Synthetic and Biomass Alternate Fueling in Aviation

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Slides part of, but not used in oral presentation → X

Hydrocarbon (HC) Addiction

- **Our planet is gripped by our addiction to hydrocarbon energy generation sources.**

  "*Addiction is a terrible thing. It consumes and controls us, makes us deny important truths and blinds us to the consequences of our actions.*"

  U.N. Secretary-General Ban Ki-Moon

- **"*We take pride in our clean, green identity as a nation and we are determined to take action to protect it. We appreciate that protecting the climate means behavior change by each and every one of us*."** Prime Minister Helen Clark, New Zealand

Will Biomass Fueling ?

- ***Reduce Hydrocarbon Addiction ?***
- ***Reduce CO2, NOX, etc., nanoparticulate, altitude H2O–cloud emissions health / climate hazards ?***
- ***Reduce foreign control of our future ?***
- ***Require cooperative world wide investments ?***
- ***Require paradigm shift in source and use of energy ???***

Consequences of inaction are existential to humanity !!!

Civil Aviation Alternate Fueling Flight Demonstrations

- Feb. 24, 2008, Virgin Atlantic 747–400 40-min. **biojet fueled flight**

  One of four GE CF6-80C2B5F turbofan engines
  London to Amsterdam (320 km) altitude to (7.6 km)
  80% Jet-A: 20% processed **coconut oils**
  Ground tests to 60JetA:40biojet no discernable problems
- February 1, 2008, Airbus A380 3-hr **GTL fueled flight**

  One of four Rolls-Royce Trent 900 engines fueled
  Bristol to Toulouse to assess environmental impact
  GTL (gas-to-liquid) fueling 50% Jet-A: 50% Blend
  Goal regulatory 50:50 blend (2009): 100% GTL (2013)
- CAAFI Civil Aviation Alternate Fuels Initiative

  Research, Emissions, Business, Regulatory Groups Groups &
  Transportation Research Board, (TRB) Road, Rail, Air, Marine, Transit

Civil Aviation Alternate Fueling Flight Demonstrations

- December 30, 2008, Air New Zealand, 2-hr. flight Auckland over Hauraki Gulf. RB211-powered 747-400, 1 of 4 engines fueled 50:50 blend processed-jatropha UOP biojet and Jet A

- January 7, 2009, Continental [GE CFM56–7B] 737-800 1.5hr flight over Gulf of Mexico, one of 2 engines 50:50 blended biofuel of [47.5% jatropha +2.5% algae] UOP biojet + Jet A.

- January 30, 2009 JAL [P&W JT9D #3] 747-300 1.5 hr flight about Haneda Airport, #3 engine 50:50 blend biojet:JetA [feedstocks camelina 84% (Sustainable Oils), jatropha (Terrasol) <16%, algae <1%(Sapphire) UOP-processed

Virgin Atlantic
24 Feb 2008
20% biojet
(coconut oils)

Air New Zealand
30 Dec 2008
50% biojet
(Jatropha)

X

7 Jan 2009 Continental 47.5;2.5 % biojet

JAL 30 Jan 2009 [42;8;trace] % biojet (Camelina)

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Military Aviation Alternate Fueling Flight Demonstrations

- March 2008 B1B flew supersonic (50%JP8 : 50%SPK)
- **SPK** (Synthetic Paraffinic Kerosene) Standard

  MIL-DTL-83133F 11 April 2008

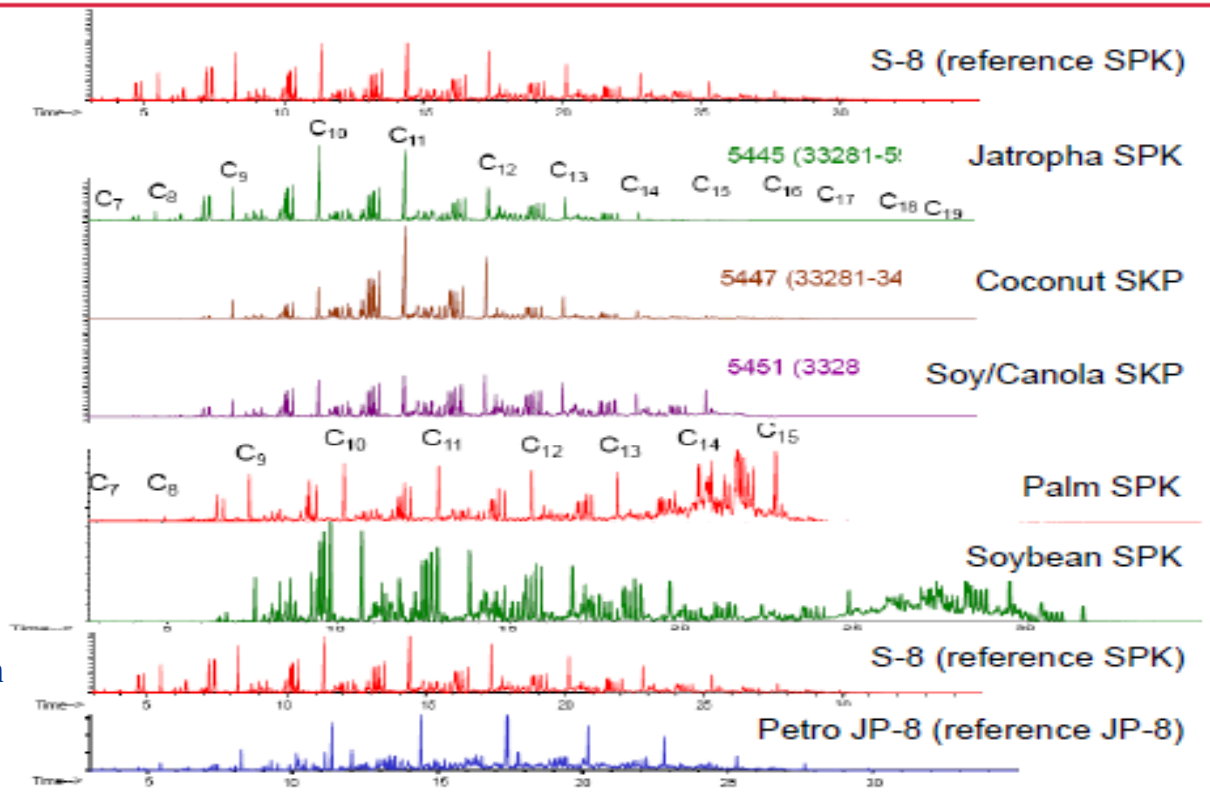
  Sperseeds MIL-DT-83133E 1 April 1999.
- SPK: CAAFI-ASTM modification for ASTM D1655.
- 17 Sept 2008 **50yr-old KC135 and F22 Raptor**

  Fueled 50:50 JP8-SPK

UOP Biofuels Feedstock Processing

- **UOP process : removes "O" and "S" (deep hydrotreat)**
- **Add oxidation stabilizers…necessary ? …additives ?**
- **HC paraffinic signatures differ but satisfy (exceed) MIL fuel spec**
- **Certification on fast track via Boeing flight testing**
- **Preclude other fuels ? Butanol process known, compatible; DME? etc**

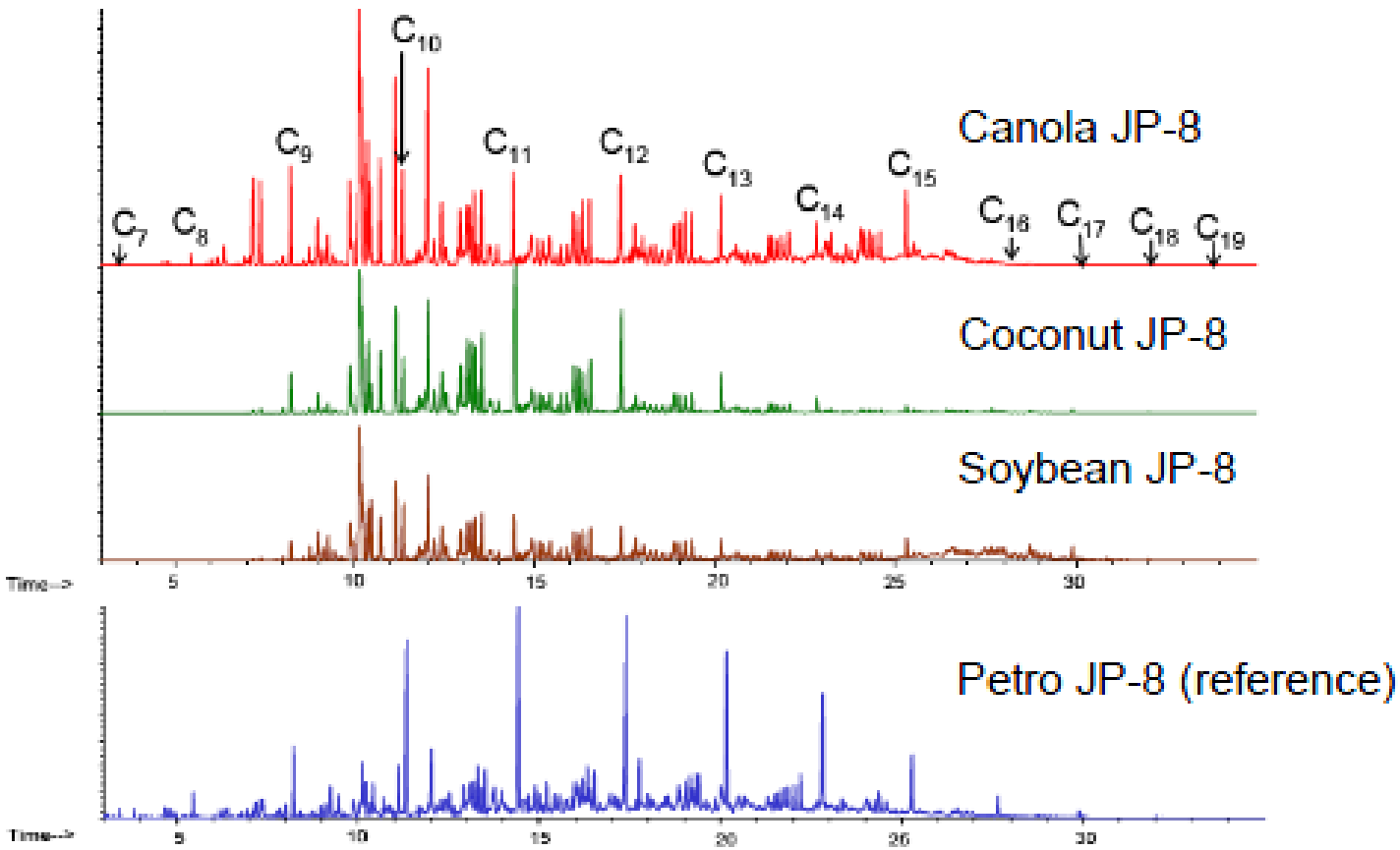
UOP SPK Carbon Distribution



[Holmgren, Jennifer R

Jennifer.Holmgren@uop.com]

UOP JP-8 Carbon Distribution



[Holmgren, Jennifer R Jennifer.Holmgren@uop.com]

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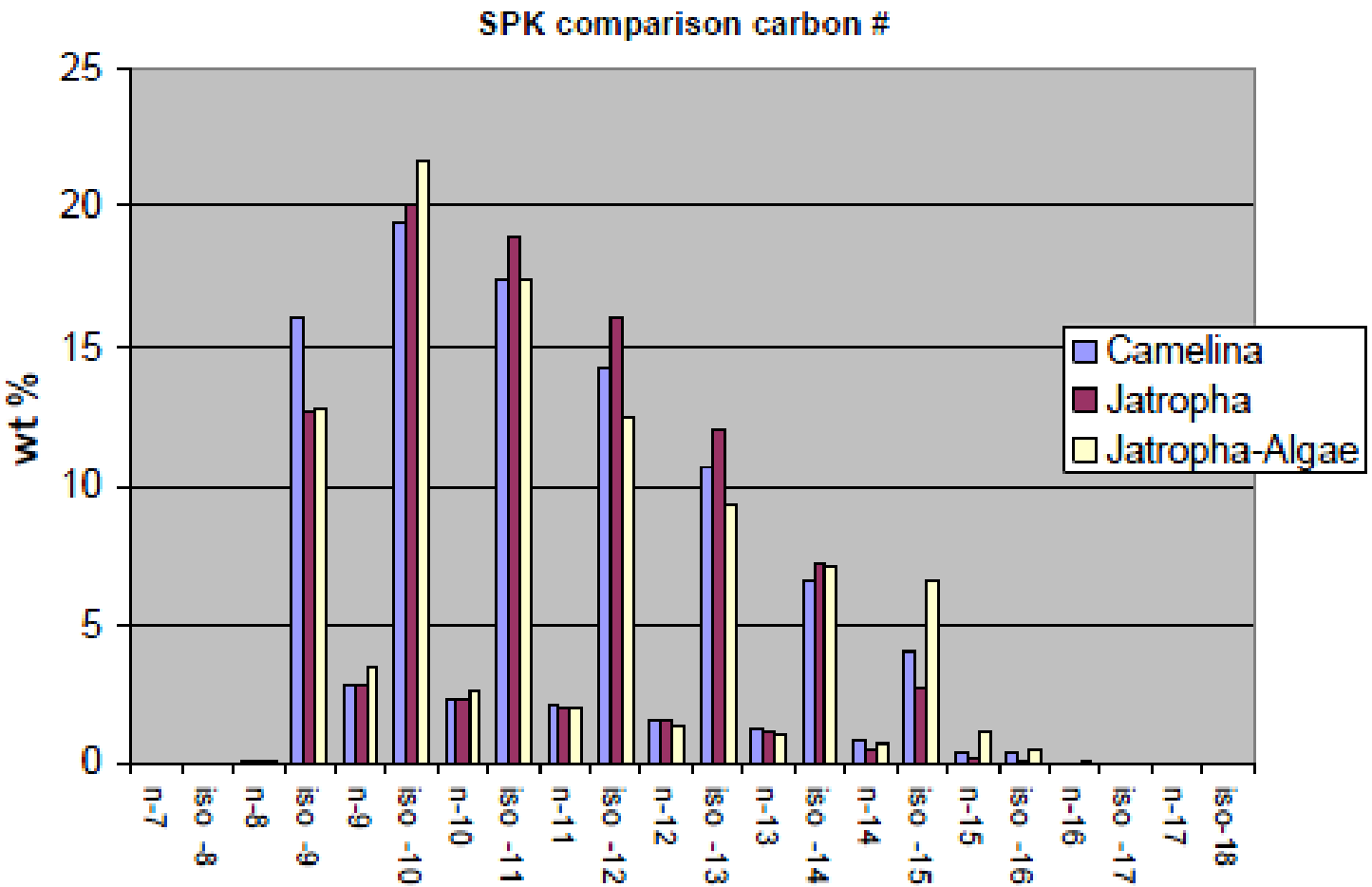
HRJ Carbon Distribution: Flight Demonstration HRJ



[Holmgren, Jennifer R Jennifer.Holmgren@uop.com]

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(HC)-Fueled Heat Engine Exhaust Emissions
Health Hazards CO2, NOX, etc., Particulates

- Particulate pollution : ***ultrafine particulates directly translocate to promote vascular system diseases.*** [Ultrafine: < 0.1 µm (< 100 nm)]

  Journal of America College of Caradiology (JACC) *.

  chronic respiratory diseases due to particulates are better known **

- Exhaust (tailpipe) emissions (20-140 nm) includes aircraft, mobility/stationary systems

•**Simkhovich, B.Z, Kleinman, M.T., Kloner, R.A. (2008) Air Pollution and Cardiovascular Injury Epidemiology, Toxicology, and Mechanisms, Journal American College of Cardiology, 2008; 52:719-726, doi:10.1016/j.jacc.2008.05.029 (Published online 13 August 2008).**
http://content.onlinejacc.org/cgi/content/short/52/9/719
** **Schwartz, J**. (1993) Particulate Air Pollution and Chronic Respiratory Disease, Environmental Research, 62, pp. 7-13

