Environment-Enhancing Energy – Third Generation Biofuel

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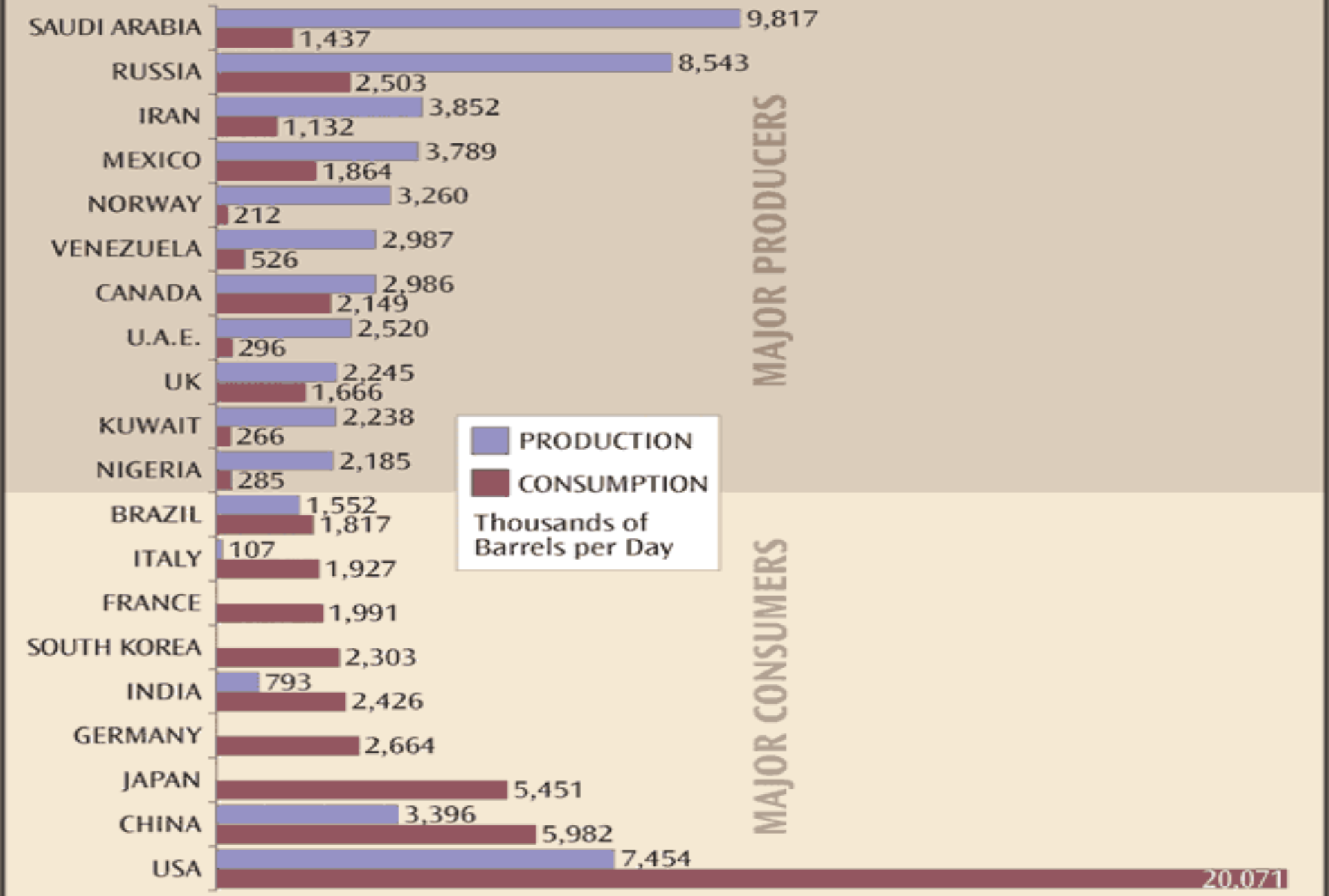
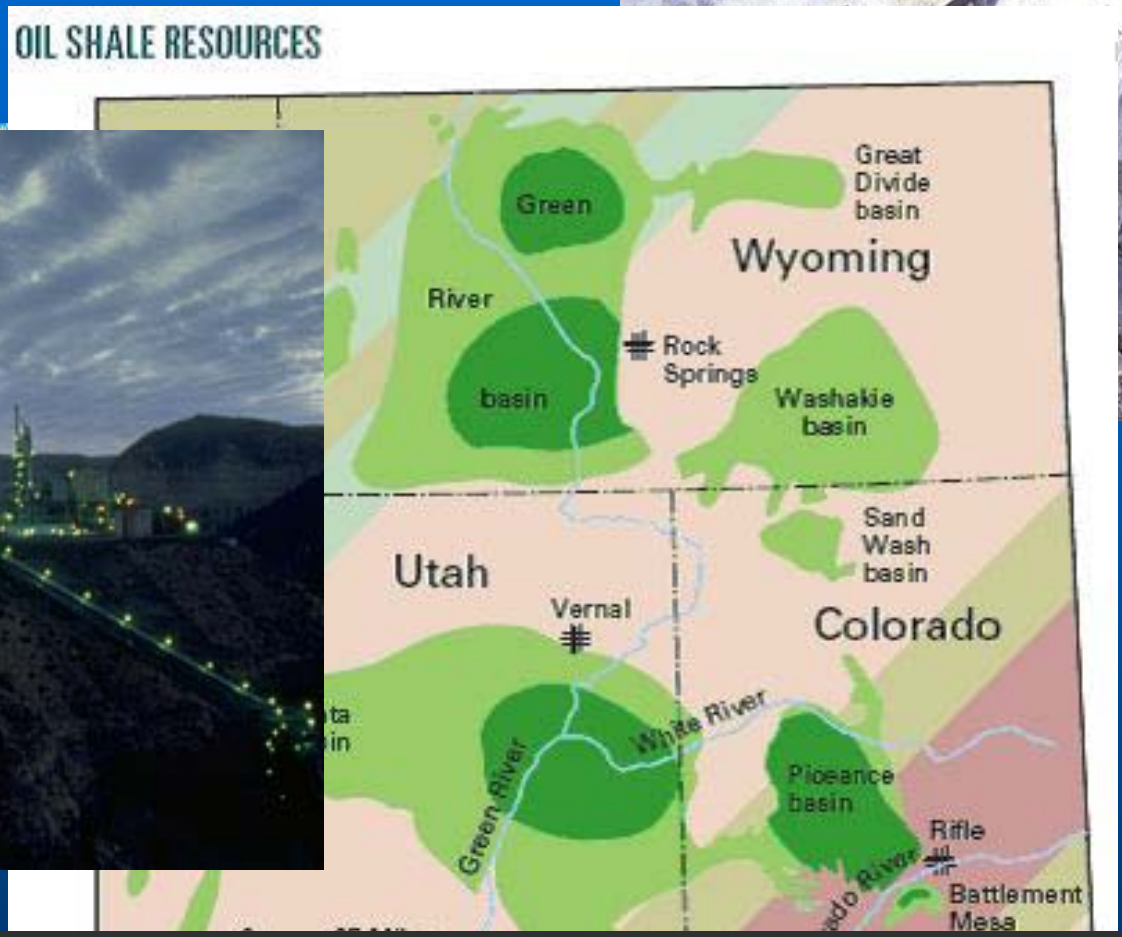
An Introduction to E^2-Energy

