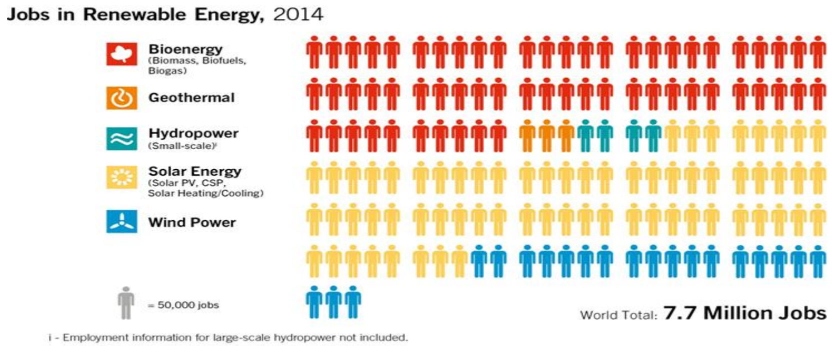




Benefits of Seaweed Utilization

- Obtaining valuable products like proteins (Omega 3&6), minerals as nutrition value, bio fertilizer, commercial heat and electricity to grid.
- Sustainable utilization of Egypt Solar energy, GHG (CO_2) from coal plants and power stations, and huge amounts of wastewater.
- Solve the environmental problems associated from accumulation of seaweed on seas offshores.
- Reducing unemployment % via jobs offerization.



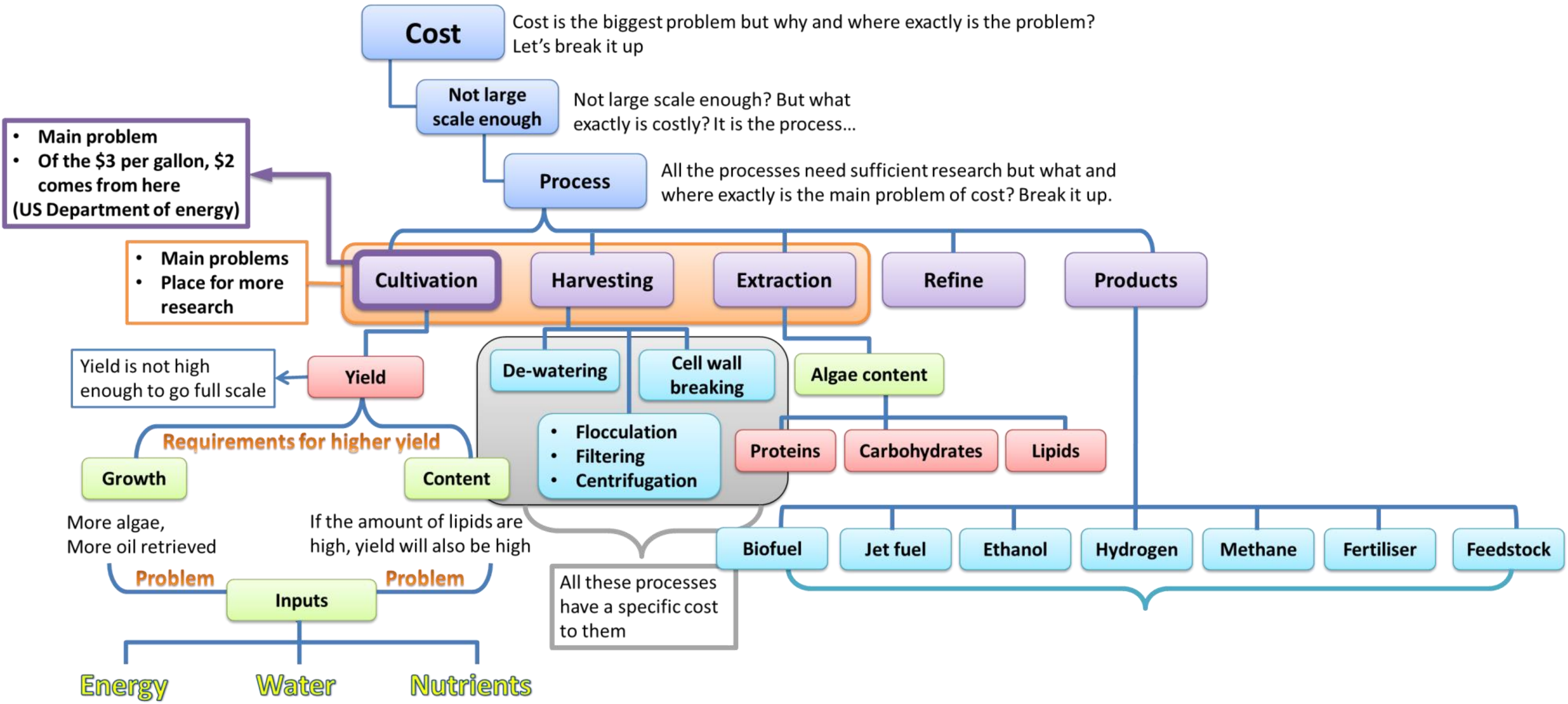


Assessment of Technologies Suggested for Sustainable Utilization of Seaweeds

Assessment Criteria	Suggested Approaches for Seaweed Utilization		
	Approach 1	Approach 2	……..
Sustainability			
Process Complexity			
Total Capital Investment (TCI)			
Total Manufacturing Cost (TMC)			
Net Profit (NP)			
Energy Return On Investment (EROI)			
Pay-back Period			
Rate of Return (ROR)			
Products Market Situation			
Country Policy			
Country Economic Affairs			
EIA			

Concluding remark

Seaweed are **potential sunlight-driven cell factories,** so for sustainable utilization of Seaweed, each step needs to optimize individually according to the market conditions and the country economics.



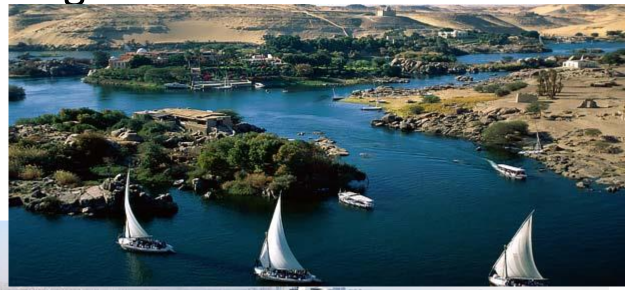
Egypt CAN DO

I think Egypt **CAN** do that but more feasibility studies are still required

Welcome to visit Egypt

Welcome to Invest in Egypt

Cheap labor
Wide desert areas
Huge wastewater
GHG Emissions
Seaweeds on Seas Offshores
Country policies
Incomplexicity of investment regulations
Taxes offers



Author Biography

Hassan I. El Shimi, PhD.

Researcher in Green Chemistry Applications
Lecturer at Chemical Engineering Department
Cairo University, Egypt
Member of Arab Engineers' Federation

Linked in: https://eg.linkedin.com/in/hassan-el-shimi-883755a4
Website: http://scholar.cu.edu.eg/?q=hassanelshimi/

Cairo Univ. St., Giza, Egypt
Tel. : +2 01024497780
: +2 01118087862
Email : hassanshimi@gmail.com

Research area

Renewable energy "Biofuels", Storage of energy from renewable sources, Environmental engineering "Solid waste management and Wastewater treatment", Process and plant design, Process economics, Industrial Biotechnology, Experiments Statistics. In addition, International arbitration in engineering contracts "FIDIC & BOT".

Thank you for your time!