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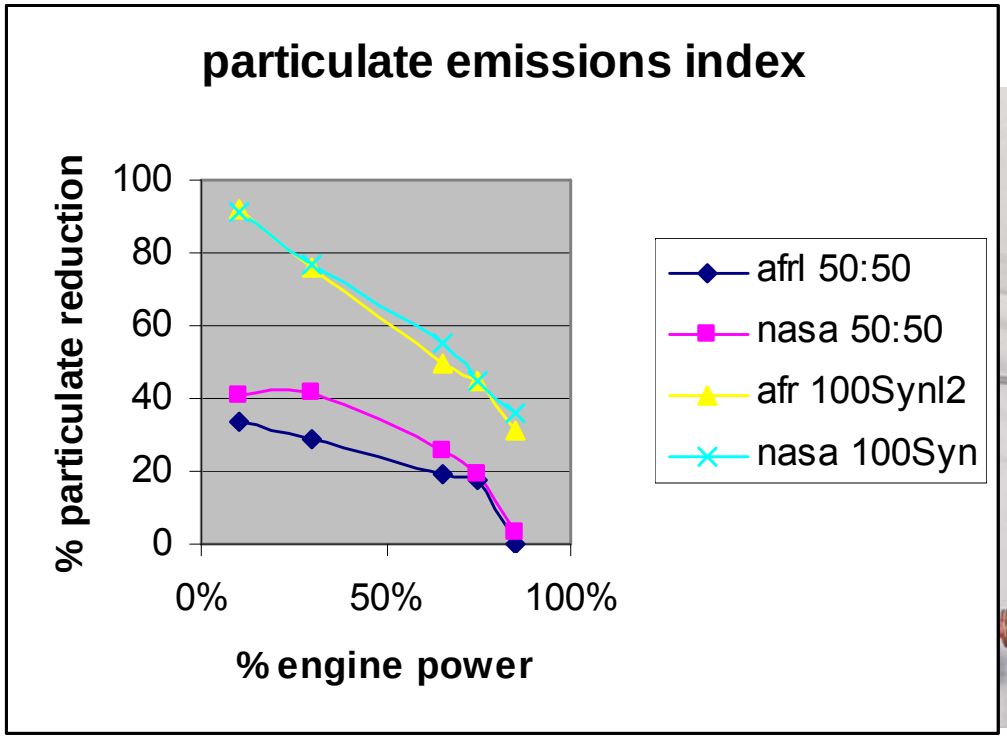
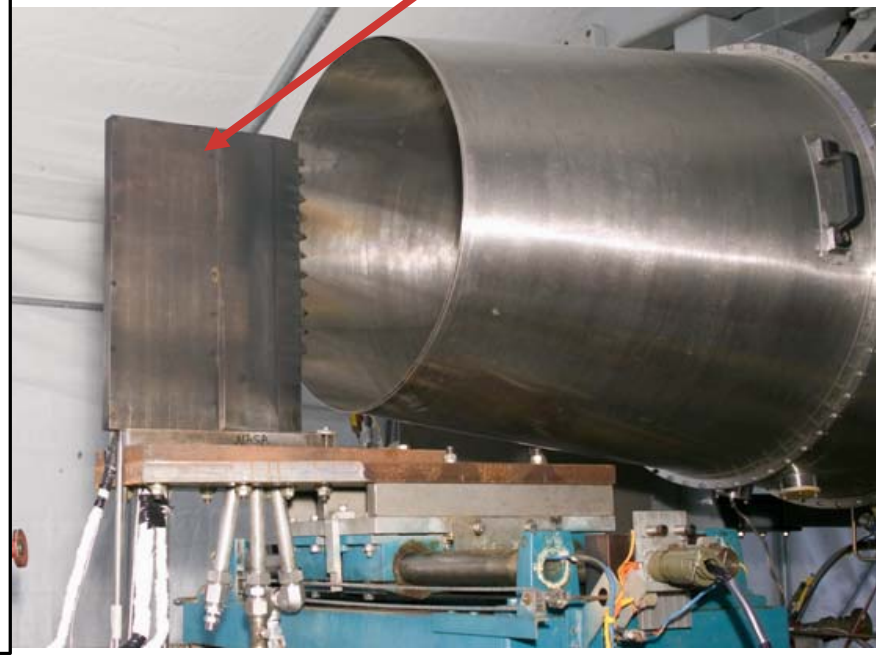
Civil-Military Engine Emissions Testing

- March 2008 PW-308 Engine Emissions FT- Jet A fuel test
- Fuels AFRL-FT, NASA-FT (Fischer-Tropsch), Jet A

Decreased particulate number with % power decrease for FT and Blends vs Jet A.

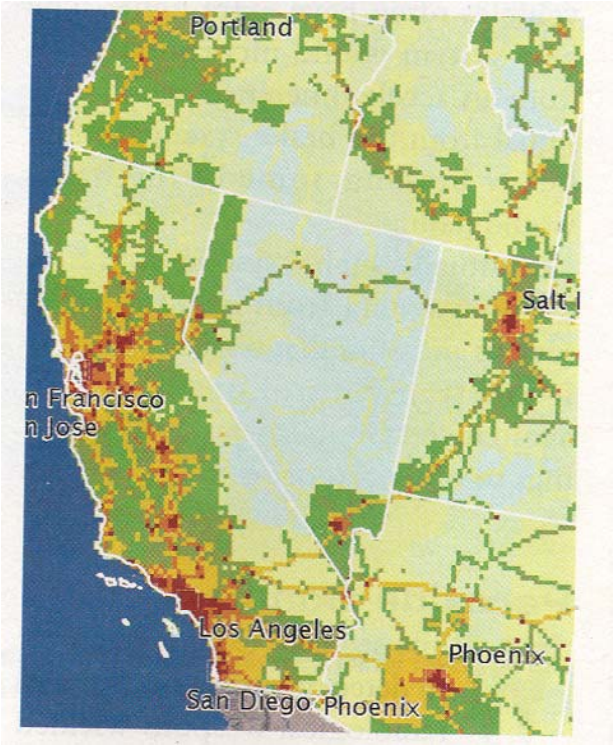


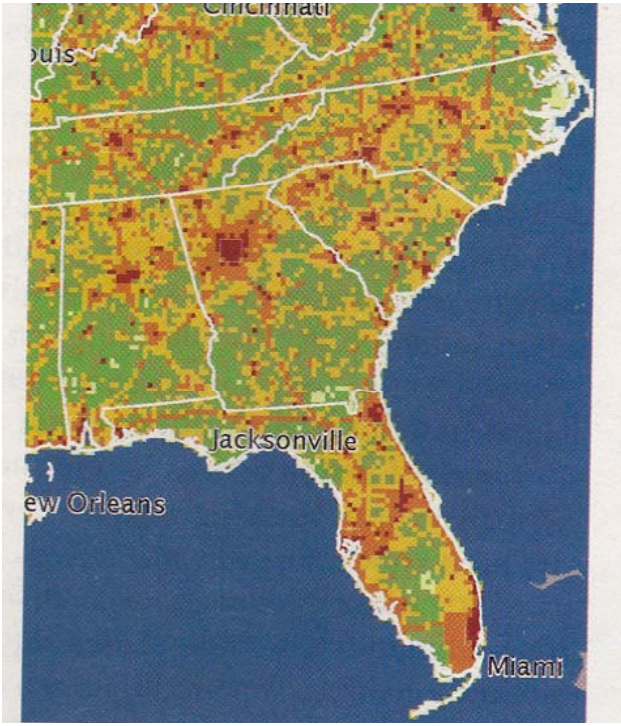
Exhaust Emissions Rake



Tracking Carbon and Ultrafine Emissions

- Since 1950's global CO2 level 300 ppm to 400 ppm
- Increased CO2 level in human respiration (toxicity)
- Visual mobility HC-fueled corridors and population centers (USA) [from Mech Engr. June 2008, p22]
- Direct link with ultrafine (nano) particulate emissions





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EPA - GHG Endangerment Ruling; 17 April 2009

- Greenhouse gases contribute to air pollution that
  " …*threaten the public health and welfare*.."
  http://epa.gov/climatechange/endangerment.html
- All of the primary greenhouse gases qualify as air pollutants, and can be regulated by the EPA under CAA - Massachusetts Supreme Court ruling, 2 April 2007 [*Massachusetts v. EPA*, 549 U.S. 497 (2007)]
- GHG's [CO_2 ,CH_4, NOX etc] climate / health hazard
  [e.g., excess CO_2 in body lowers pH (acidosis)],
- *Particulates* climate / major undeclared health hazard
  [e.g., cardiovascular and lung diseases]
- **ALL** HC-heat engines are Major Sources

Why Biomass Fueling ?

- *Reduces "fossil" fuel Addiction , health hazards, economic control*
- *Requires cooperation , new investments, source and use of energy*

Demo Biomass Fueling ?

- **Flight testing demonstrates feasibility 50:50 Blends**
- **Fast track certification (MIL 50:50 cert ; ASTM pending)**
- **Promotion, Glamour and Popular Press complete**

How Biomass Fueling ?

- **Now the hard work begins**
- **How to generate Billions gallons biojet**

There are **Issues**

1. Population is expected to grow 40% in 40-50 years
2. Aviation is expected to grow at 4%/yr
3. 95 Billion gals JetFuel used in 2007 expect 220Bgal (2026); replacement or even low % blends requires huge investments and huge biomass production
4. Projected fuel burn reductions ATM 15% Future Aircraft 50% Future engines (intercool, recoup) 25% (must respect thermo)
5. Legacy aircraft + Future ATM + Future Fleet implies

   Fleet [2026] < 40% fuel burn reduction
6. CO_2 goals > 80% reduction + no increase in other emissions
7. Aviation ground rules limit fueling options to "do no harm"
8. **Given 1-5 , 6 & 7 goals cannot be met**

9. Aviation & fueling industries recognize **8 ;** space does not
10. Given 1-9 **will aerospace grow, decline or equilibrate** ?
11. **Alternative fueling requires paradigm shift in the conception, source, use of energy AND its funding.**

It will cost more with reduced dependence on coal/gas/nuclear

12. **IF** serious consideration given 1-11, biomass fueling could provide a resolution to 10, using multiple sources.
13. **Resources**: 97% seawater, 43% arid land, Solar Source
14. Conserve freshwater, arable land, protect food supply, health and climate
15. Aerospace : conserve energy, climate …fly lower and slower .. fewer space launches and debris …Telecommunications [Tel-e-everything]…..

The Problems

How to make these Fuel Resources

Secure

Sustainable

Economically viable

Sufficient Supply

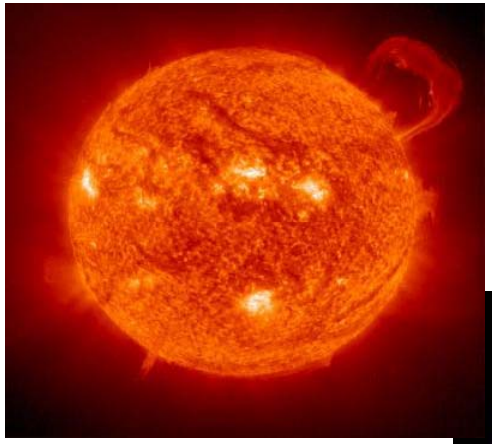
And Satisfy the Ground Rules

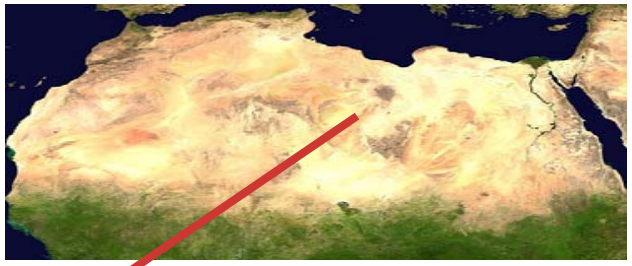
Aviation Ground Rules 2nd Generation Biomass Fueling

Criteria	KLM	Virgin Atlantic.	Boeing	Airbus	Air Transport Association
Water	No use of drinking water	Should not divert water away form food agriculture or drinking water	Does not require freshwater irrigation	Does not compete with water use for food crops or with drinking water	
Defores tation	No deforestation or forced relocation of people	Should not lead to deforestation	Does not lead to deforestation directly or indirectly	Does not compete with natural carbon sinks such as rainforest	
Soil	No soil degradation	Should apply sustainable agronomy principles (e.g., equivalent of FSC)	Apply sustainable practices	Apply sustainable practices	
Land and Food	Not compete with food or make use of arable land	Should not conflict with staple food crops	Does not compete with food	Does not compete with land use for food crops	
Emissio ns	No negative influence on biodiversity	Should have lower life cycle carbon emissions	Reduce CO2 (ie on order of -50% from current Jet A fuel)	Beneficial on a life cycle basis both in terms of global warming and local air quality	Voluntary Emissions Reduction
Supply			Supply sufficient quantity of lipids that could be converted to biojet fuel [11.5B US gal (2026)]	Aspirational goal to have up to 30% of commercial aviation fuel being biofuel in 2030. Set as a stretched goal to support scenarios discussion.	Reliable supply is critical; must be compatible with existing fueling infrastructure ; must meet regulatory and standards required by FAA
Economic Feasibility			Have some hope of becoming economic feasible (ie Processed biofuel costs no higher than today's Jet A fuel (<$4/gal)	To be demonstrated	Beneficial to both suppliers and purchasers
Feedsto ck			Assume the raw oil from multiple feedstocks could be equally easily converted into biojet fuel	Multiple feedstock will have to be used	Feedstock neutral; fuel must satisfy Safety and Quality, Environmental benefits, Reliability of supply, and be Economically feasible

Do No Harm

What are Our Abundant Resources ?





- Arid Land (43% Earth's Lands)

- Brackish / Waste Waters

- Sun
  - Seawater (97% Earth's Water)

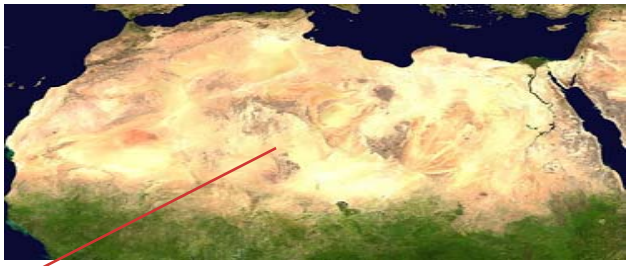
- Biomass

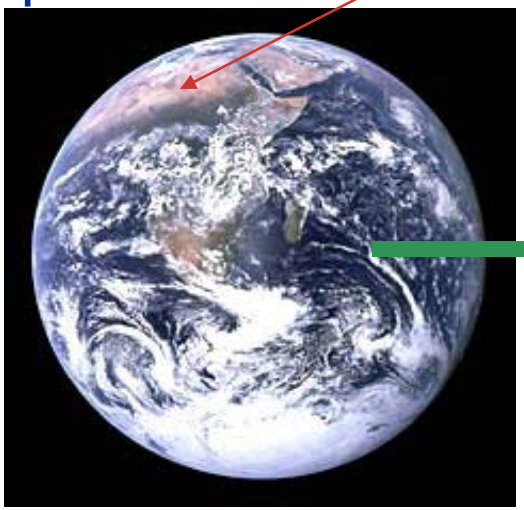
Halophytes are saltwater/brackish-water tolerant plants

Applying Abundant Resources and Halophyte Agri /Aqua culture

Assumptions

- **Sun**: solar incident radiation at 230 W/m2 daily
- **Seawater** (brackish water) irrigation
- **Arid Lands** : Total size of the Sahara Dessert (8.6×10^8 ha,13.6% of world arid or semi-arid lands)
- **Biomass**: Developed to its theoretical limits [10%]

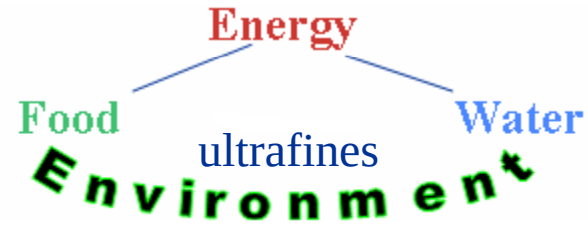




Halophyte Agriculture Could Produce 6 kQ/yr 13× the World Q (2004)

Why Our Interests are Halophytes Algae Bacteria Weeds and Seeds

In a nut shell, here is the basis for our interest in Halophytes and derivatives



- 97% earth's water is seawater
- 80% (or more) plant nutrients are in seawater
- 43% earth's land is arid or semiarid
- 40% population growth in next 40-50 yrs.
- Global warming threatens methane hydrates in permafrost and ocean (CH_4 release, 20X worse than CO_2 as GHG)
- Ample solar energy available
  (to 13X total World Q in terms of biomass)
- Projected dearth: food supply, freshwater supply, energy supply
  current and projected environmental disasters + famines … by 2050 cities consume 50% world's freshwater…soil losses 5-10M ha-arable/yr …50% applied farm nutrients lost in runoff, leaching or erosion; worst is Gulf of Mexico
- Projected rise in CO_2, NOX etc., ultrafine particulate emissions health hazards impacts all living matter and Climate
- Inaction will lead to demise of humanity

This is an existential matter

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Raw Biomass Costs for $4/gal-biofuel

- Raw-Biomass conversion to fuel at 20%

  5 kg-raw-biomass = 1kg-biofuel

- Non-biomass costs (ROI, marketing, personnel, transport etc…) 30% of fuel cost

- Maximum allowable raw-biomass cost

  $4/gal x ¾ x gal/3.4kg-fuel

  = about $1/kg-fuel

  1000 kg/ton / 5 kg-raw biomass

  Less than **$200/ton-raw-biomass**

Coal Spot (Sept.-Nov. 2008) $150 - $130 /ton (Volatility)

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Three Paths to Enhanced Biomass Productivity

- Seed selection characteristics
- Gene modified selection
- Trans-genetic diversity

- Synthetic biology

  Specific Function Biomass Products

Most human life calories provided by wheat, rice, corn, soybeans …**just one global disease short of famine**.

Jonathan Gressel *Genetic Glass Ceilings*

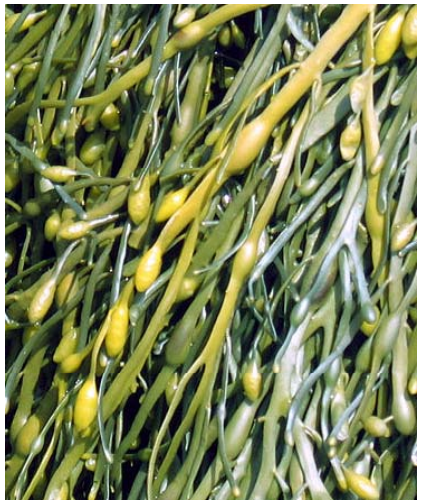
- ***No one feedstock source biomass fueling solution***
- ***Live systems do not scale like inanimate systems***

Common plants, weeds and seeds address (Food, Energy, Water)

Arundo donax & Seaweed

- **Arundo donax grows rapidly, produces 23-50 ton/acre looks a little like bamboo, able to tolerate some salinity or brackish waters. Non-containment risk is high; tends to overwhelm native vegitation.**

- **Seaweed is technically an macro-algae, a food-fuel feedstock to many world wide. Its nutritional complement is enormous.**



- **Celluose plants better suited to produce ethanol - Oil-seed better suited for biodiesel**

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Common plants, weeds and seeds address (Food, Energy, Water)

Camelina

- Camelina looks like wild mustard plants.
- Can prosper on marginal (near arid) lands. Fast growing (85-105 days)
- Can survive winters of Montana and Dakota's. Banned in some states
- Oil-Seed yields to 3.2 mt/ha (1.4 t/a) with (35-45%) oils ; High Omega-3
- General purpose food-fuel feedstock
- Biojet life cycle CO2 60-80% less than Jet A ?