MAJOR OIL PRODUCERS AND CONSUMERS



Source: BP Statistical Review of World Energy 2004 <http://www.bp.com/statisticalreview2004>

Shale Oil



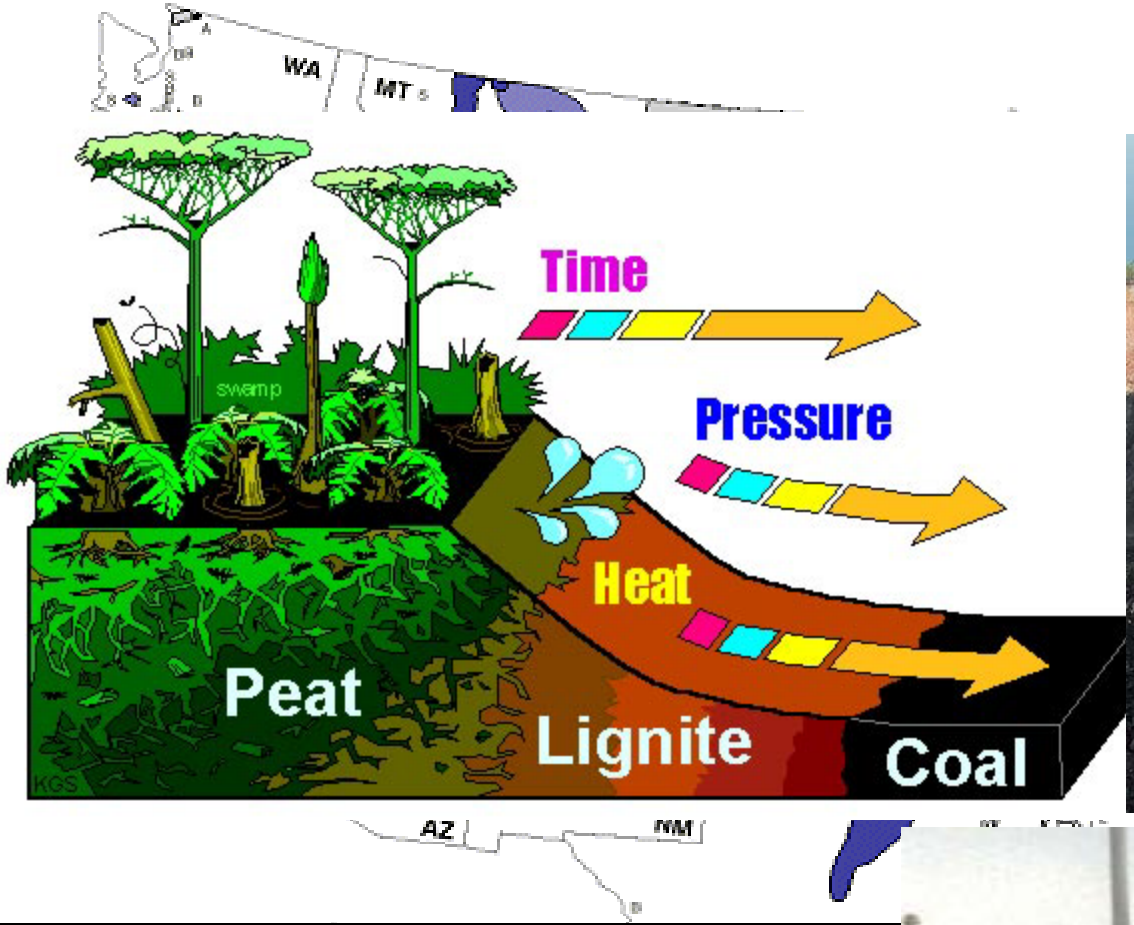
The Oil Shale reserves found in the Green River Formation can produce an estimated 1.5 to 1.8 trillion barrels of crude oil [source: RAND， 兰德公司]. This is three times more than the oil reserves Saudi Arabia currently holds. This amount could meet the United States' current oil demands for about 300 years.

[Source: Argonne National Laboratory， 阿岗实验室）].

Tar Sand

The Athabasca Oil Sands are large deposits of bitumen, or extremely heavy crude oil, located in northeastern Alberta, Canada. These oil sand contain about 1.7 trillion barrels (270×10^9 m^3) of bitumen in-place, comparable in magnitude to the world‘s total proven reserves of conventional petroleum, or another 300 years of US and Canadian Demand. (EIA, 1997)

Coal



This vast identified 1.7 trillion ton reserve, could meet the US fuel demand for another ~200 years. (EIA, 1997)

SCALE OF ALASKA ONE HALF THAT OF CONTIGUOUS UNITED STATES

All fossil fuels have a challenge

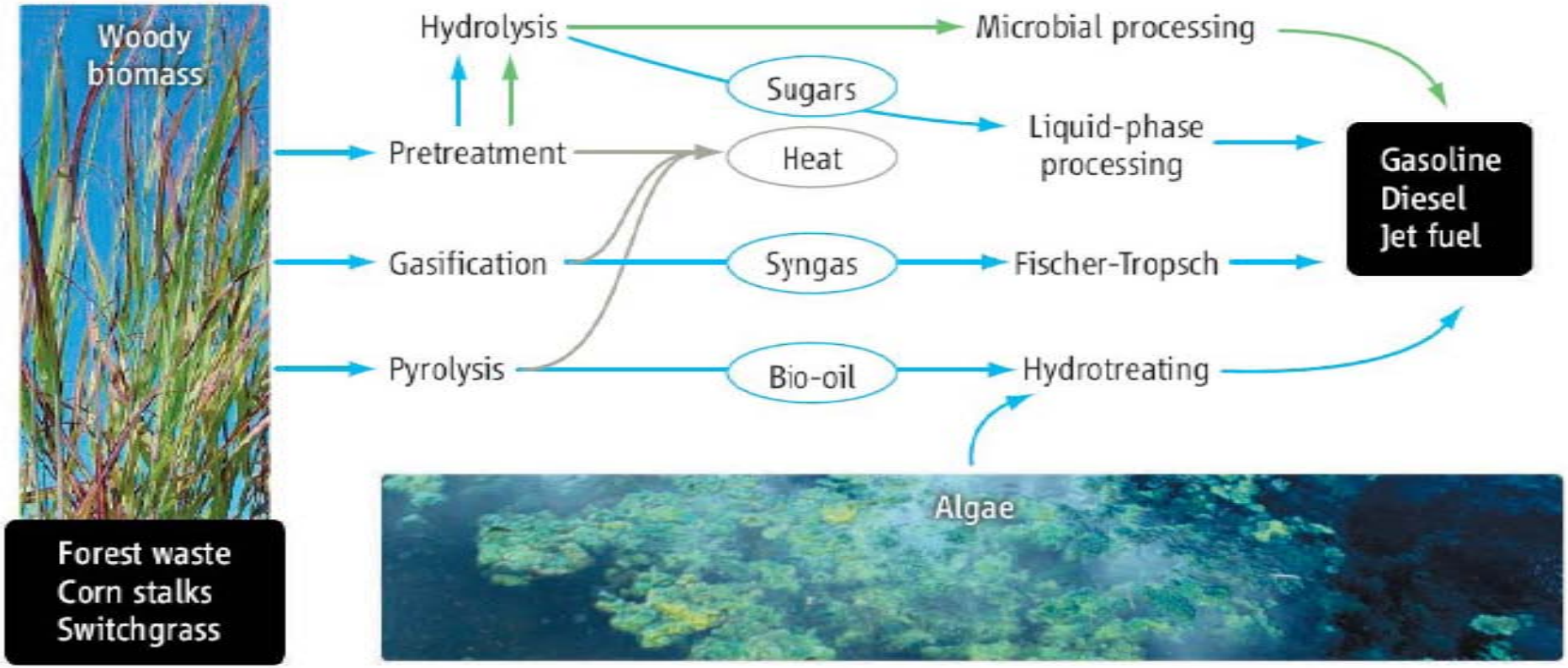
Tar sand refinery in Canada

Coal power plant

The challenge is

Economic development demands energy, yet energy consumption has historically led to increased environmental pollution. In the context of our modern society, the relationship of ‘environment’ and ‘energy’ are more often opponents rather than friendly co-existents. Environmental protection and energy production, are among the greatest challenges facing mankind in the 21st century.