Camelina

http://en.wikipedia.org/wiki/Camelina_sativa

https://www.camelinacompany.com/Marketing/GrowerInformation.aspx

http://www.hort.purdue.edu/newcrop/proceedings1996/v3-357.html

http://aginfo.psu.edu/news/2008/6/camelinaforbiofuel.html

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http://www.susoils.com/about.html

Jatropha

Common plants, weeds and seeds addresses (Food, Energy, Water)

Castor plant

Castor plant member of the economically important Euphorbia family.

Ricin laced seeds a potent poison, One milligram can kill an adult. Being worked

Grows rapidly in arable soils, yet cannot tolerate frost. Its tolerance to arid soils and saline conditions needs assessment.

Colorless to pale yellow liquid, one of the world's most useful and economically important natural plant oils. Yields to 1400L/ha 1.25mt/ha (0.5t/a)

http://en.wikipedia.org/wiki/Castor_oil_plant

http://www.castoroil.in/uses/fuel/castor_oil_fuel.html

Castor plant

Soil Root
Establishment
Soil Pathogens

Castor (ricin) problems similar to Jatropha (curcin)

Seeds contain 0.2 to 3% ricin

1 mg/kg toxic
fill car with 50 liters (13 gallons diesel)
enough ricin coproduct to kill 3 people
at lowest content, 45 at highest

Not transgenic - no environmental impact studies needed - no regulatory scrutiny
Ricin protein "easy" to eliminate transgenically!

Prof. Jonathan Gressel [TransAlgae Ltd.] Why Transgenics are Imperative for Biofuel Crops , NASA-GRC Cleveland Ohio, 10March 2009

Issue also being worked at processing plant

Trans GM and Plant Toxins

- Modification (decrease) lignin content in feedstock
- Enhance cellulose content

- **Jatropha plant**

- All parts are considered toxic but in particular the seeds. Main Toxins: purgative oil and a phytotoxin or toxalbumin (curcin) similar to ricin

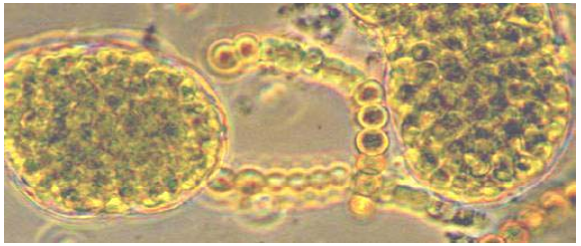
  [curcin control by prolonged autoclaving?]
  http://www.inchem.org/documents/pims/plant/jcurc.htm#SectionTitle:2.5%20%20%20%20%20%20Poisonous%20parts.

- **Castor plant**

- Similar problems as Jatropha; Seeds contain 0.2 to 3% ricin X

Bacteria Address (Energy, Food, Water)

- Cyanobacteria: oldest forms and found almost any habitat
- The chloroplast facilitates endosymbiotic relation between cyanobacteria living in plant or algae cells.
- Bacterial genomes easier to modify (maybe)
- Can fix either nitrogen or carbon
- Bacteria are prolific and reproduce rapidly.
  With proper conditioning can be harvested daily
- Natural blends or modified bacteria can absorb solar energy at different wavelengths,
- Some can tolerate extremes in temperature such in the hot springs at Yellowstone National Park.
- **Bacterial biomass potential achieve or exceed 100 g/m2-day** theoretical biomass limits set by Weismann (2007)



Nitrogen fixing

Genetic modeling

Weissman, Joseph C. (2007) From Laboratory to Pilot Plant – Lessons Learned from a Microalgae Biofuels Project Algae Biomass Summit, Nov. 15-16, Grand-Hyatt Hotel, San Francisco, CA, USA.
http://www.wsgr.com/WSGR/Display.aspx?SectionName=news/emailer/Event141/info.htm

Algae addresses (Food, Energy, Water)

- Availability of solar, seawater, spent freshwater (eg livestock) and arid land.
- "there is only 0.03% CO_2 in our (lower) atmosphere and on this thin thread hangs our very existence" [Spoher, 1953]
- Increasing CO_2 concentration increases biomass
- Force CO_2 fed algae systems
- CO_2 source (about same productivity)
  - Pond ("pure" CO_2) tanks or pipelines
  - Power Plant Desulphurized flue gas (FGD) CO_2
- Bioreactors (horizontal and vertical)
- Round numbers, 2 kg-biomass requires 1 kg-water and 3 kg-CO_2 plus maybe up to 1 kg N (nitrogen) nutrient fertilizers (seawater irrigation provides some 80% of the nutrients needed for plant growth)
- Yields vary 2000-6000 gal/a

Halophytes Are Salt and Brackish Water Tolerant Plants That Address Issues (Food, Energy, Water)

seawater 35000ppm salt ; can't drink >3000ppm; normal 500 ppm

- ***Salicornia bigelovii,*** a leafless annual salt-marsh plant with green jointed and succulent stems (sea asparagus)
- Indigenous to US , also grown Arabian Sea coasts of Pakistan and India: Oil content 15-35%
- The "fatty" acid (nutritional) values salicornia oil comparable to safflower oil

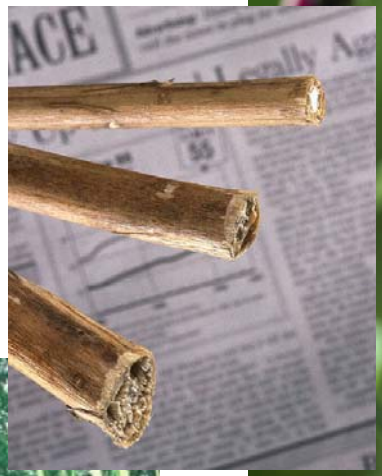
- ***Seashore mallow,*** a perennial, grows coastal marshlands or inland brackish lakes. Oil content similar to soybeans (about 20%) with a fatty acid composition more like cottonseed. **Malvaceae Family**

- ***Distichlis spicata***, a grass, suited to high temperatures and high-radiation of southern Australia, grows and spreads in saline waterlogged soils. Remediates soils

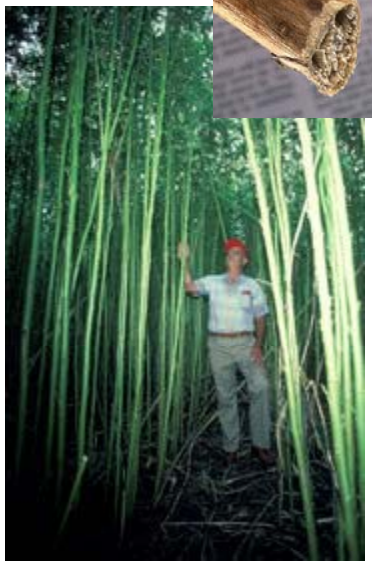
.

Malvaceae Family bio-stock traits

Bioplastics & Fibers Potential



http://en.wikipedia.org/wiki/Cotton



http://en.wikipedia.org/wiki/Okra

http://en.wikipedia.org/wiki/Kenaf

Kosteletzkya virginica

[Seashore Mallow]

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Halophytes Address (Food, Energy, Water)

- *"fir" trees* : *Tamarix jordanis excretes mostly NaCl.* Tamarix aphylla (salt cedar) accumulates starch and has carbonate precipitates on its twigs.

Salt Nodules

Branches (leaves)

- *Euphorbia tirucalii* grown with salty water or recycled sewage water.

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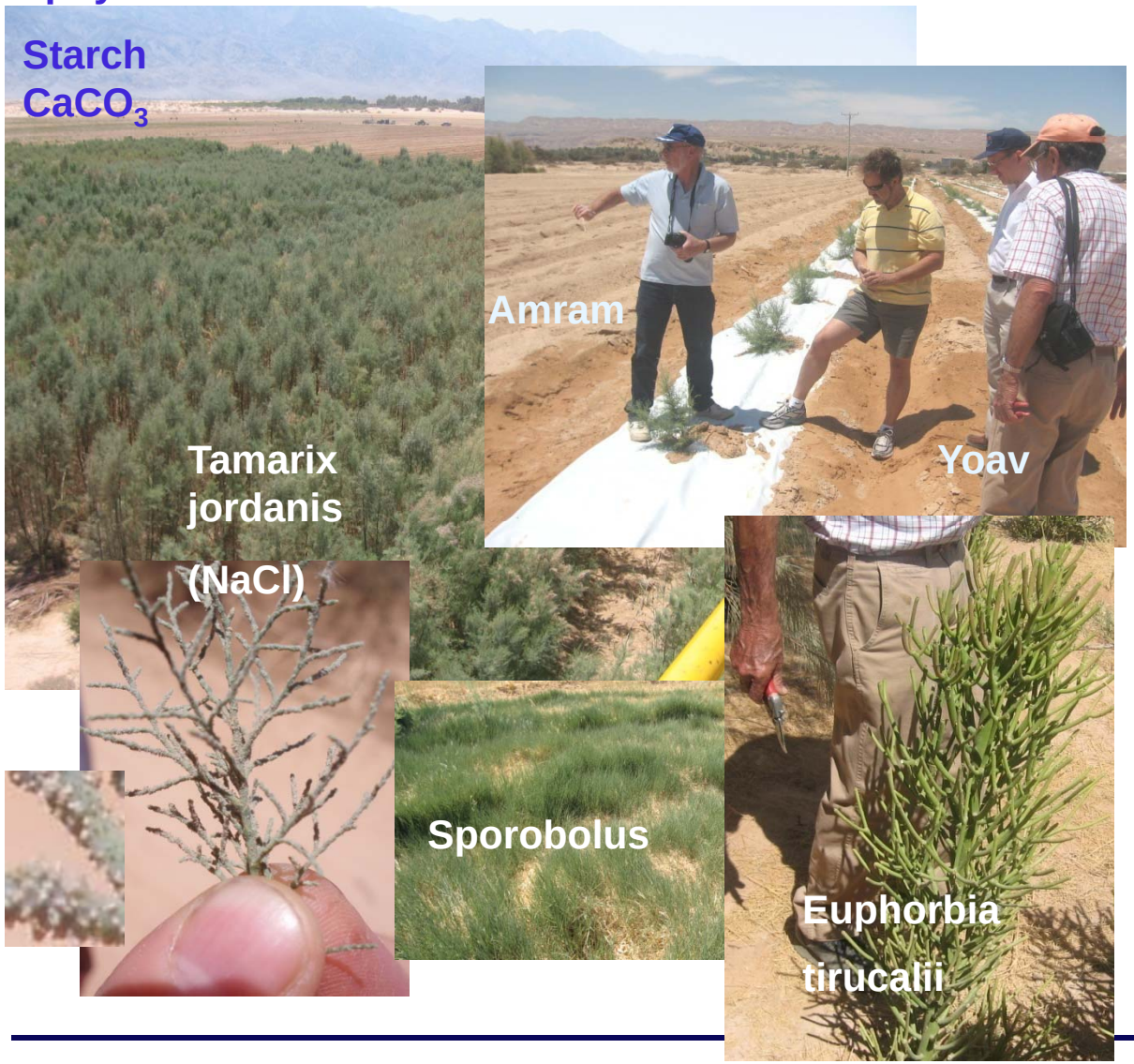
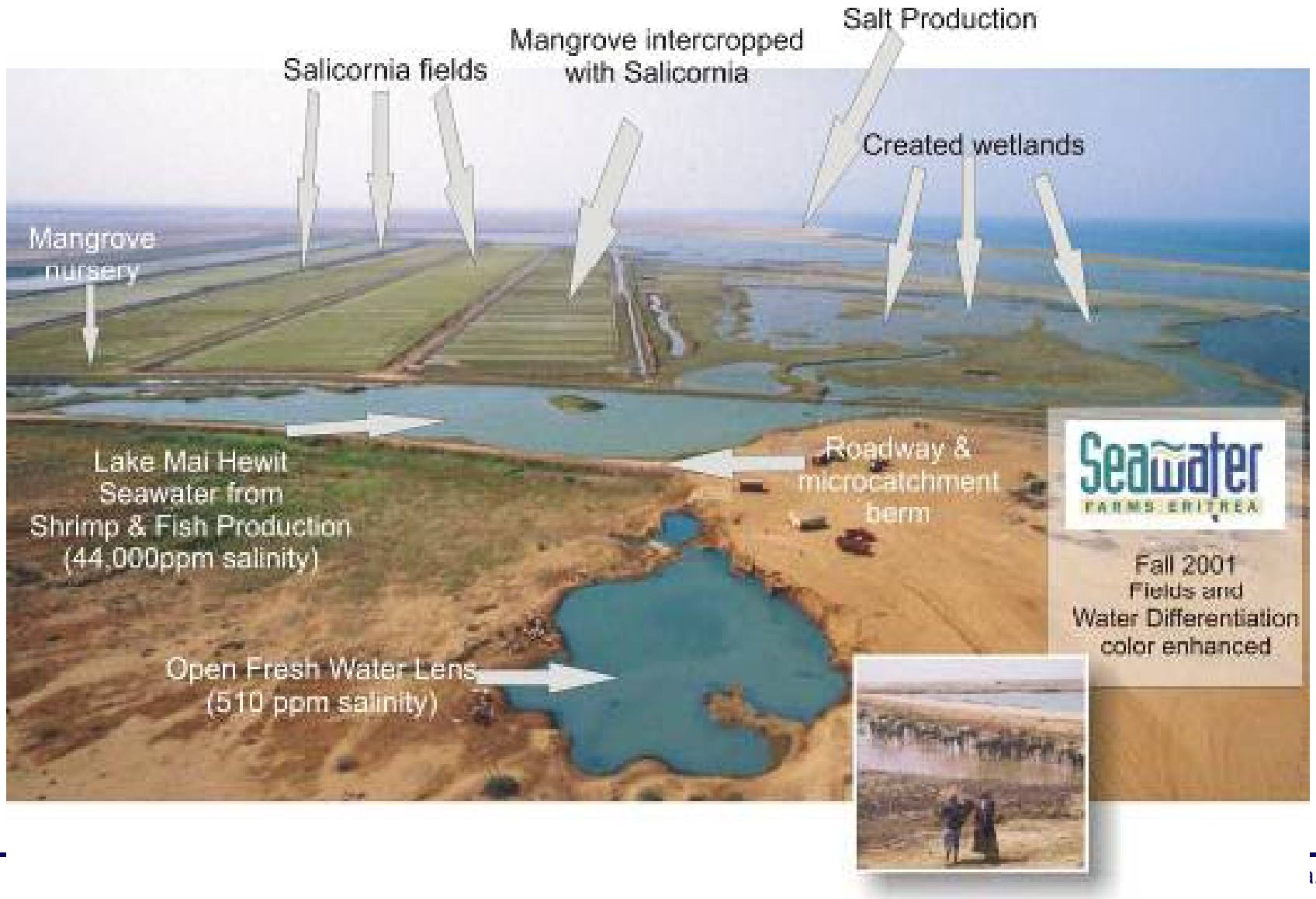
Halophyte Fields Yotvata

Yoav Waisel [YoavW@tauex.tau.ac.il]
Amram Eshel [AmramE@tauex.tau.ac.il]



- Novel halophytes as well as classic ones.
- Biomass via invasive fir trees (weeds) Tamarix (Salt Cedar)
- 100 mt /(1.5yr) total biomass, 80mt/1.5yr carbon
- Branches and needles collect salts on surfaces
- Plant sap (more viscous in salt water, less in fresh) bleeds similar to milkweeds
- Collect research data base on potential halophytes for fuels and food
- Moving toward sustainable saline agriculture

Live Cycle Systems



Halophyte Production (salicornia)

- Salicornia [Annual] salt tolerant to 2X seawater
  optimum productivity to 1.3X seawater
- Over 6 years of field trials in Mexico (others United Arab Emirates, Saudi Arabia, Eritrea, India)
- Total **Biomass** 2 kg/m2 ; **20 m-t/ha (8.1 t/a)**
- **Oilseed** 0.22 kg/m2 ; **2.2 m-t/ha (0.9 t/a)**

  Oil @35% 0.077 kg/m2 ; 0.77 m-t_m/ha (0.31 t/a)

  Sp.Gr. ~ 0.9 3.4kg/gal **226 gal/ha (92 gal/a)**

  Aviation grade *76 gal/ha (31 gal/a)*
- Water requirements **1.35 X glycophyte irrigation**
  (prevents salt build-up at roots)
- SeawaterFoundation **Total Live Cycle System**

Glenn et al. U Arizona, Scientific American Aug 1998; Hendricks & Bushnell ISROMAC12–2008–20241, Dr. Carl Hodges (2007,2008) http://www.seawaterfoundation.org/

Halophyte Production (seashore mallow)

- Seashore Mallow [Perennial] (salt tolerant to coastal seawater)
- Over 4 years of field trials in Delaware Coastal Plain (others China, Egypt) [results for top-end harvest ; less for production fields]
- Total **Biomass** 1.8 kg/m2 ; **18 m-t/ha (7.3 t/a)**
- **Oilseed** 0.145 kg/m2 ; **1.45 m-t/ha (0.59 t/a)**

  Oil @20% 0.03 kg/m2 ; 0.29 m-t/ha (0.12 t/a)

  Sp.Gr. ~ 0.9 3.4kg/gal **85 gal/ha (35 gal/a)**

  Aviation grade **29 gal/ha (12 gal/a)**
- Water requirements < **1.5 X glycophyte irrigation +**

  (prevents salt build-up at roots)

+ soil texture, drainage, natural rainfall, evapotransporation dependent
- Harvesting : Conventional Soybean Combine
- Soil remediator
- Bioplastics and fiber potential

Prof. John L. Gallagher, U. of Delaware
http://www.ocean.udel.edu/people/profile.aspx?jackg

Soil Carbon Sequestration

- U.S. forests store 150 B metric tons CO2equiv
  - 2 percent of global terrestrial carbon
- US currently sequester more carbon than they emit,
  - 10 percent U.S. CO2 emissions/yr [*Heinz Center*]
- Potential Carbon Negative Aviation IF sequester carbon and refurbish the soils
  - biomass fueling
  - properly manage
    - agricultural (arable) lands
    - forests and grass lands
    - decrease petrochemical balance

Hendricks, R.C. (2008) Potential Carbon Negative Commercial Aviation through Land Management, ISROMAC12–2008–20242, The 12th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, Honolulu, Hawaii, February 17-22, 2008

Beyond Drop-in Fueled Aviation

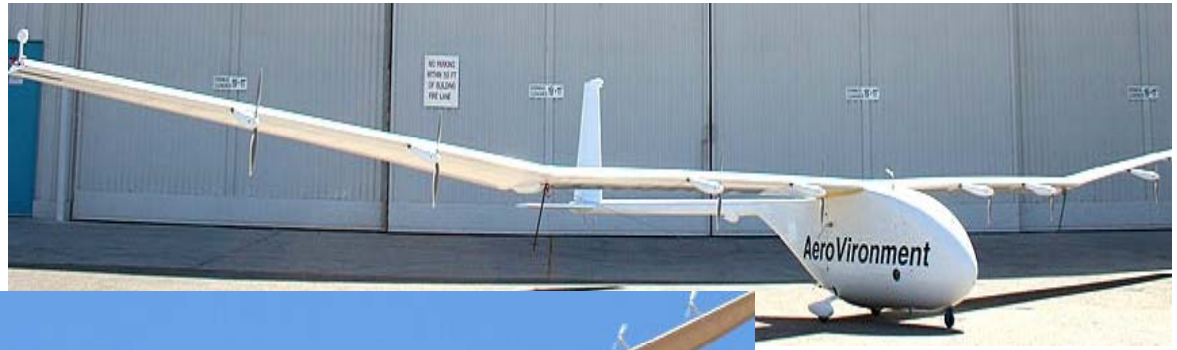
- Unmanned vehicles
  - Solar powered
  - Hydrogen fuel cell power
  - Hybrid electric systems
  - LH2 - Compressed Air propulsion systems
  - Combined solar-hydrogen fuel cell systems
- Single seat aircraft demonstrators with and without battery-boost TO. Difficult to scale to large systems
  - Holds promise of Clean Flight Systems
- Total Aircraft Reconfiguration/Design (Bushnell)
- Recuperated / Intercooled Energy Recovery Engines
- LENR / CANR (low energy nuclear reactors)
  http://www.lenr-canr.org/

Solar-Electric ; LH2- Fuel Cell Electric

http://www.avinc.com/

Solar Powered Helios & Zephyr

http://news.bbc.co.uk/2/hi/science/nature/6916309.stm



Stratospheric Persistent *UAS* (unmanned aircraft systems) : Global Observer

First Flight – June 2005

http://www.spacewar.com/reports/AeroVironment_Flies_Worlds_First_Liquid_Hydrogen_Powered_UAV.html

Missions : Communications Relay & Remote Sensing
Features : Stratospheric Global Persistence (all latitude)
Endurance/Range : Up to several days/global
Payload : Up to 400 lbs. for GO-1 & 1,000 lbs for GO-2
Operating Altitude : 65,000 feet
Propulsion System : Liquid hydrogen powered

X

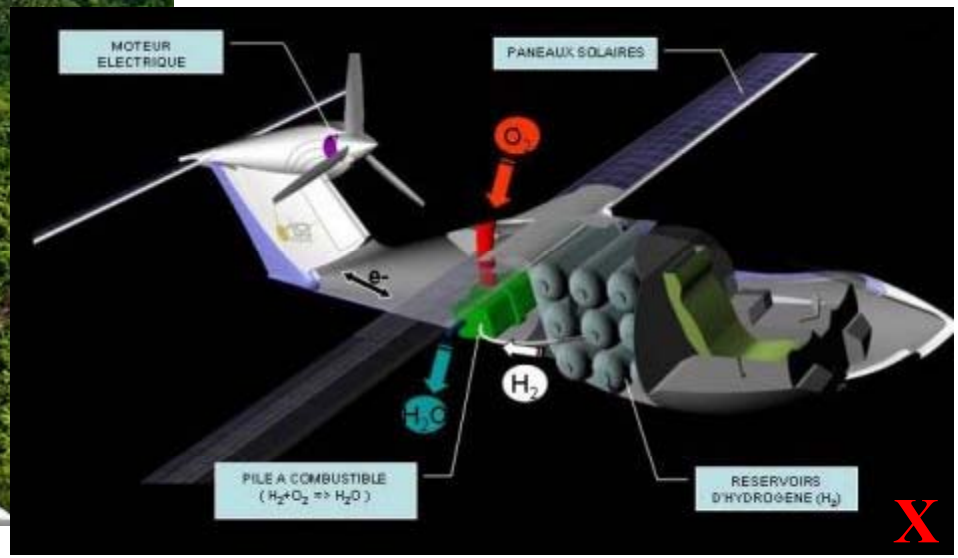
2008 Battery Assist Hydrogen Fuel Cell-Electric

- Boeing 3 April 2008 : 3 test flights at 1 km.
- Battery boosted TO; fuel cells only at cruise
- http://news.bbc.co.uk/2/hi/technology/7330311.stm
- Potential for fly-back battery booster vehicle separation at cruise.

X

2009 Solar-Hydrogen-Electric

- Hydrogen fuel cells power Electric engine that is more efficient at altitude; Range about 1500 km.
- Hy-Bird PV cells provide cruise on-board power and hydrogen fuel cell TO peaking. [no battery boost cited]
- www.hy-bird.com or www.lisa-airplanes.com
- http://news.bbc.co.uk/2/hi/americas/4643575.stm AeroVironment



X

The Problems

How to make these Fuel Resources

Secure

Sustainable

Economically viable

Sufficient Supply

And Satisfy the Ground Rules

X

Patent Ownership Issues

- Foreign held patents control product
- Patents on biomass feedstock product

algae	bacteria
crop	halophyte, glycophyte
	castor, jatropha, camelina,

Need :

cooperative investment in product research to implement partial product control

There are additional issues such as Biophotonics, Red Light biomass, Carbon Chain "slicing", UOP paraffinic footprints, additive packages, bio-oil/water contamin

Additional Issues

- Biophotonics
- Red Light biomass (solar peaking in red / flashing)
- *Carbon* Chain "slicing"
- UOP (others) paraffinic footprints
- Additive packages
- Bio-oil/water contamination
- 'meal" value/ oil-value and bio toxicology
- Celluluosic biomass availability and conversion
- fermentation, pyrolsis systems and oil type / use
- wastes solids/liquids (touched upon)

X

Conclusions

- **Must use Earth's most abundant natural resources**

  Biomass, Solar, Arid land (43%), Seawater (97%) with nutrients (80%) plus brackish waters and nutrients resolve environmental triangle of conflicts energy-food-freshwater and ultrafine particulate hazards

- **Requires Paradigm Shift - Develop and Use Solar * for energy; Biomass for aviation and hybrid-electric-compressed air mobility fueling with transition to hydrogen long term. *** (PV-Thermal-Wind-drilled geothermal)

  Employ Telecommunication (tele-everything)

Consequences of Inaction

- Imperative (*existential*) humanity **Controls** and **Resolves**
  Triangle of Conflicts [energy, food, freshwater]
  Emissions, in particular CO_2, CH_4, nano and ultrafine HC
  - emissions peaking
  - emissions levels
  - emissions toxicity

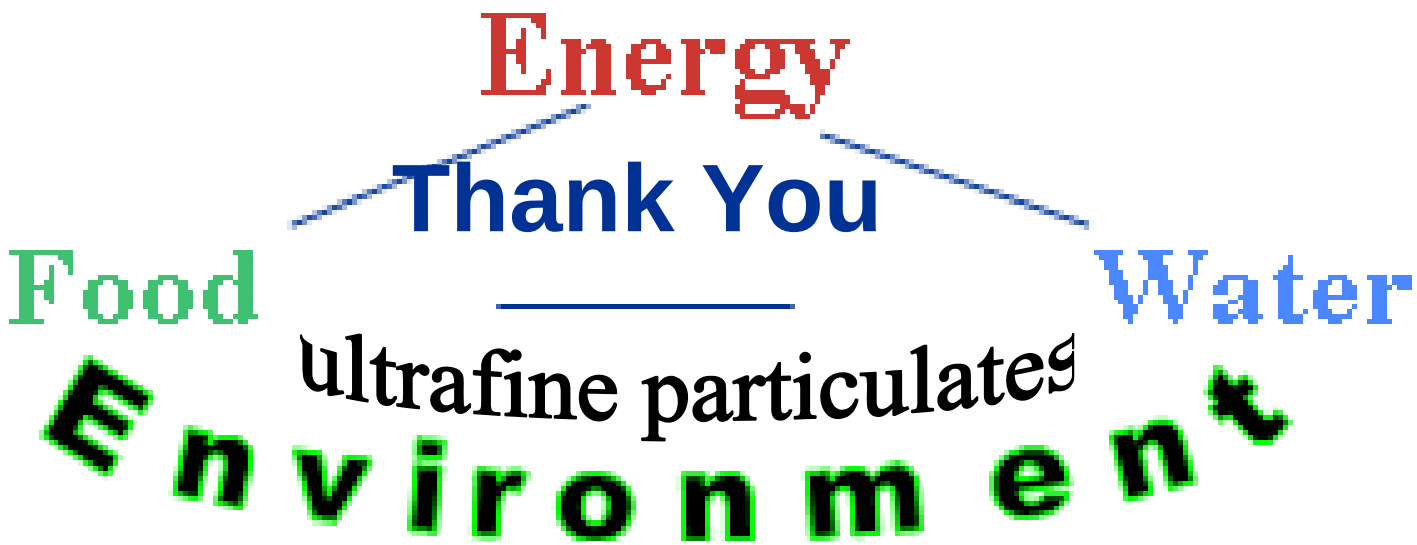
- Current CO_2 level and peaking have vivid similarities to Permian (~ 260 Mya) and dinosaur (~ 65Mya) periods

- Each of which led to **mass extinction** with multiple lesser extinctions over past 400 My.

- Known historical volcanic emissions, yet lack direct historical evidence to ultrafine particulate emissions.

- Ostensibly, **foreign control** of energy, food or freshwater supplies, implies **limited world influence**.

X



Hendricks, R.C. and Bushnell, D.M. (2009) Halophytes, Algae, and Bacteria Food and Fuel Feedstocks, NASA/TM--2009-215294

Hendricks, R.C. and Bushnell, D.M. (2009) Synthetic and Biomass Alternate Fueling in Aviation, submitted to Mechanical Engineering Magazine.

Daggett, David L. , Ben-Amotz, Ami and Benemann, John (2009) Feasibility of Algal Oil for Renewable Jet Fuel, submitted to Journal of Applied Phycology.

Support & Discussion Materials

What happens to the Ricin ?

http://books.google.com/books?id=E2kTAAAAYAAJ&pg=PA292&lpg=PA292&dq=castor+bean+wight&source=web&ots=TRBnhCaZ0C&sig=wmDHJ0cAmc_xYwr3s8T0W-WIKTs&hl=en&sa=X&oi=book_result&resnum=6&ct=result#PPA1,M1

- 1904 Agricultural bulletin
- 50 lb/bu and 2 gallon-oil/bu
- 5% ricin http://cti.itc.virginia.edu/~whg2n/biom204/handouts/translation.pdf
- 3% ricin http://www.aun.edu.eg/distance/pharmacy/poison/castor_bean.htm
- Ricin 0.6%by wt. **http://www.dickdestiny.com/blog/2008/03/castor-seeds-ricin-not-much-of-threat.html**
- 60% oil yield from castor plant http://www.biodieselmagazine.com/article.jsp?article_id=622
- 1,000 to 1,500 seeds/lb and 2,200 lb/acre harvest http://www.hort.purdue.edu/newcrop/afcm/castor.html
- 25 lb-beans /gal-oil → ¼ lb ricin/ gal-oil produced at 1%
- World market is $0.4B; 1 B lb → $0.4/lb → $10/gal http://www.ars.usda.gov/is/AR/archive/jan01/plant0101.htm
- 11.5B gal requirement → 288B lb harvest or 131 M acres → 2.88 B lb of ricin at 1% by weight.

Biomass Fueling Test Examples

- Heavy Duty Diesel Engines Diesel-Biodiesel Blends
- Emissions decrease with % increase in blend
  - CO_2 formation
  - CO
  - particulates
  - unburned HC
  - SOx
- Increases in NOx (to 10%)
- Renewable, non toxic, feedstock diversity

- T-63 Small Gas Turbine Engine JP8-Biodiesel Blends
- Particle number density (PND) decrease with % increase in blend at cruise and take-off power (small decrease in size), but PND increases at idle.
- Pyrene and fluoranthene found in soot data
- Typical turbine engine particulate size 30-70 nm

Effects of biomass burning: http://cat.inist.fr/?aModele=afficheN&cpsidt=14518203
Erie Ohio Biofuel producer: http://www.lakeeriebiofuels.com/

- Potential Aviation Feedstock & Blends
- Current 3:1 bio-oil / bio-jet assumed 3:1
- Atmospheric Carbon Benefit Ratio 3:1 to 3:2
- Oil-seed / bio-oil ratio 4:1
- Biomass / oil-seed ratio 10:1
- Blend bio/petro 1:4
- kg- bio-jet / gal 3.34
- World aviation demand B-gal/yr 100
- Sustainable Biomass Demand B-t/yr 3.5 to 7

- **1. Bacteria are least understood with highest potential for meeting production and cost demands.**
- **Can fix C or N (fuels or fertilizers)**
- **Makes use of sea and brackish waters.**
- **OPEX and CAPEX not in public literature, so undetermined Much R&D required, but achievable.**

- **2. Cultivated algae can meet production demands.**
- **OPEX and CAPEX are high.**
- **An established industry with Ben-Amotz leading the way with public data.**
- **Potential for free ride with wastes systems**
- **Need cost reduction.**

- **3. Open seas algae have potential to meet demands.**
- **Risk and Cost largely unknown; need R&D.**
- **Jonathan Trent / Dennis Bushnell / Bob Hendricks working on systems.**

- **4. Halophytes and “Weeds” can meet production demands.**
- **Makes use of sea and brackish waters, remediates soils.**
- **Needs R&D.**
- **Foreign / domestic arid areas.**
- **Development of saline agriculture and aquaculture life cycle systems.**
- **Partially established industry, mostly in arid climates.**

- **5. Wastes can meet partial demands.**
- **Pyrolsis and fermentation are established methods**
- **Needs further R&D to become effective**
- **Needs to be symbiotic with biomass production.**

- **All the above need policy changes to be effective.**
- **For example, if government taxes (fed, state, local) are relaxed and government lands used for production, cultivated algae and halophytes could satisfy liquid fuel demand.**

Policy changes are critical.