Biofuel Options *(Regalbuto, 2009)*

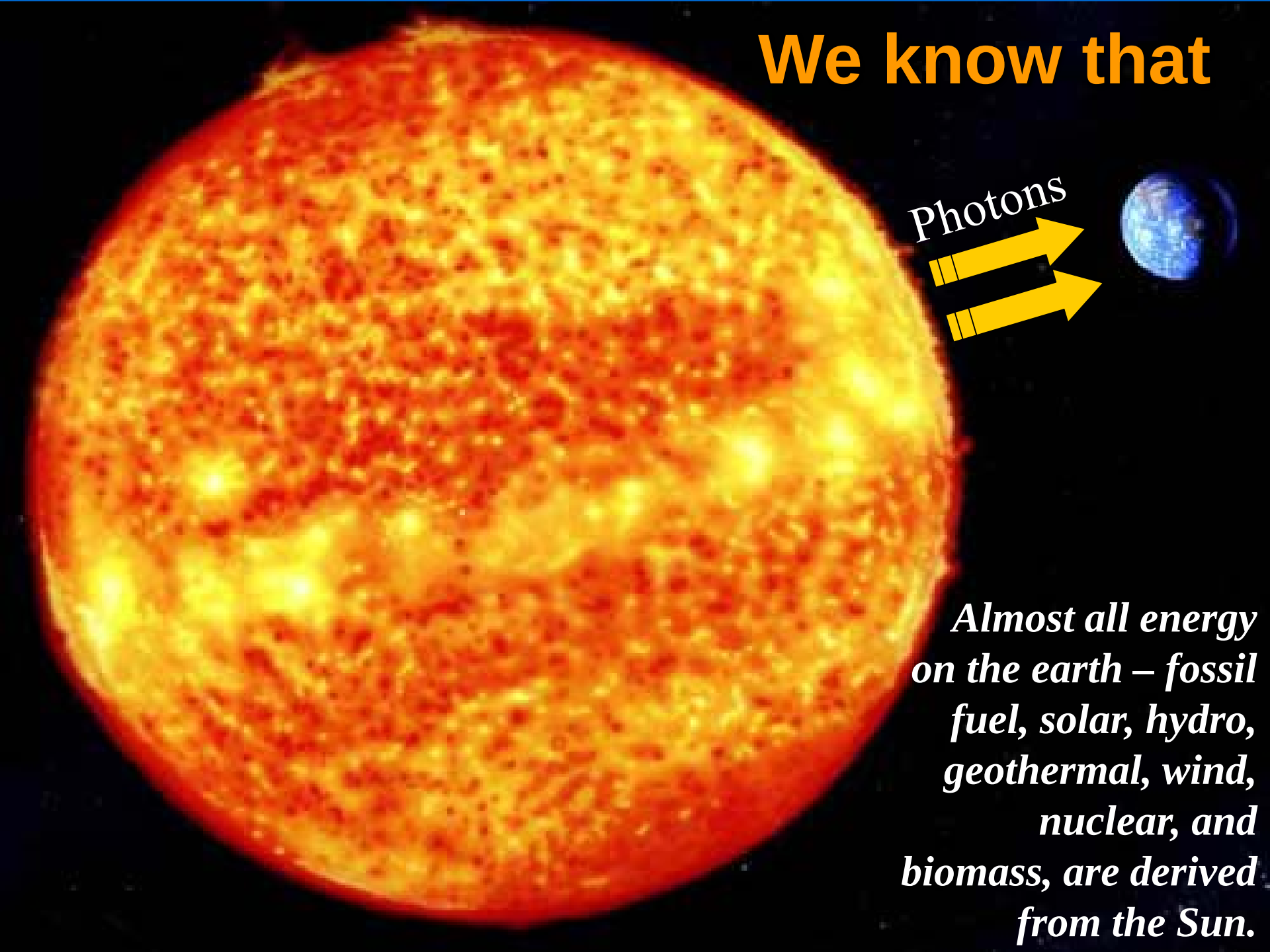


Many paths to biomass hydrocarbons. Woody biomass, or lignocellulose, as well as plant lipids can be converted to hydrocarbon biofuels. The image on the left depicts one lignocellulose source, switchgrass, and the image at the bottom depicts one plant lipid source, algae. Conversion routes may combine a variety of biological, thermal, and catalytic processes (depicted with green, black, and blue arrows, respectively).

Three-Generations of Biofuel

- 1st Generation -- grain and sugar based ethanol
- 2nd Generation – lignocellulosic material to ethanol and/or hydrocarbons
- 3rd Generation: biowaste and algae based biocrude oil

We know that



Almost all energy on the earth – fossil fuel, solar, hydro, geothermal, wind, nuclear, and biomass, are derived from the Sun.

A widely accepted theory…

Based on the biogenic hypothesis, all fossil fuels found on earth – petroleum (including oil shale and tar sand), natural gas and coal,– are formed through processes of Thermo-Chemical Conversion (TCC) of biomass buried beneath the ground and subjected to millions of years of elevated temperature and pressure.

Comparison of average oil yield

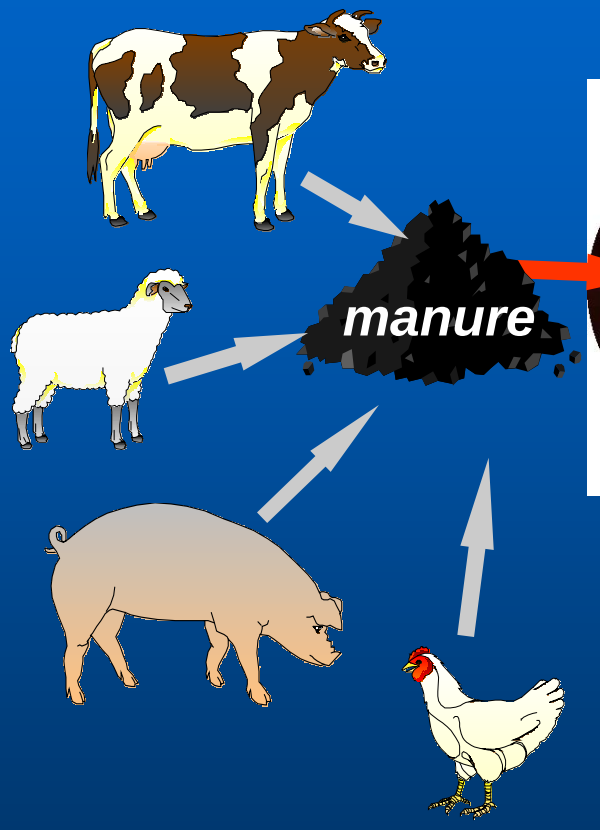
Crop	Average oil yield (L/hectare)
Castor 蓖麻子	1,413
Sunflower 向日葵	952
Safflower 红花	779
Palm 棕榈树	5,950
Soybean 大豆	446
Coconut 椰子	2,689
Algae 藻类	*100,000*

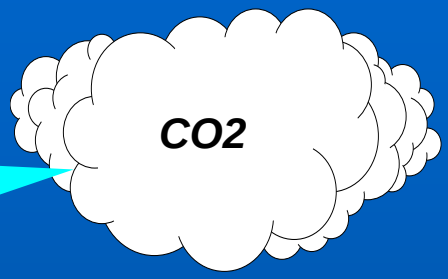
http://www.oilgae.com/algae/oil/yield/yield.html

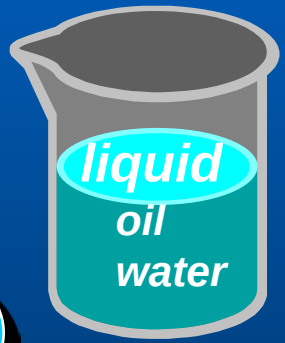
Algae Biodiesel

- Existing methods to obtain algae oil
  - Mechanical extraction
  - Solvent extraction
  - Supercritical fluid separation
- Limitations of existing algae oil paradigm
  - Require high-oil content oil species, which is usually associated with lower yields and is more prone to contamination
  - Dewatering or drying is energy intensive
  - Easily being contaminated