Heat Engine Exhaust Emissions (HC)-Fueled Systems

Health Hazards

- Particulate pollution : ***ultrafine particulates directly translocate to promote vascular system diseases.***

  Journal of America College of Caradiology (JACC) *. chronic respiratory diseases due to particulates are better known **

- Classified by Aerodynamic diameter (AD)

(AD)	**Examples**
Coarse: 2.5 -10 µm (PM10)	Road and agricultural dust, tire wear
Fine: < 2.5 µm (PM2.5)	Gas to particulate conversion in combustion and industrial processing
Ultrafine: < 0.1 µm (< 100 nm) Nanomaterials particulates	Exhaust emissions (tailpipe), aircraft, (HC) fueled mobility/stationary systems

•**Simkhovich, B.Z, Kleinman, M.T., Kloner, R.A. (2008) Air Pollution and Cardiovascular Injury Epidemiology, Toxicology, and Mechanisms, Journal American College of Cardiology, 2008; 52:719-726, doi:10.1016/j.jacc.2008.05.029 (Published online 13 August 2008).**
http://content.onlinejacc.org/cgi/content/short/52/9/719
** **Schwartz, J**. (1993) Particulate Air Pollution and Chronic Respiratory Disease, Environmental Research, 62, pp. 7-13

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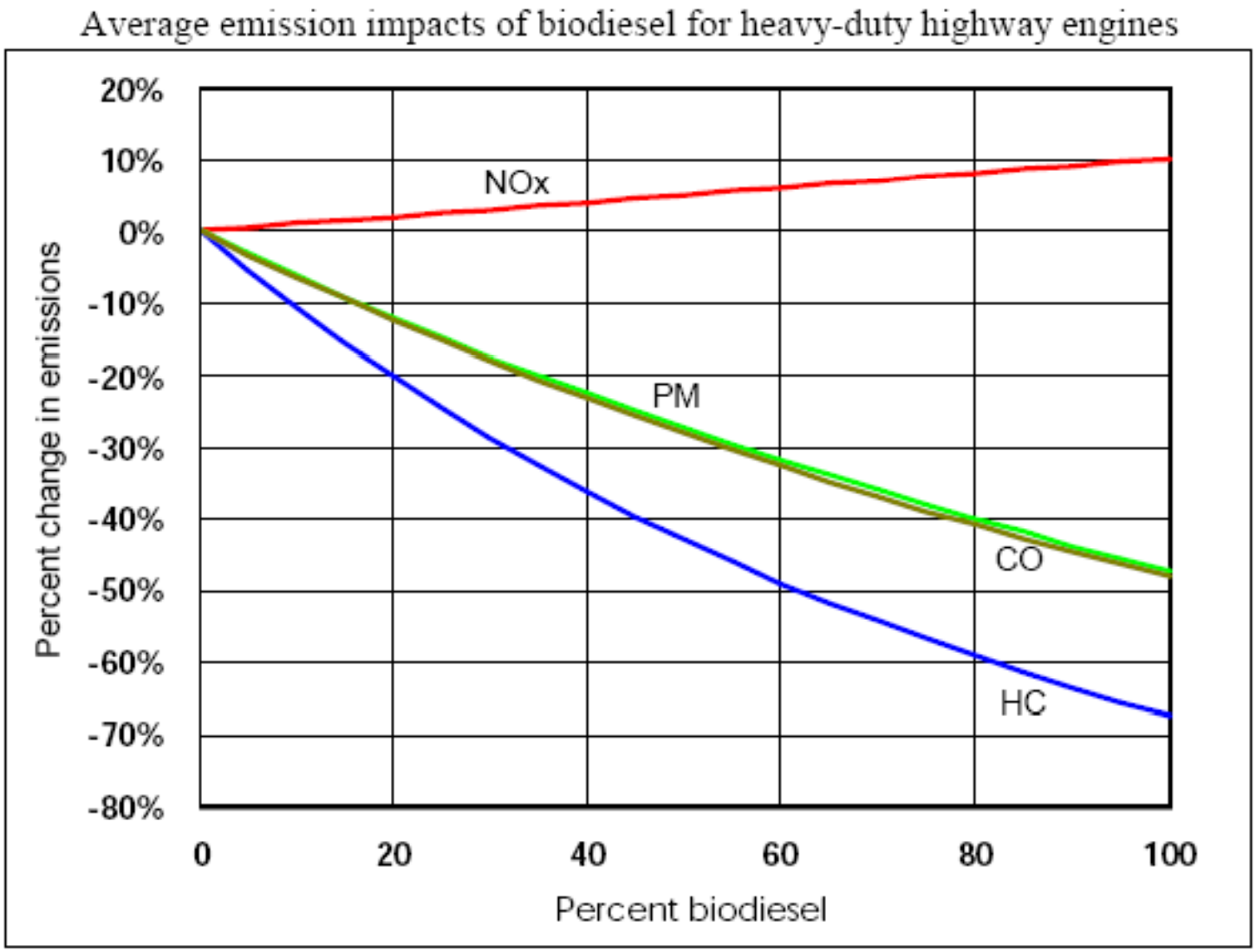
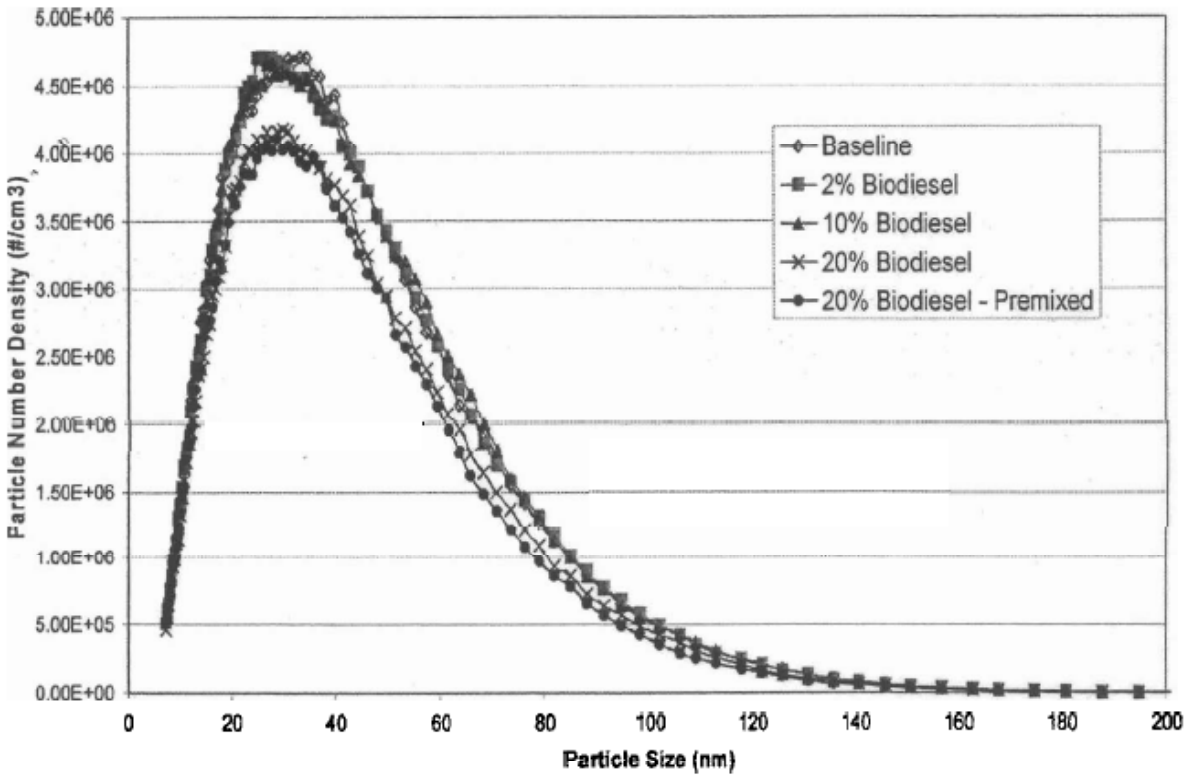
Effects of biomass burning: http://cat.inist.fr/?aModele=afficheN&cpsidt=14518203
Erie Ohio Biofuel producer: http://www.lakeeriebiofuels.com/

Fig. 3 Diesel Engine with Diesel-Biodiesel Fueling



http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

Fig. 4 Gas Turbine Engine Particulate Distribution



Particle size distribution from T63 engine at cruise for JP-8 and JP-8/biodiesel blends.

Pyrene : Toxic to kidneys and liver

Fluoranthene: carcinogenic

Corporan et al. (2005) Impacts of Biodiesel on Pollutant Emissions of a JP-8-Fueled Turbine Engine, Air & Waste Management, Association, 55 pp.940-949.

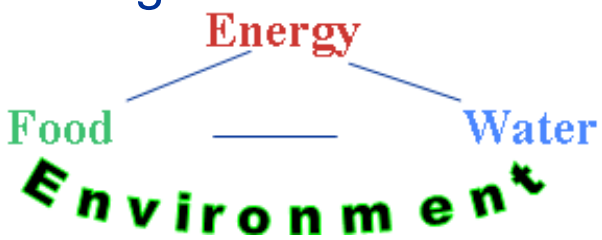
Solar & Biomass Earth's abundant natural resources

- What are "new" sources

  Solar PV-Thermal-Wind-geothermal (more efficient less constructed)

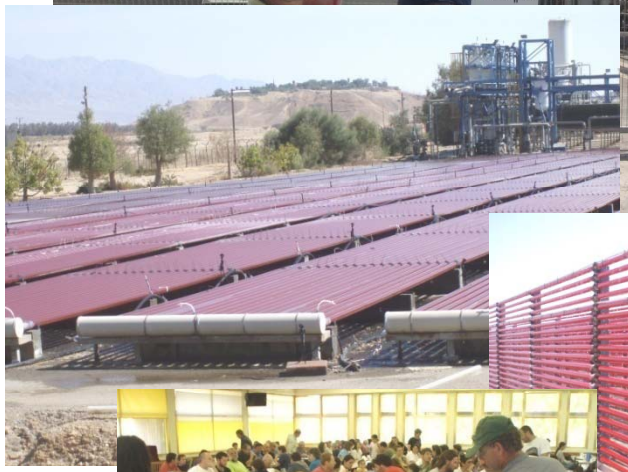
  Biomass (less efficient but more natural, pervasive)

- Biomass: photosynthesis transformation of environmental carbon, water, and nutrients ie inorganic carbon to organic carbon.
  - sugarcane, soybeans, salicornia, algae, bacteria : food or fuel sources
  - cellulosic waste soil conditioner or fuel source
  - Others such as jatropha are nonfood sources, seed oils fuel source.
- Directly addresses global resources toward energy, food, and fresh water —the Triangle of Conflicts— environmental and climatic issues.



Kibbutz Yotvata / Ketura – Advanced Technology

- Biogas facility at Kibbutz Yotvata
- Solids separated and waters sent to fermenter with clean waste water but sent to fields for irrigation CH4 to gas generators and electric generators
- Cows milked on rotating platform life cycle is well regimented
- Bio reactor horizontal larger pipes and vertical (Kibbutz KETURA)
- Red algae for coloring pond fed salmon prior to serving are not pink (rather gray in color) adding algae dies salmon pink
- Bio reactor fowled by foreign matter …shut down for 1.5 yr for cleanings ? Algae need to be protected against extremes in heat



Ocean and Bay Dead Zones [hypoxic – low oxygen] Spent-freshwater treatment and algae recovery Systems

- Spinning mesh wheel develops an algal biofilm that feed on the suspended wastes (German Concept)

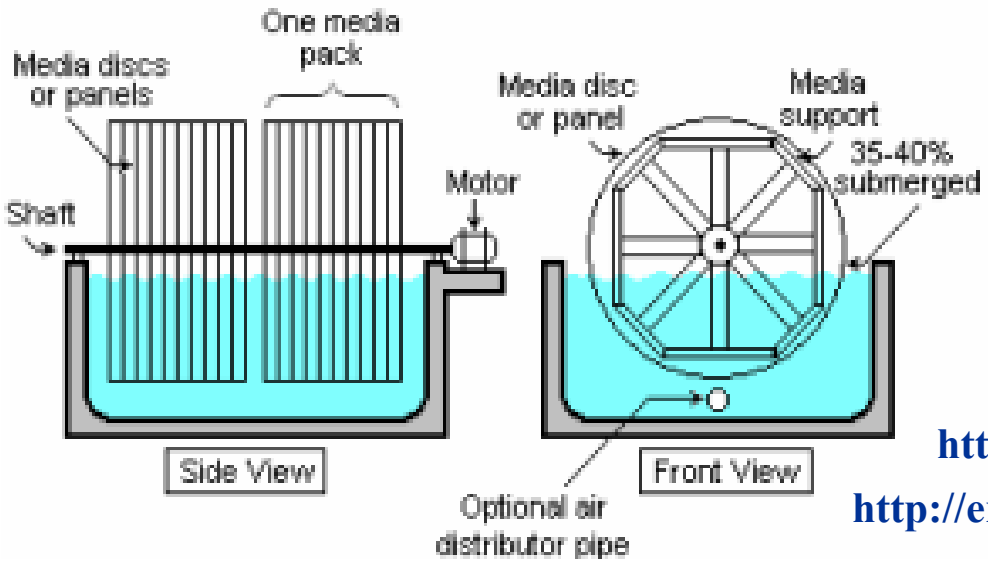
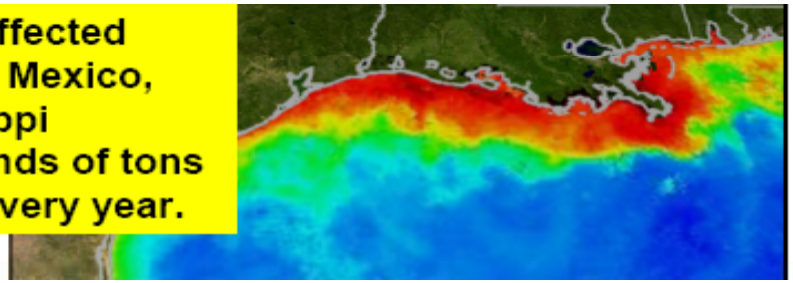


Photo: Kirsten Rodsgaard-Mathiesen©

http://www.aquaflowgroup.com/pressroom.html

http://en.wikipedia.org/wiki/Sewage_treatment

Among the worst affected areas is the Gulf of Mexico, where the Mississippi discharges thousands of tons of agrochemicals every year.

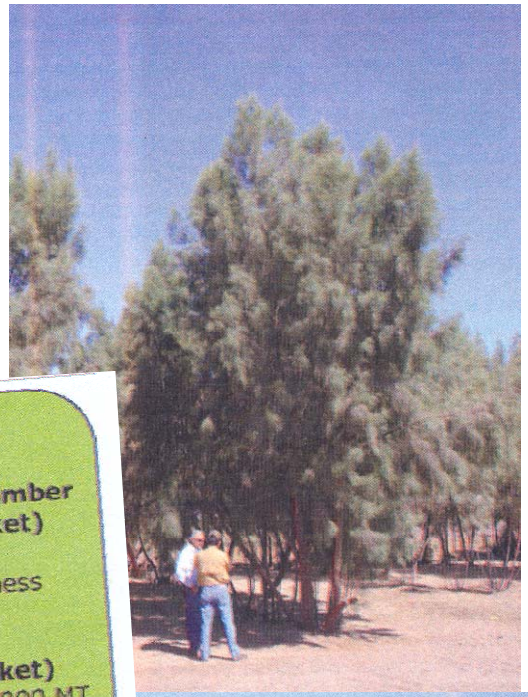


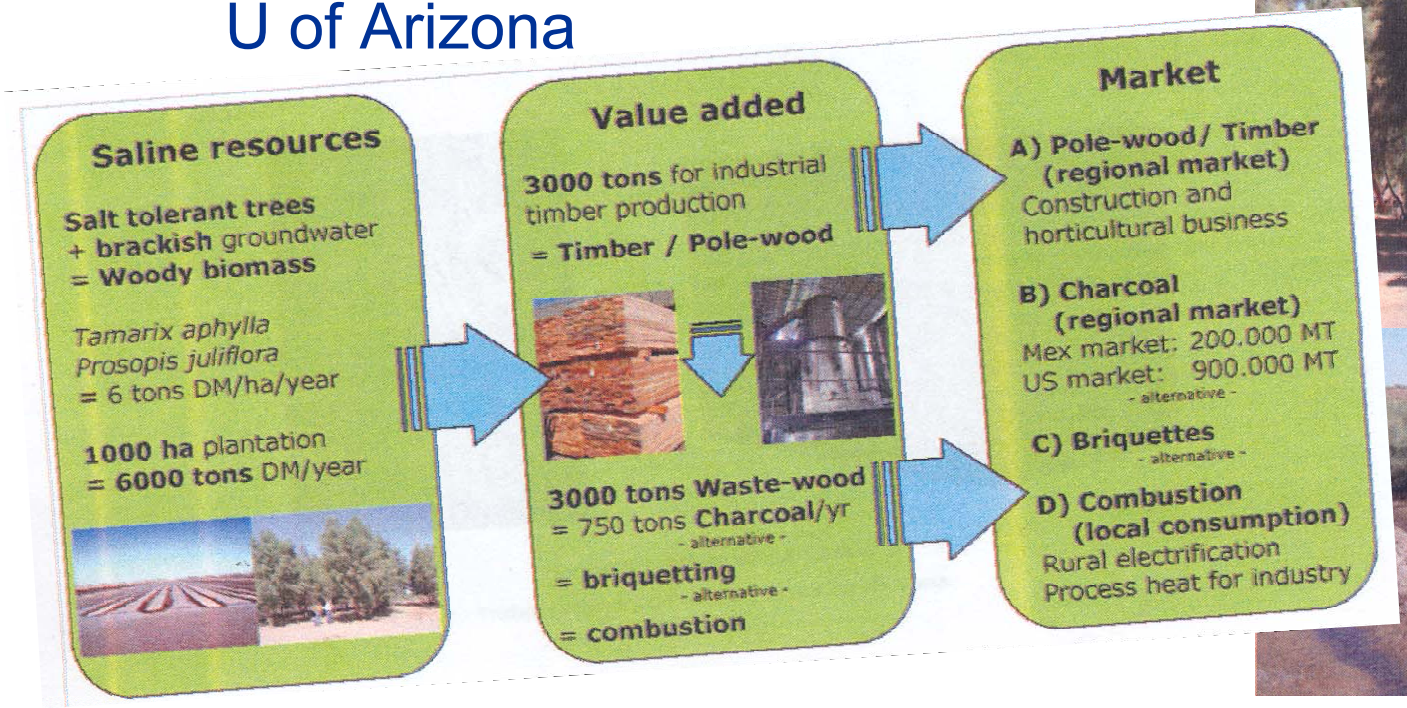
Tradici, Mario, R. (2008) Microalgae biofuels: potential and limitations. Algae Biomass Summit, Algae for Energy, Seattle Washington 23-24 October 2008 http://algalbiomass.org/, Department of Agricultural Biotechnology University of Florence, Italy

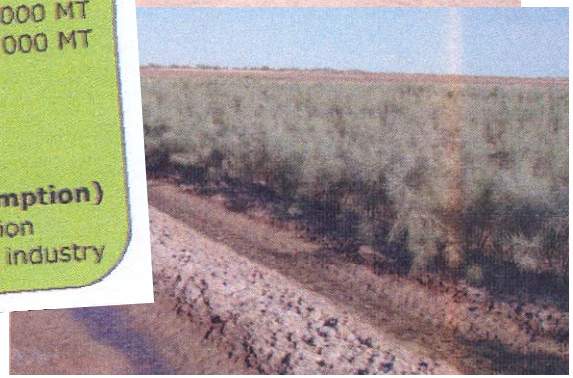
Colorado Delta Project

www.oasefoundaion.eu/project 34

- Tamarix aphylla [similar to Yotvata]
- Value added marketing
- Prof. Ed Glenn Dr. Carlos Valdes U of Arizona

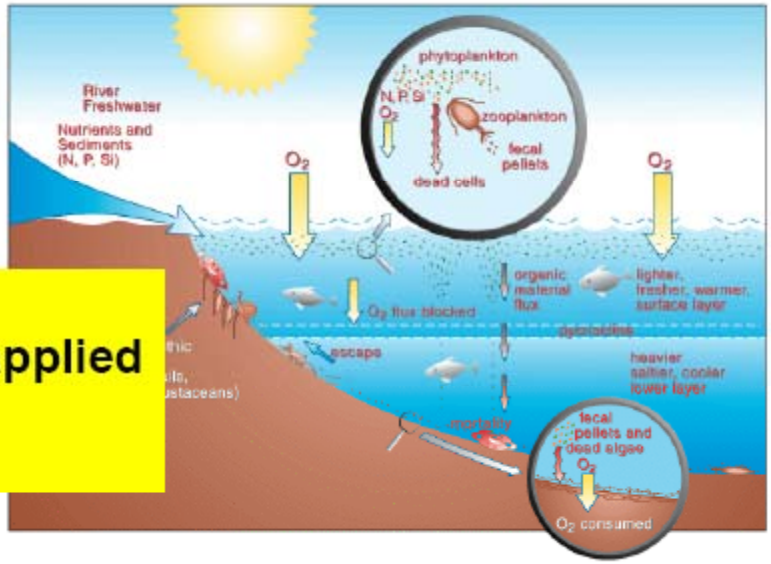






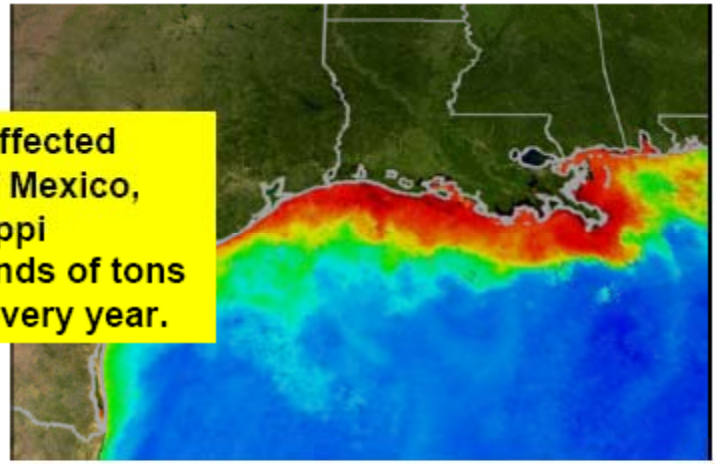
Nutrient Runoff and Ocean/Bay Dead Zones (hypoxic)

V - Ocean dead zones



Up to half of all nutrients applied on farm are lost in runoff, leaching or erosion.

Among the worst affected areas is the Gulf of Mexico, where the Mississippi discharges thousands of tons of agrochemicals every year.



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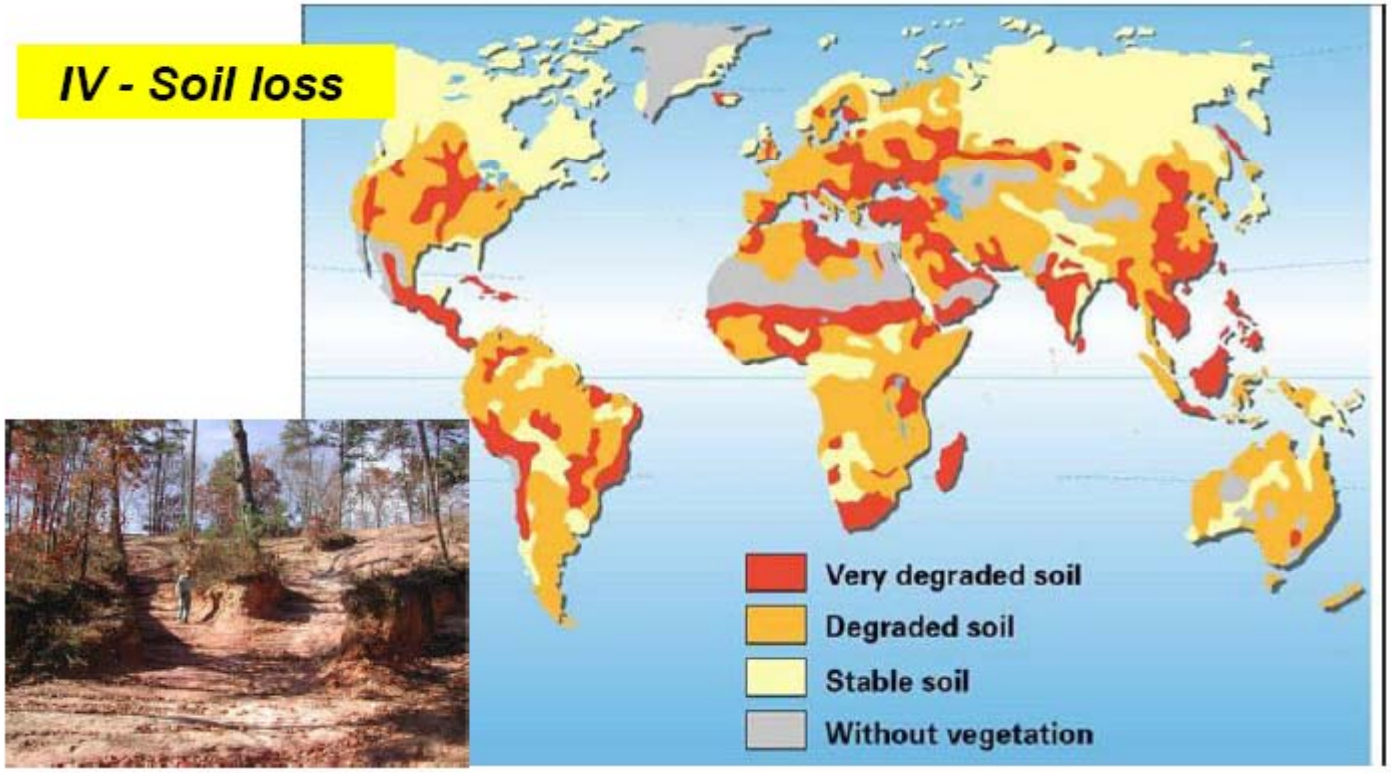
Jatropha plant Expedition….

Soil Loss Issues

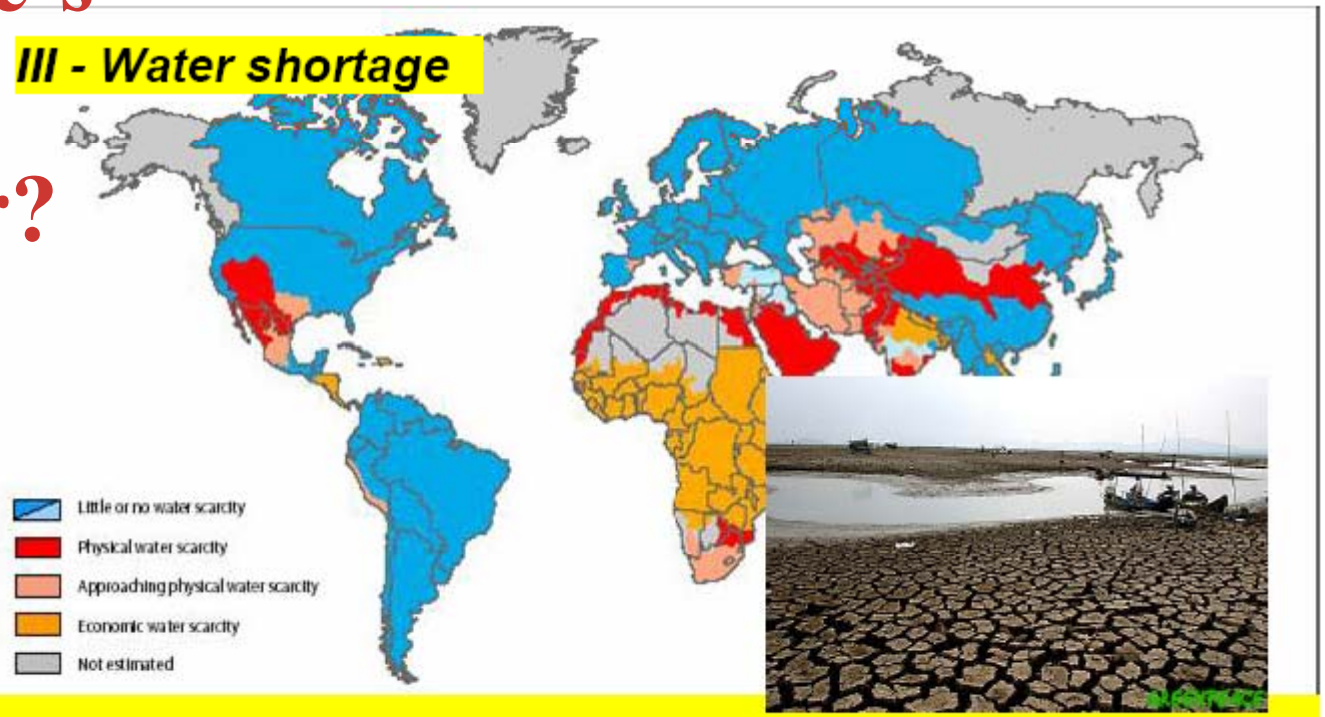


- there is a loss of about 5-10 million ha arable land a year.

Tradici, Mario, R. (2008) Microalgae biofuels: potential and limitations. Algae Biomass Summit, Algae for Energy, Seattle Washington 23-24 October 2008 http://algalbiomass.org/, Department of Agricultural Biotechnology University of Florence, Italy

World Freshwater and Spent-water Issues

Where's the Water?



Groundwater is in decline everywhere

By 2050 cities will consume half the world's fresh water

(Julian Cribb, FTSE, May 2008)

Mario R. Tradici, Mario, R. (2008) Microalgae biofuels: potential and limitations. Algae Biomass Summit, Algae for Energy, Seattle Washington 23-24 October 2008 http://algalbiomass.org/, Department of Agricultural Biotechnology University of Florence, Italy

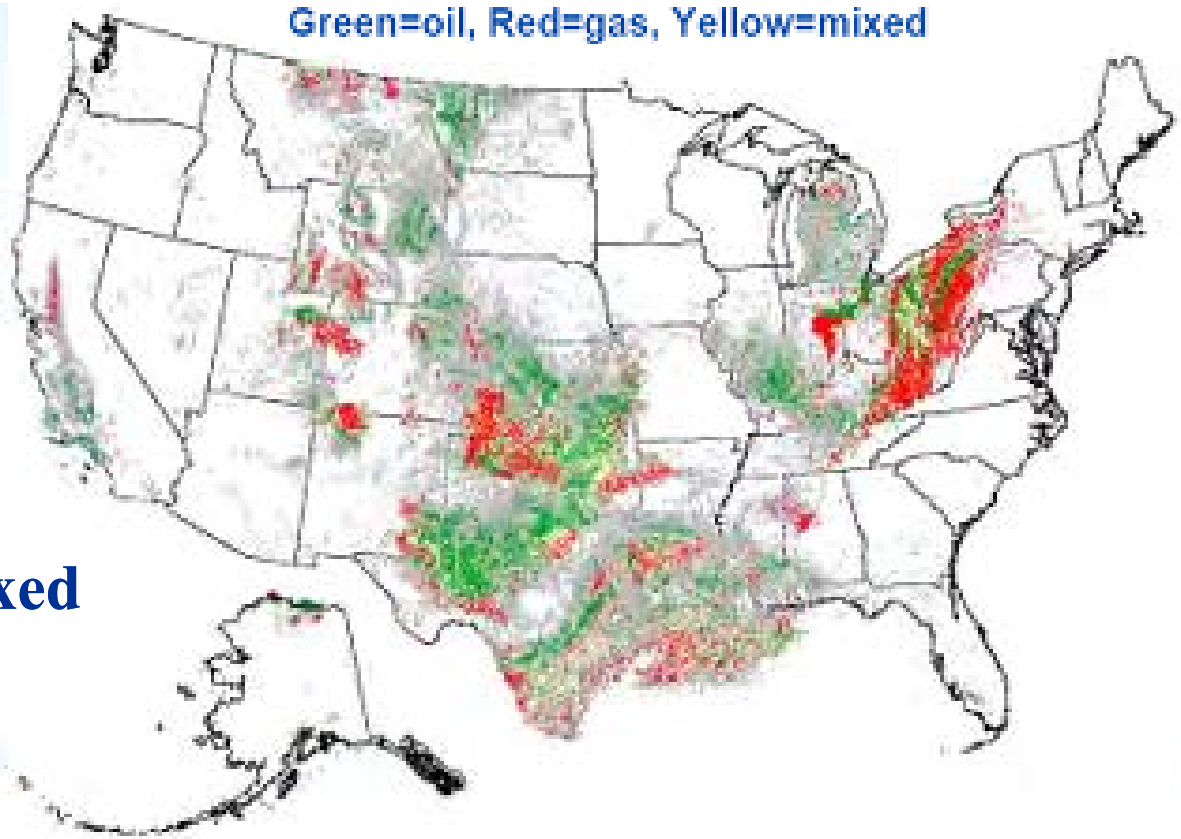
Water Issues : Oil and Gas Wells Producing and Abandoned Potential Halophyte Algae Bacteria Water Sources

Where's the Water?

Green =Oil

Red=Gas

Yellow=Mixed



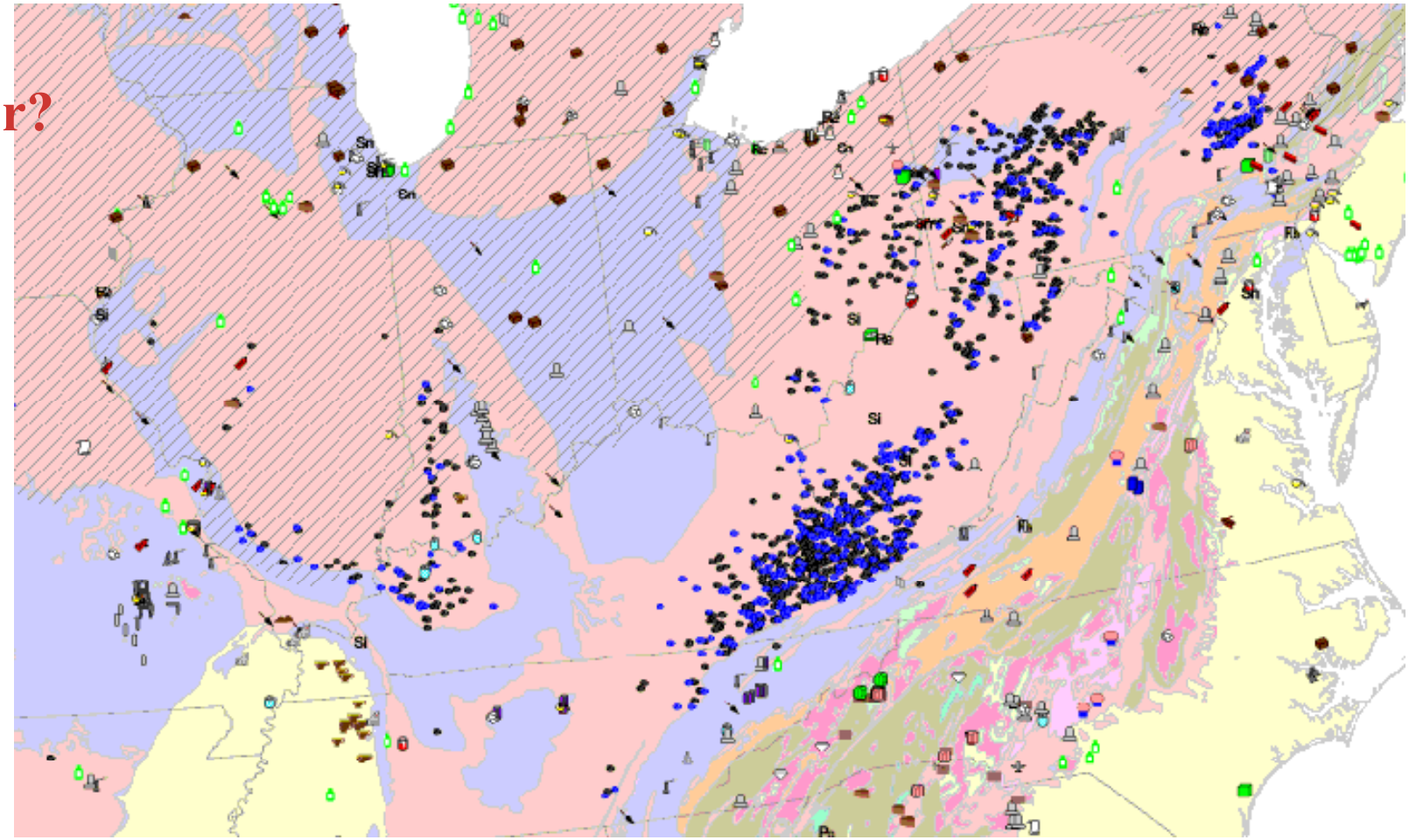
- 1. **[Pate, R. (2007)]** Sandia National Labs
- 2. http://wrri.nmsu.edu/conf/brackishworkshop/presentations/johnson.pdf

Water Issues : Coal Mine and Mineral Processing Plants

Producing and Abandoned, Impounded Brackish and Toxic Water, Waste Water, Spent-Freshwater : Potential Halophyte Algae Bacteria Water Sources