TCC Batch Reactor







An example of experimental results from batch reactor

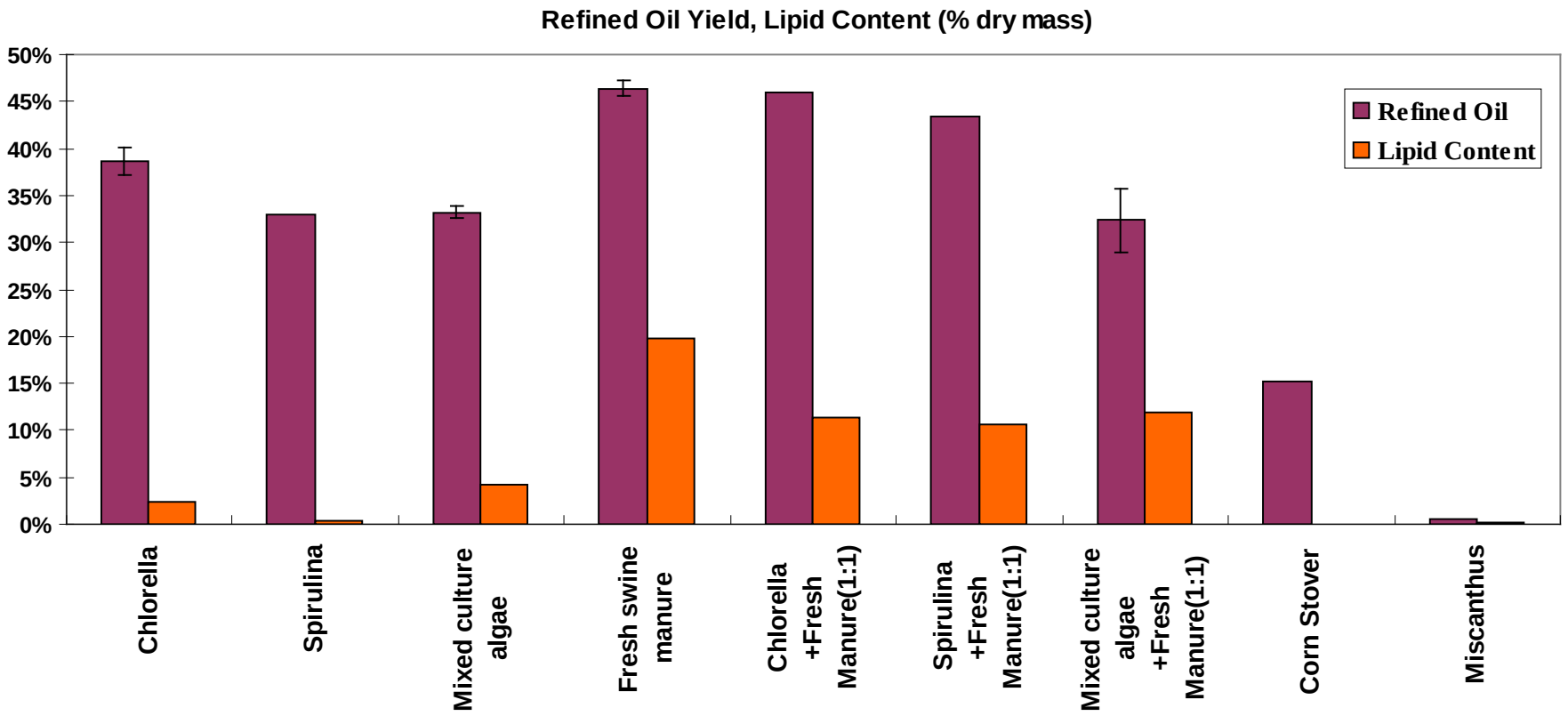
Group/specific	*Mean ± SD*	*Maximum value*
Oil production rate, % of volatile solids	62.3 ± 15.8	79.9
COD reduction rate, %	64.5 ± 5.6	75.4
Benzene solubility, %	76.6 ± 9.8	96.5
Heating value of the oil product, kJ/kg	34,580 ± 2,500	38,250
Elemental composition§		
Carbon, %wt	71.0 ± 4.7	77.9
Hydrogen, %wt	8.9 ± 0.6	9.8
Nitrogen, %wt	4.1 ± 0.5	--
Sulfur, %wt	0.20 ± 0.05	--
Oxygen, %wt #	12.0 ± 4.8	--
Ash, %wt	4.2 ± 2.1	--
Carbon recovery rate, % of input C	76.0 ± 21.4	--
Hydrogen recovery rate, % of input H	69.0 ± 19.2	--

§ Dry basis. # By the difference: O = 100 – C – H – N – S – ash.

Continuous TCC system (UIUC)

Pilot plant (40 barrels/day, Houston, Texas)

Conversion Efficiency



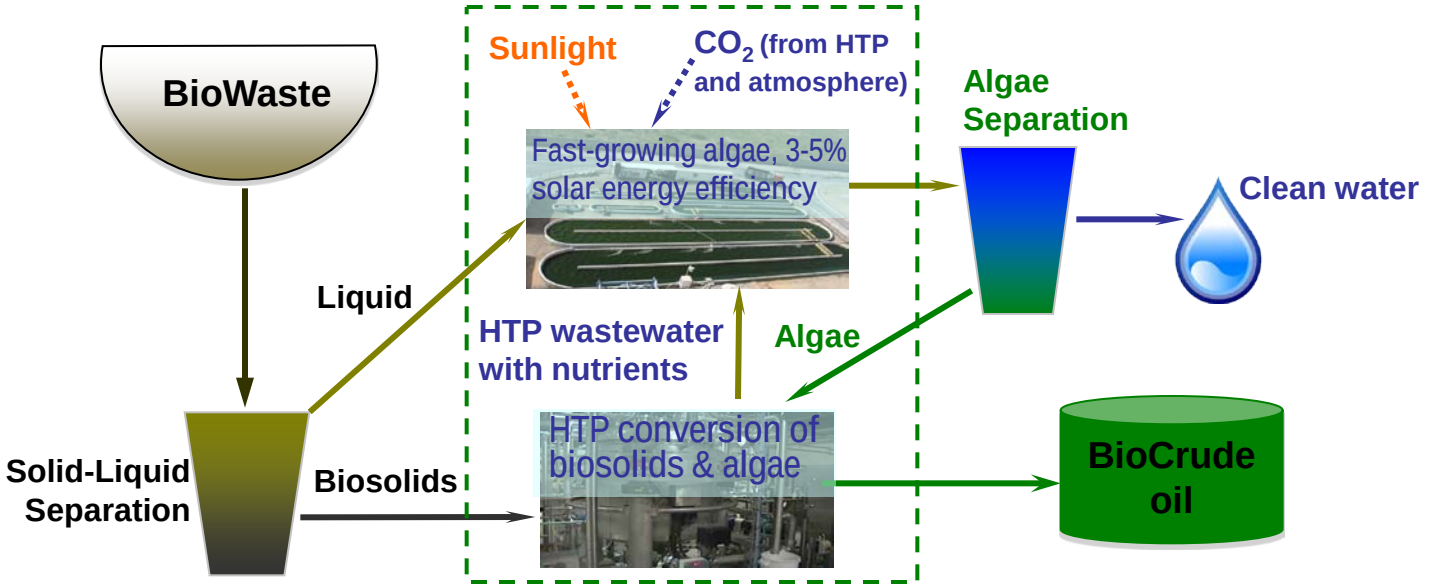
Initial lipid content and HTP oil conversion efficiency for different feedstocks

Zhang, *et al.*, *University of Illinois*

NSF EFRI No. 0938088

Title: Environment-Enhancing Energy (E^2-Energy) – Hydrothermal Processing Biowaste and Algae into Crude Oil, Sequestering CO_2 and Improving Water Quality

Vision: ***To initiate a paradigm shift that synergistically integrates two competing elements -- 'energy production' and 'environment protection' -- into one complementary process, which can satisfy our entire national liquid fuel need…***



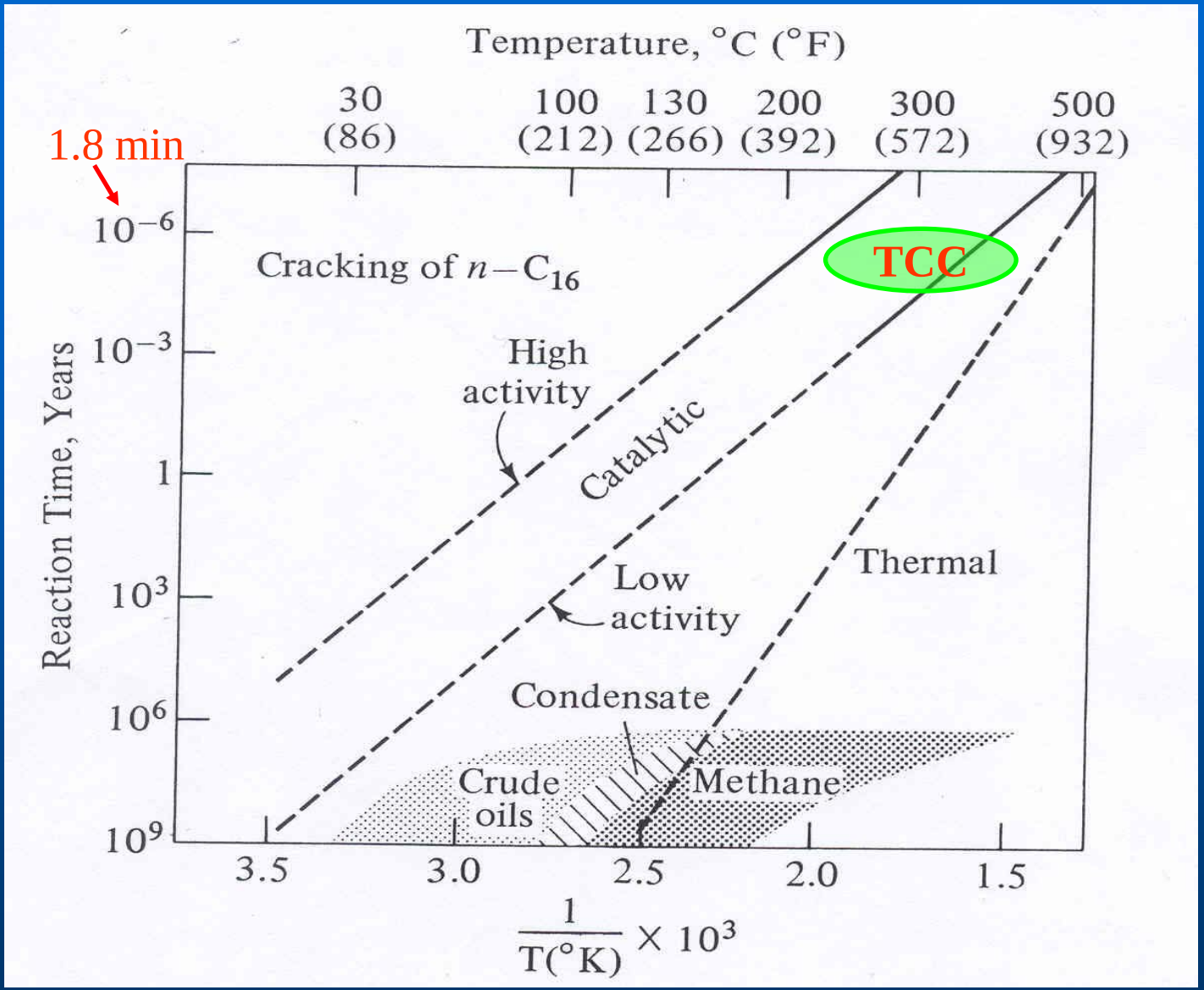
The E^2-Energy Road Map: Waste biosolids are converted into biocrude oil via hydrothermal process (HTP). HTP wastewater recovers most of the nutrients, which are fed to fast-growing algae, which recycle back into the HTP and are converted to oil. Algae growth cleans the water and sequesters CO_2 from the atmosphere and HTP.

A sustainable energy ought to be an

Environment-Enhancing Energy (E^2-Energy) – Our E^2-Energy process will convert bio-waste from animal, human and food processing into crude oil via thermochemical conversion (TCC), and produce algae using the waste water from those streams. The algae then will be fed back to TCC process to convert into oil. During the algae growth the nutrient in waste water is utilized and atmospheric carbon dioxide is sequestered, thus the environment is improved .

ThermoChemical Conversion

Mimicking Mother Nature's millions-of-years process of turning deceased living matters buried beneath the ground into petroleum, swine manure and other bio-waste, have been converted into crude oil in minutes using thermochemical conversion (TCC) technology in 10 – 40 minutes.