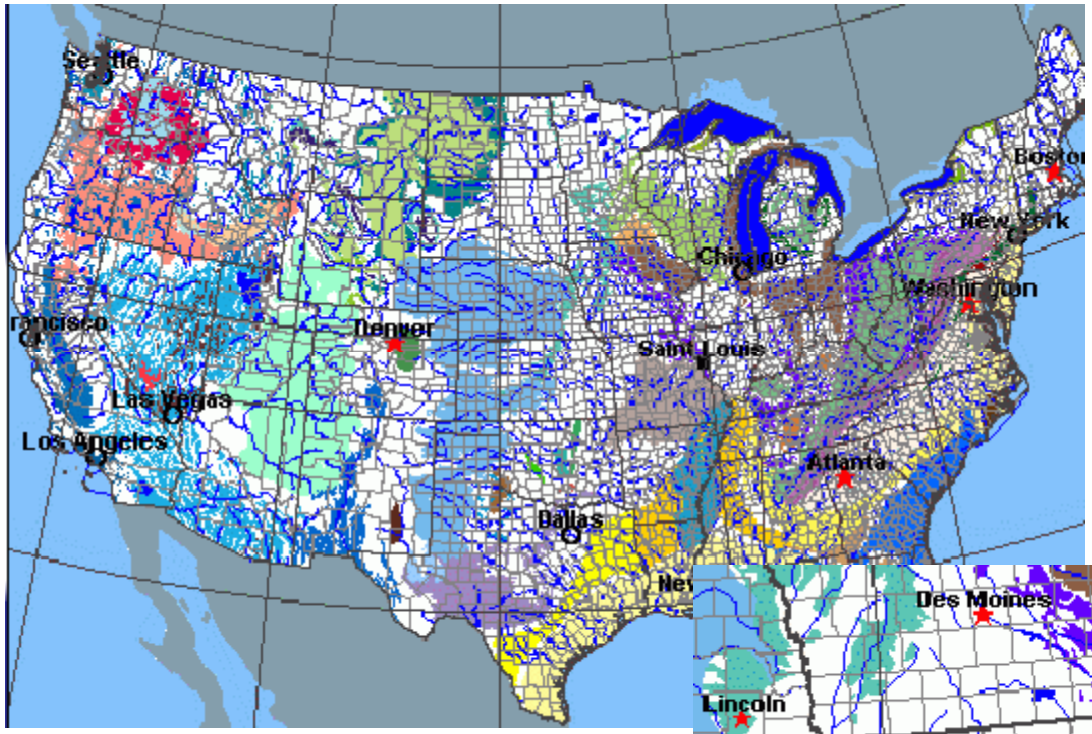
http://minerals.usgs.gov/minerals/pubs/mapdata/

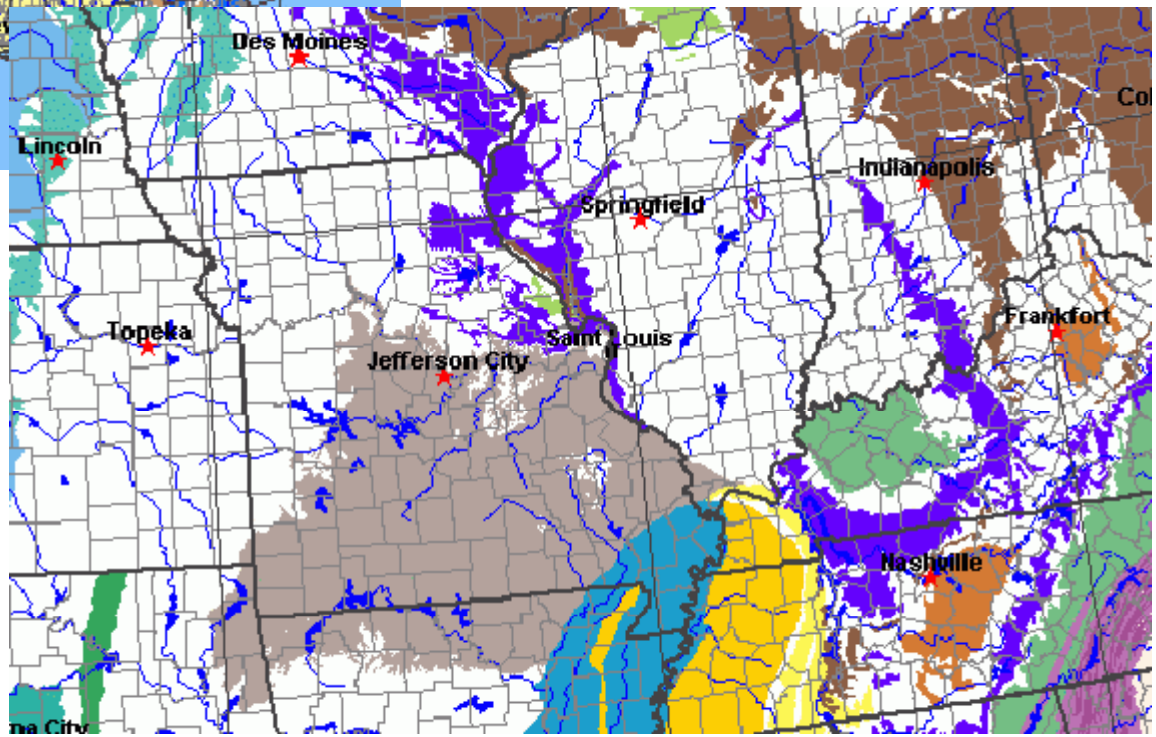
Where's the Water?



Where's the Water?

Aquifers - US Water Sources

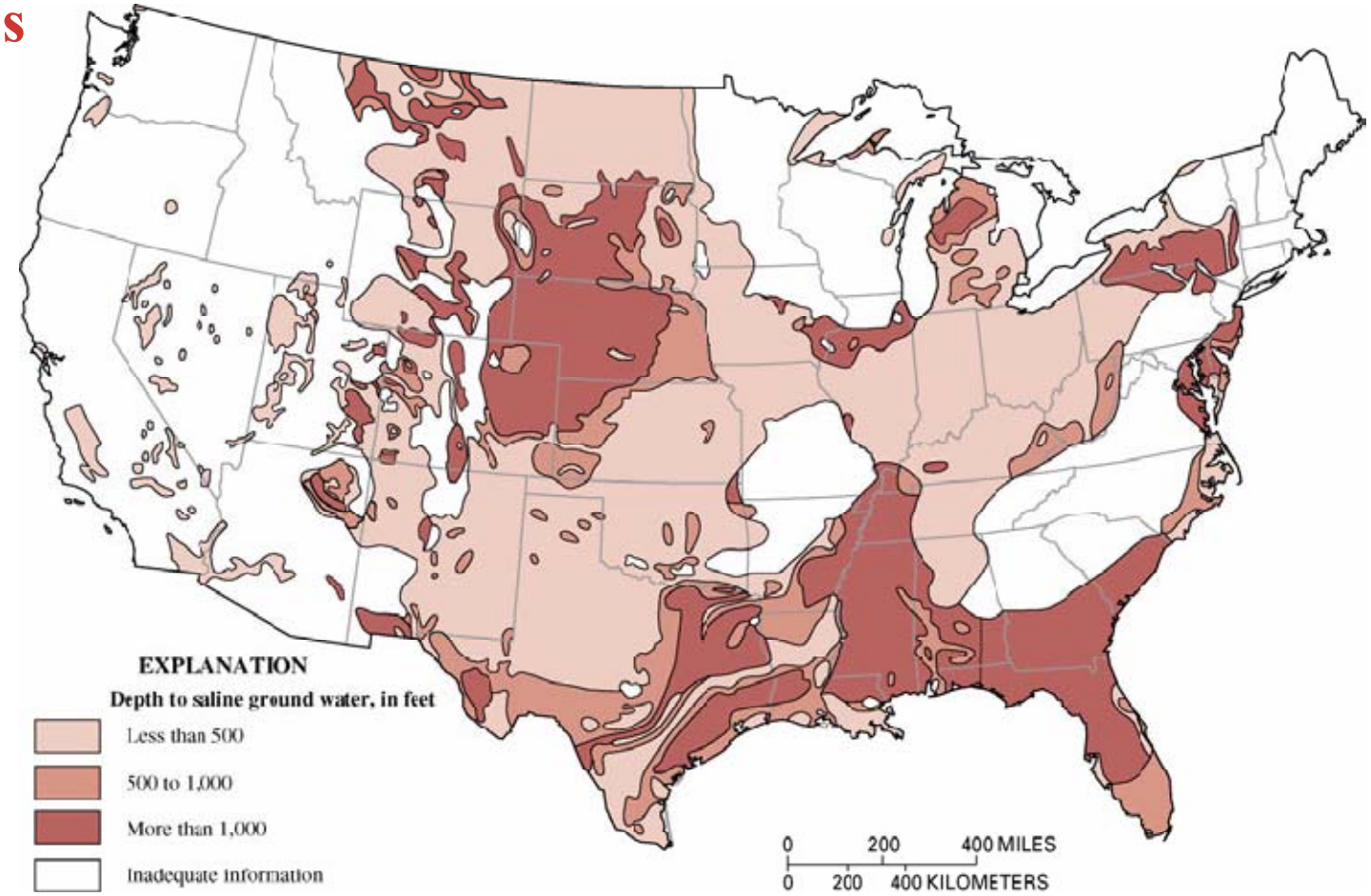




- http://nationalatlas.gov/natlas/Natlasstart.asp
- http://wrri.nmsu.edu/publish/watcon/proc49/dennehy.pdf

Water Issues: Salinization of Aquifers
Depth to Saline Ground Water

Where's the Water?



< 500 feet
500-1000
> 1000
No data

- **Feth, J.H., and others, 1965, Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids: U.S. Geological Survey Hydrologic Investigations Atlas 199, 31 p.**
- **[Pienkos, P.T. (2007)] NREL (National Renewable Energy Laboratories)**

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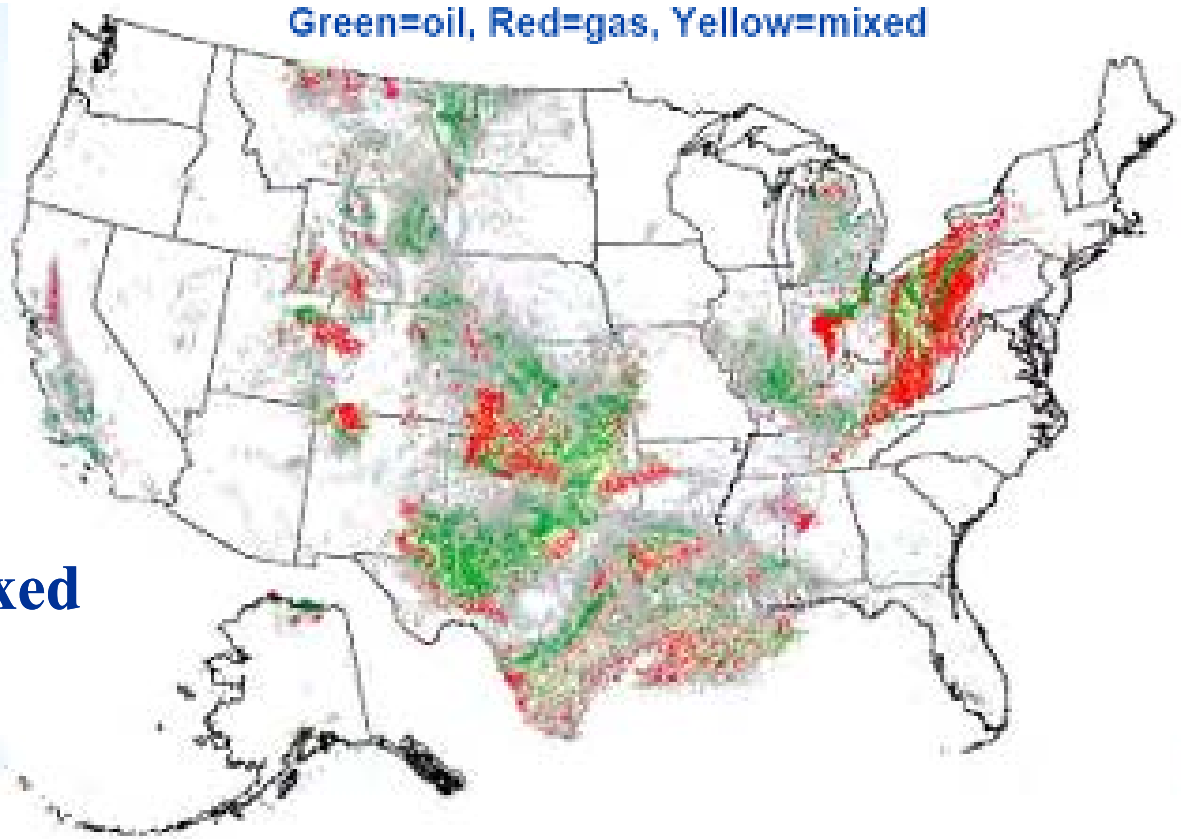
Green =Oil

Red=Gas

Yellow=Mixed



- 1. **[Pate, R. (2007)]** Sandia National Labs
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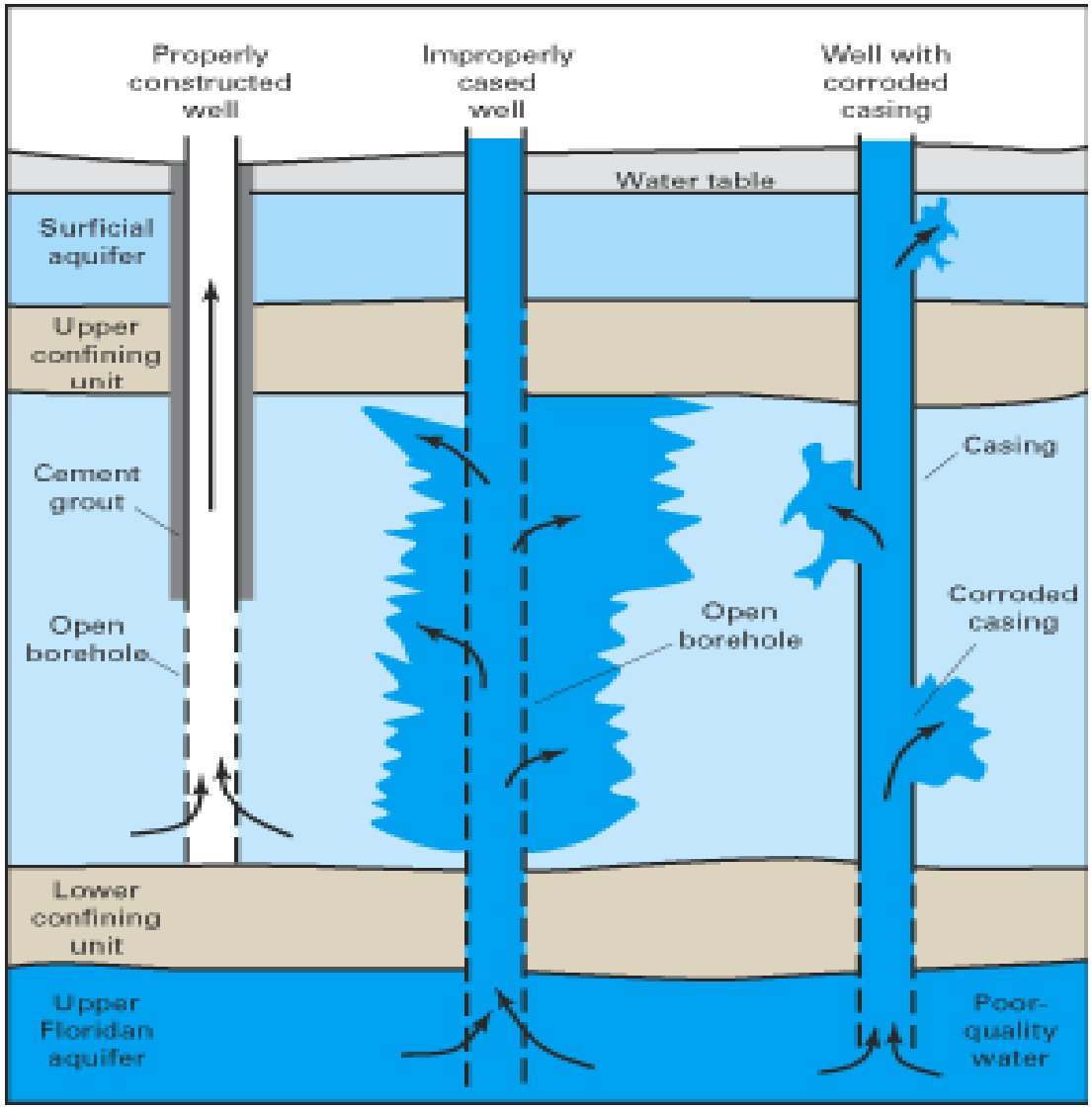
Salt and Brackish Water Bridges Between Aquifers

http://pubs.usgs.gov/circ/2003/circ1262/#heading144463296

- Contamination through failed, uncased, or improperly constructed wells
- Conduit for flow between aquifers of differing water quality.