Source: Hunt, John. 1979.
Petroleum Geochemistry and Geology

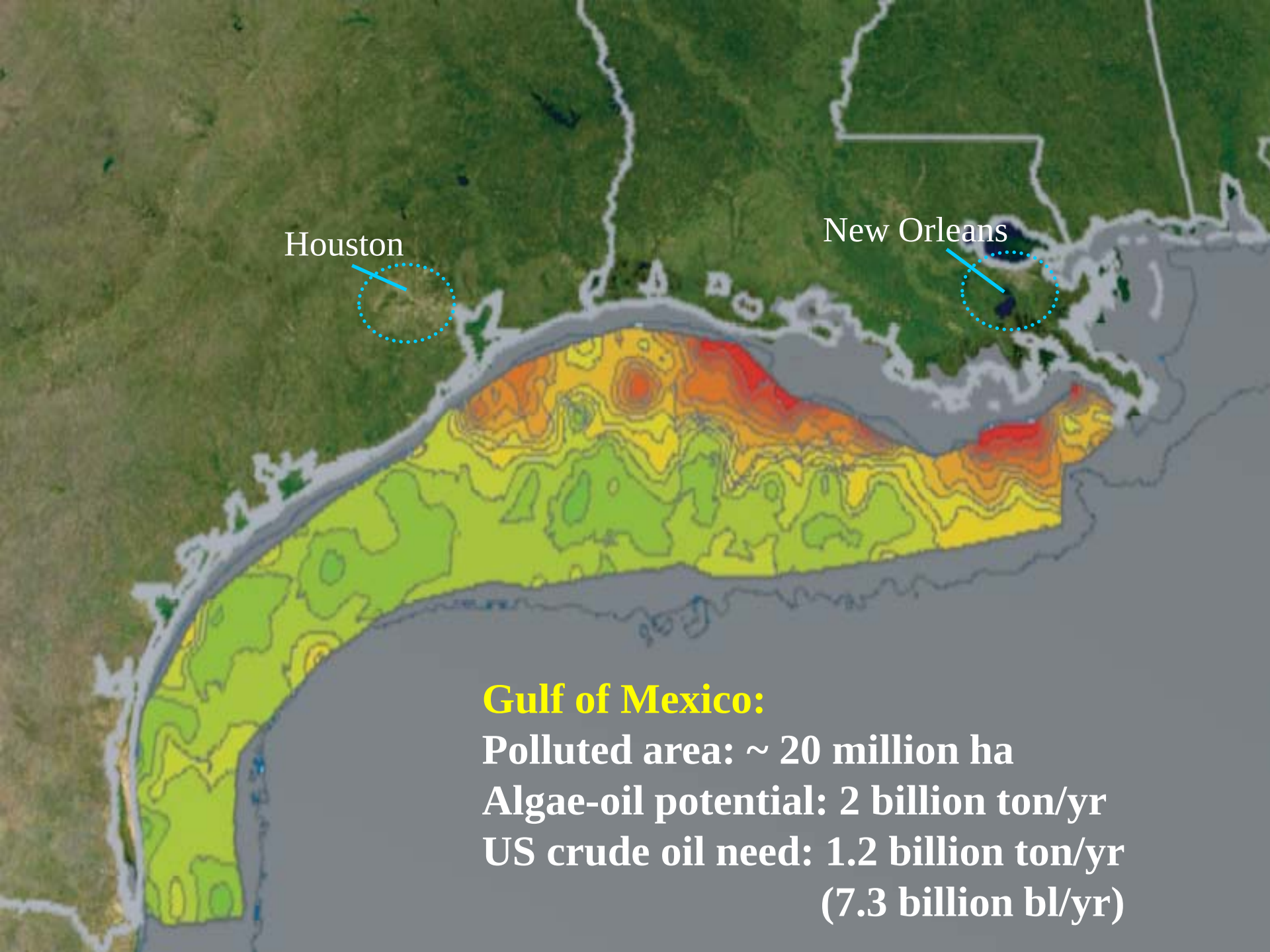
Qingdao（青岛）2008


Dianchi（滇池）

Chaohu, Anhui (巢湖）

Taihu（太湖）

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN



Gulf of Mexico:

Polluted area: ~ 20 million ha

Algae-oil potential: 2 billion ton/yr

US crude oil need: 1.2 billion ton/yr

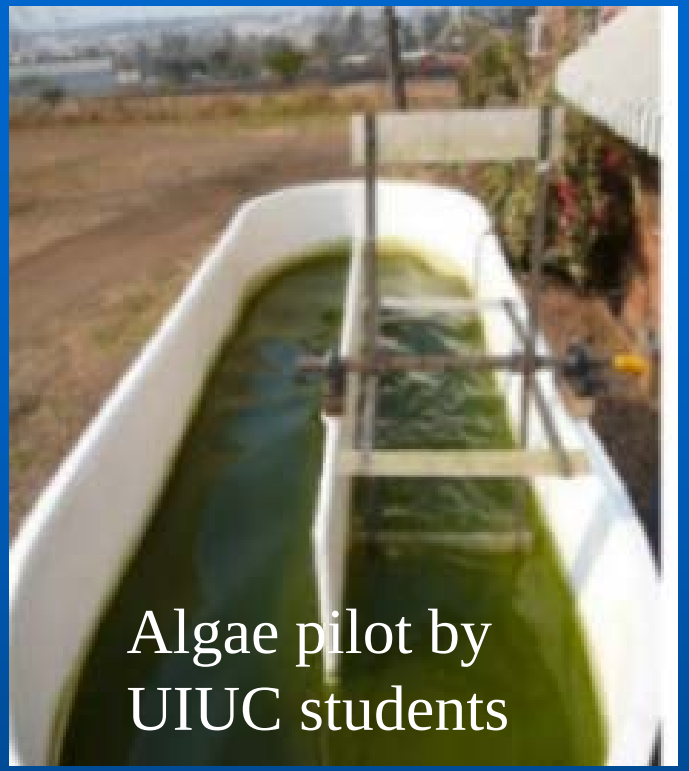
(7.3 billion bl/yr)

Now let's think big … …
The E²-Energy Potential

http://news.cnet.com/i/bto/20080620/Seambiotic_Ponds_540x354.jpg

US produces 54 billion cubic meter of waste water and 200 million tons of manure (dry mass, human and animal). If all were used to produce algae and all waste was converted, it would be equivalent to 6.5 billion tons of crude oil. US consumed 1.2 billion tons of crude oil in 2006.

Algae pilot plant in U.K.



Algae pilot by UIUC students

Algae pilot plant in Netherland

UIUC Sustainability Committee- Algal Biofuels Demonstration Project at Abbott Power Plant

- Project Construction and Algal Culturing- Summer 2009
- First Phase Deployment- Fall 2009
- Partner with UIUC Biodiesel Initiative for biofuel conversion
- Educational-Extensional Website→ http://algae.illinois.edu/

Why E²-Energy?

- ***Safeguard national security*** – By extracting bio-waste from dispersed local communities, geopolitical threat from petroleum importation can be eliminated.
- ***Clean and reuse wastewaters*** – Nutrients in the wastewater will be reused for algae growing and conserve water resources.
- ***Sequester carbon dioxide and slowdown global warming*** – Algae, currently produces 40-50% of the free oxygen for the earth; and can reuse the CO2 produced in the HTP process.
- ***No competition with the food supply*** – Biowaste and algae grown in wastewater does not need to compete with farm land and food supply.


“Life is
sooo good.”
2007 6 3

Leap-frog Development

There are modern examples … …

- **Cellphones ••••• >> telephones**
- **Satellite dish ••••• >> cable TV**
- **3rd generation biofuel ••••• >> petroleum**
- **E2-Energy system >> wastewater treatment system**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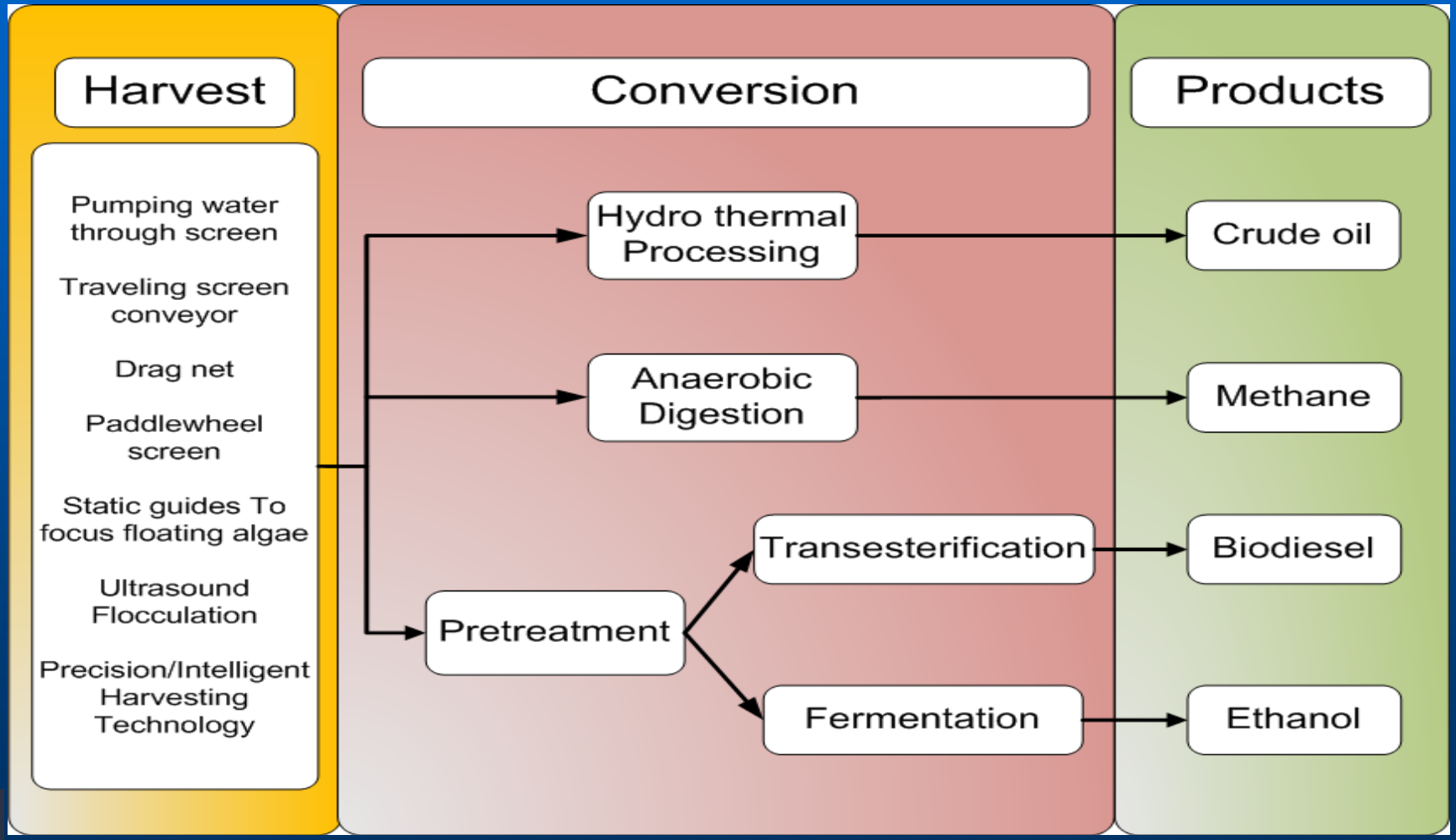
Harvested Algae Biofuel Energy Model (HABEM)



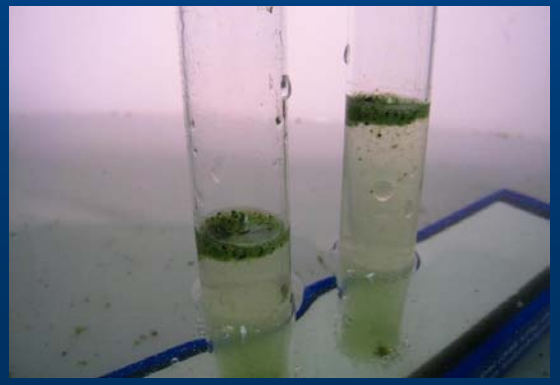
Harvest Methods

Drag Net

Screw Pump

Traveling Screen

Floatation



Consumption Energy Ratio

	HTC	AD	Trans	Fermentation
Vessel	0.46	0.74	0.66	0.63
screen	0.02	0.03	0.02	0.02
floatation	0.01	0.01	0.01	0.01
conversion	0.44	0.10	0.07	0.11
preteatment	0.07	0.12	0.23	0.22
Ecout/Eh	0.75	0.70	0.67	0.51

Conclusions

- Base on the model, harvest by traveling screen with floatation and conversion through HTC is the most benefit process, which offset 75% of harvest energy demand

- Major energy consumption is vessel fuel, thus decrease the length of harvest route becomes an important issue
  - Satellite image complementary technology could improve harvest efficiency
  - Develop wide area harvest technology

Thank you