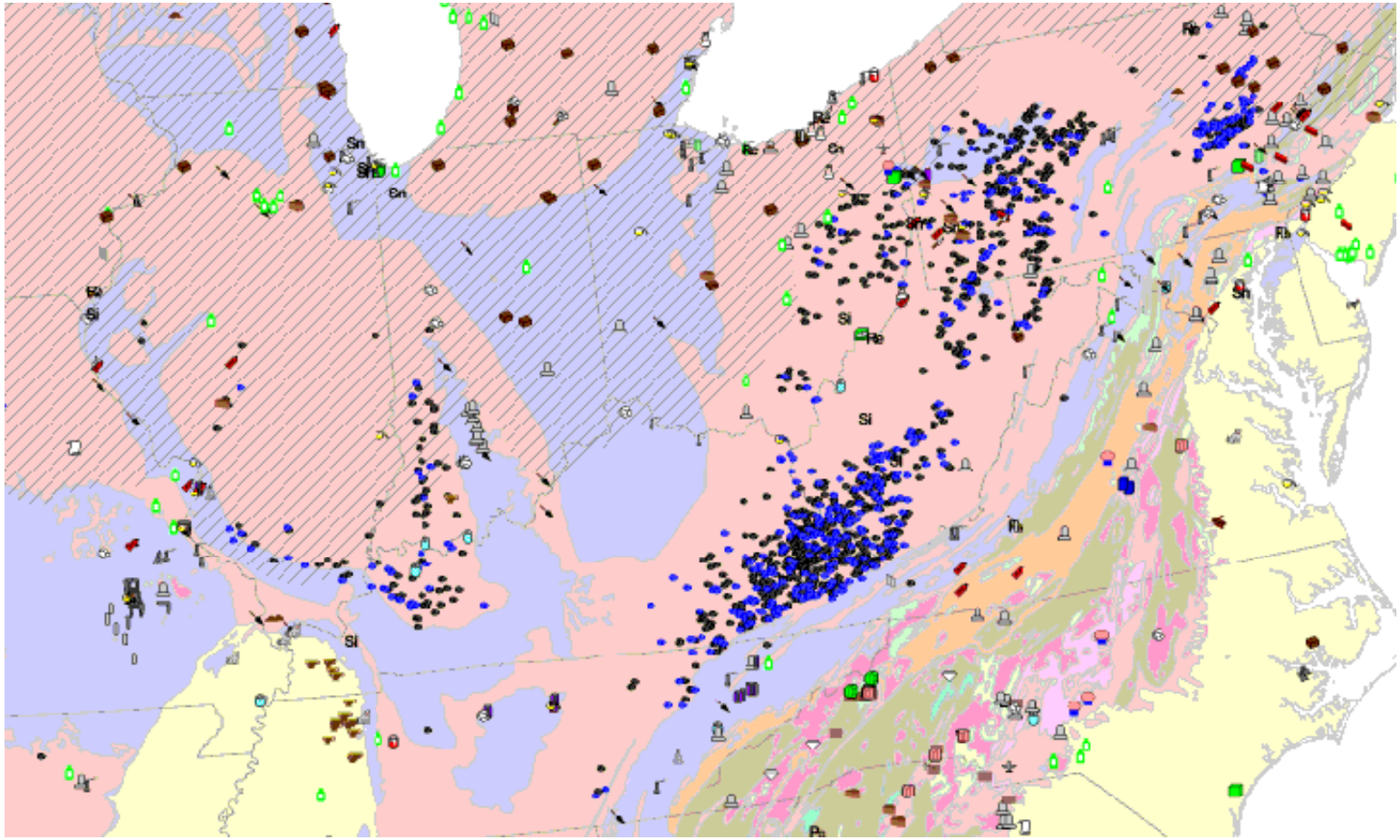


Water Issues : Coal Mine and Mineral Processing Plants

Producing and Abandoned, Impounded Brackish and Toxic Water, Waste Water, Spent-Freshwater : Potential Halophyte Algae Bacteria Water Sources

http://minerals.usgs.gov/minerals/pubs/mapdata/

Where's the Water?



So, Why Alternate Fueling ?

Ostensibly, foreign control of US

energy

food or

freshwater

supplies, implies the US would be quite limited

politically,

commercially and

militarily

in the future

What's the Problem Now ?

- We can make alternate fuels
- CTL and GTL via FT processes (Fischer-Tropsch)
- Biomass fuels [with conversion, to Jet fuel]

  Common crop oilseed [soybean, palm, coconut etc)

  Algae

  Bacteria

  Halophyte

  Wastes [municipal, livestock, forestry etc)

- So what's the problem ?
- Why aren't we in control of our fueling resources ?

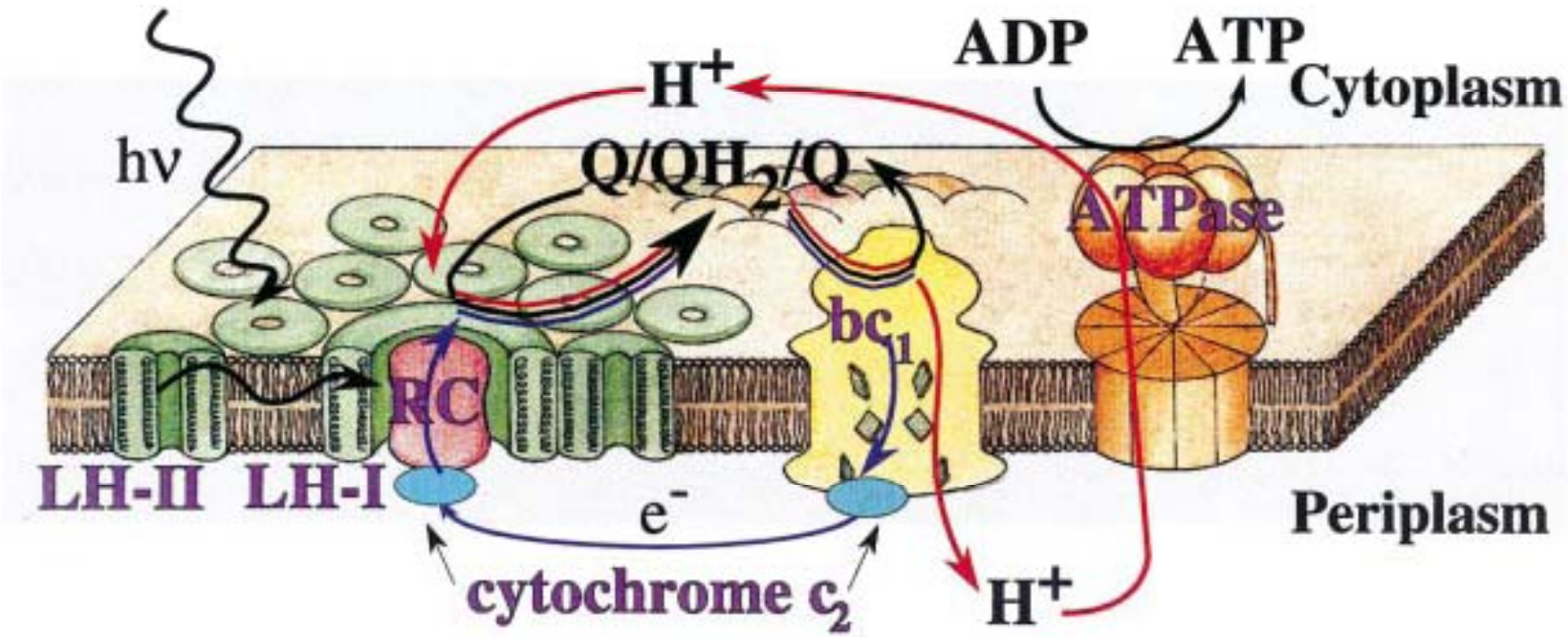
Biomass can help with [bio-oil-Jet-A] blends to meet the CO2 demands

- Bio-blends help meet the CO2 demands but we are really talking C are we not ? Team with DOA, FFA and people like Zimmer [http://www.midwesternbioag.com/] and others working the C to soil issues along with the symbiotic bacteria necessary to fix soil carbon and nitrogen etc...note that the bacteria Alan Bauer (we) cited in our proposed work can fix both N and C...so we could use these bacteria generators for both energy and soil premeditators.

distributed systems concepts, sort of synonymous with the way grain elevators and farm cooperatives developed in the past and some kibbutz systems of Israel operate today.

- Solar plant in red 680 nm
- Flash LED system vertical reactors
- Solar (wind, thermal, drilled geo , PV) source efficiencies at 30% vs 10% conversion plants
- Green house and warehouse biomass factories
- (reminds me of old factory sky lighting replaced bulb
- Jim Cook's Univenture algae harvestor
- Summary Energy for terrestial biomass drop in capture CH4 hydrates and transition to H2 from seawater with O2 release.

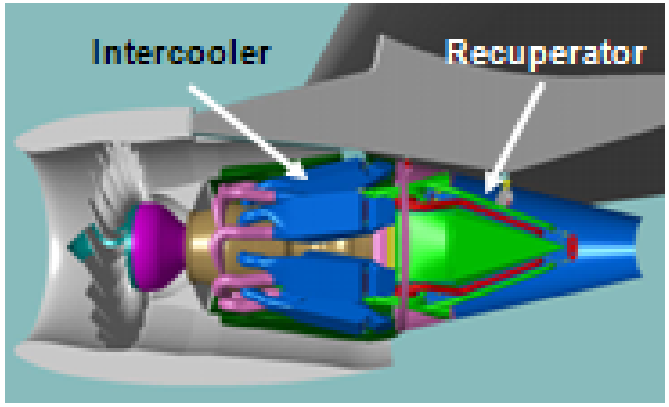
Photon Capture / Utilization

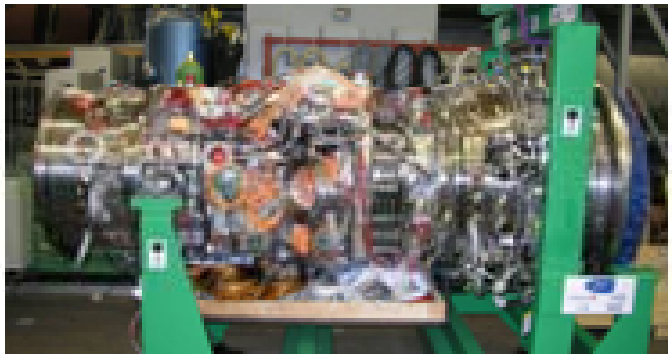


Xiche Hu1, Thorsten Ritz, Ana Damjanovic, Felix Autenrieth and Klaus Schulten, **Photosynthetic apparatus of purple bacteria** Quarterly Reviews of Biophysics **35, 1 (2002), pp. 1–62. 2002 Cambridge University Press**

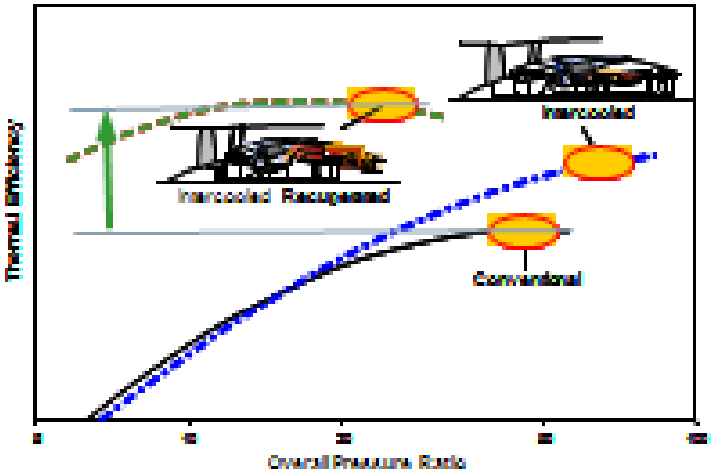
- Burton, T., Lyons, H., Lerat, Y., Stanley, M., Bo Rasmussen, M. (2009) A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland, Sustainable Energy Ireland (SEI). [explores both macro and micro algae setting total solar 6% max theoretical with 1% practical biomass productivity with potential for 0.1 to 1% road fuel supplement by 2020 http://www.sei.ie/algaereport]
- Camelina study : life cycle analysis cf. petroleum, 60-70% less CO2 conventional and 84% enhanced camelina , Prof. David Shonnard , Michigan Tech. Univ. http://www.chicagotribune.com/news/chi-ap-mt-biofuel-emission,0,1588026.story

A Longterm Perspective: Intercooled, Recuperative Geared Turbofan





Validation Testing on ATF Stuttgart, Dec. 2005



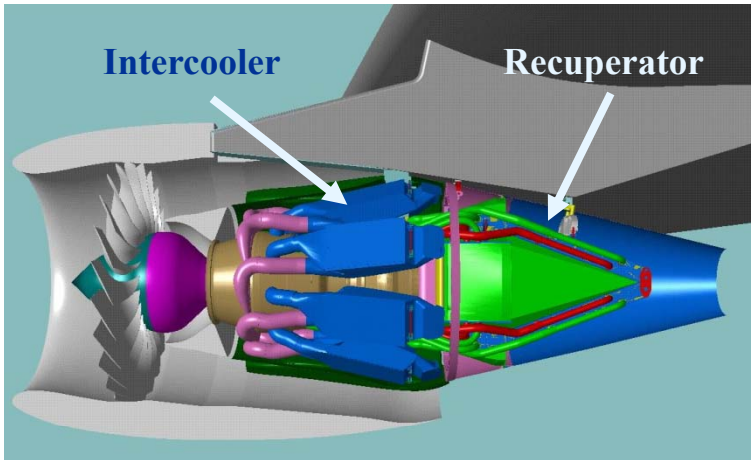
Within EU-programme "CLEAN"*) (2000-2005) european engine companies jointly prepared highly advanced technologies for future recuperative geared Turbofans.

Technological Benefits:

- 30% reduction in fuel burn
- 20-30dB reduction in noise emissions, cum rel. Stage 4
- 60% reduction in NO_x emissions, rel. CAEP6
- Reduced parts production & maintenance costs

*) Component validator for Environmentally friendly Aero-eNgine

A Longterm Perspective: Intercooled, Recuperative Geared Turbofan



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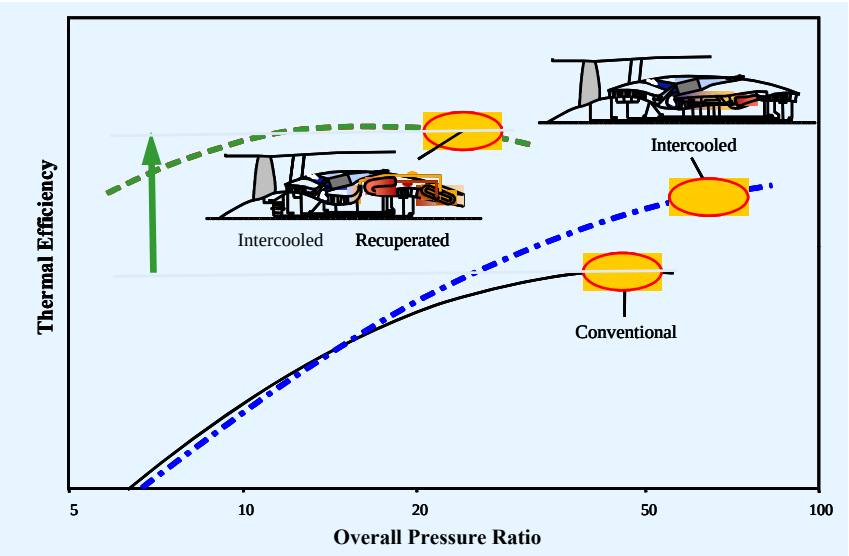

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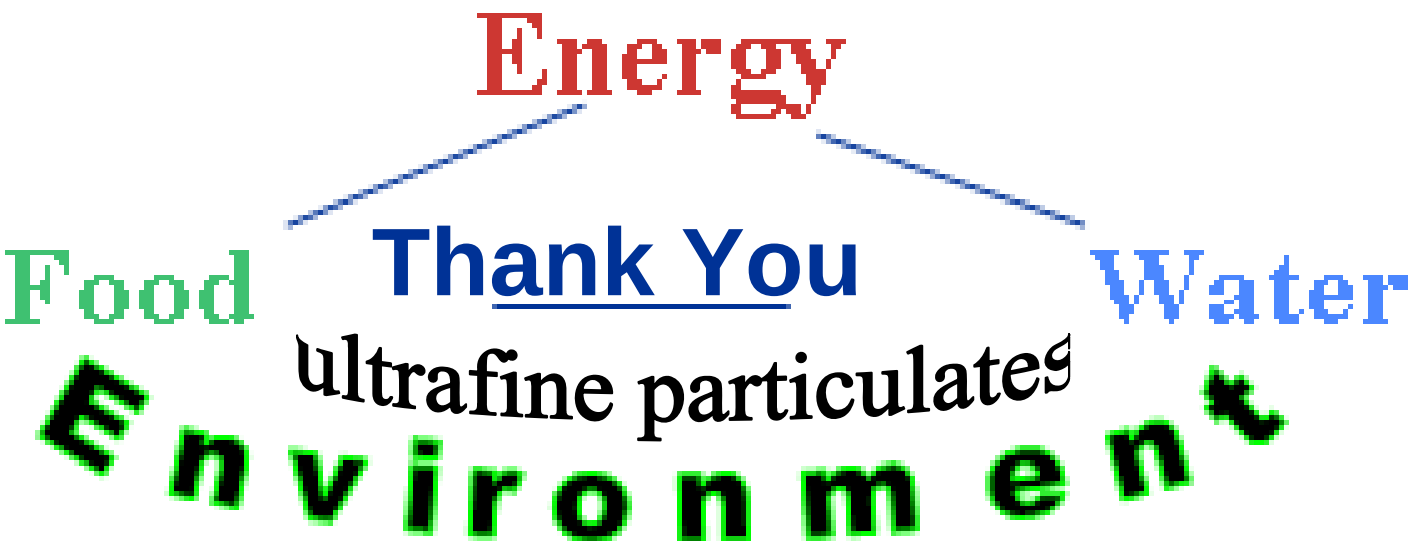

Thank You

ultrafine particulates