



Biofuels Production from Algae

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<http://www.vcerc.org/>





Virginia Coastal Energy Research Consortium



**Old Dominion University
Virginia Tech-ARI
University of Virginia
James Madison University
Virginia Commonwealth University
Norfolk State University
William & Mary (VIMS)
Hampton University
George Mason University**

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Mission and Specific Strategies



Mission: The mission of the Virginia Coastal Energy Research is to identify and develop new coastal energy resources through multidisciplinary research collaborations and environmentally responsible strategies.

Strategies: Conduct research in areas consistent with a *diversified portfolio* of energy sources in coastal areas and offshore

Initial focus:

1. Offshore wind and wave energy
2. **Coastal Biomass for Biodiesel Production**





Pilot Facility: Algal Farms, Inc., in Spring Grove, Surry County, Virginia



Algal Farms, Inc., started operating a **1-acre pond** of parallel raceways in late September 2008

Pilot productivity will be **3,000 gallons** of biodiesel fuel per acre per year

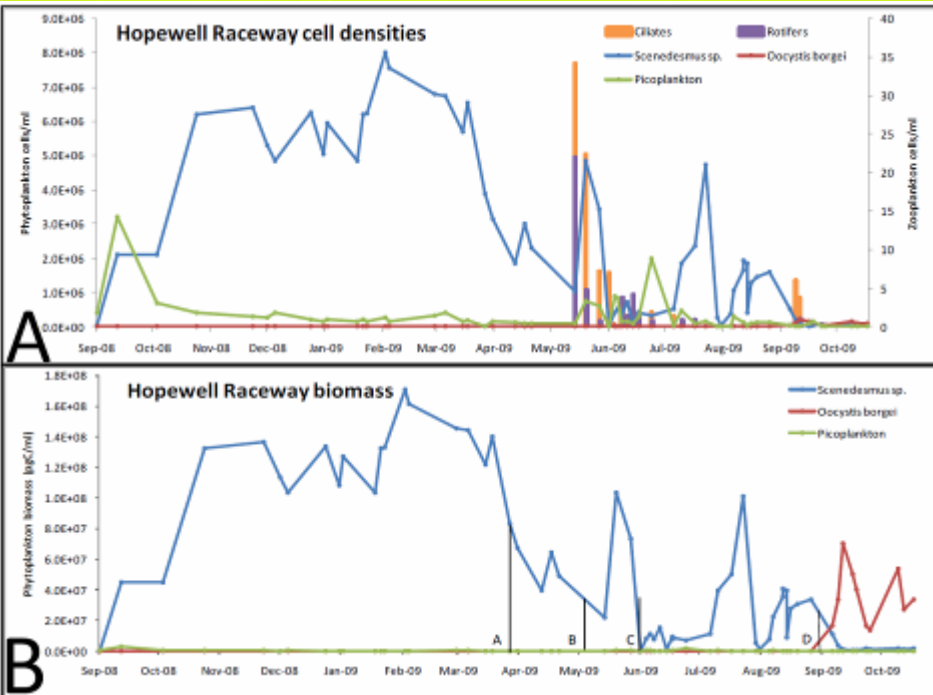
The next phase will expand pond area to **25 acres**, producing **75,000 gallons per year by 2011**

Periodic infusion of pure cultures from 500-gallon closed tanks along side of raceway will prevent take-over by invasive, oil-poor species



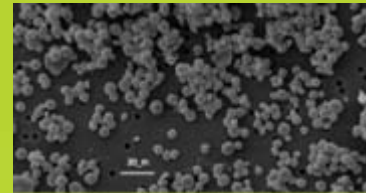


Growth Progression at Algal Farms, Inc 2008 - 2010



Two species of oil- and algaenan-producing algae:

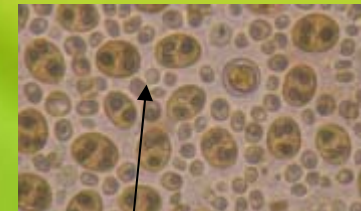
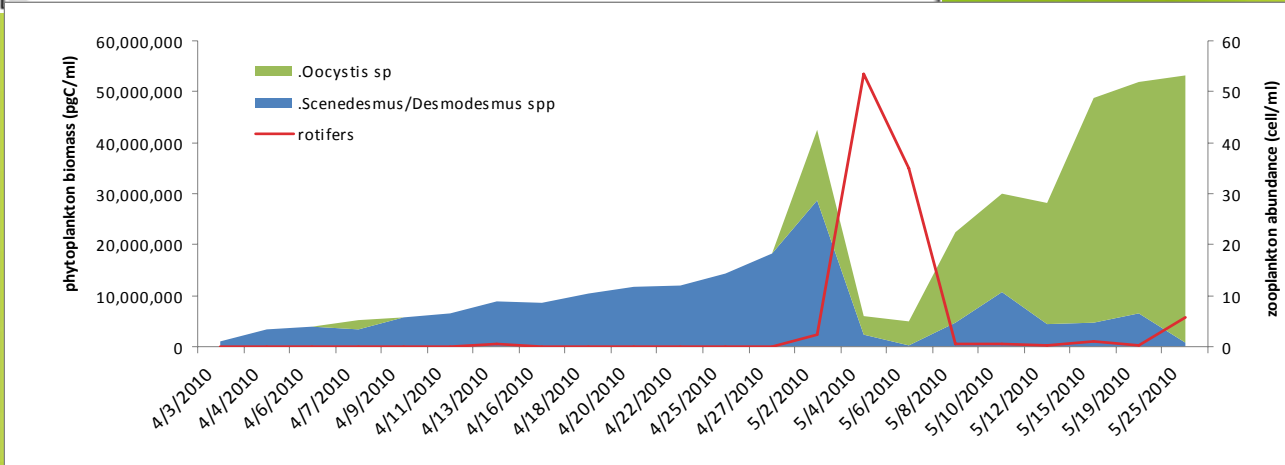
- *Scenedesmus spp.*
- *Desmodesmus spp.*



ODU greenhouse culture. *Desmodesmus* in 2 and 4 celled cenobia form with terminal spines



Desmodesmus in unicellular form without visible spines



Scenedesmus



Pilot-Scale Harvesting Process



1. Centrifugation



2. Coagulation, settling, and DAF

~10-20 g/L flocculated algae



3. Drying – collaboration with AlgaeVentures Inc.



Micro-screen belt achieves complete dryness of the flocculated algae



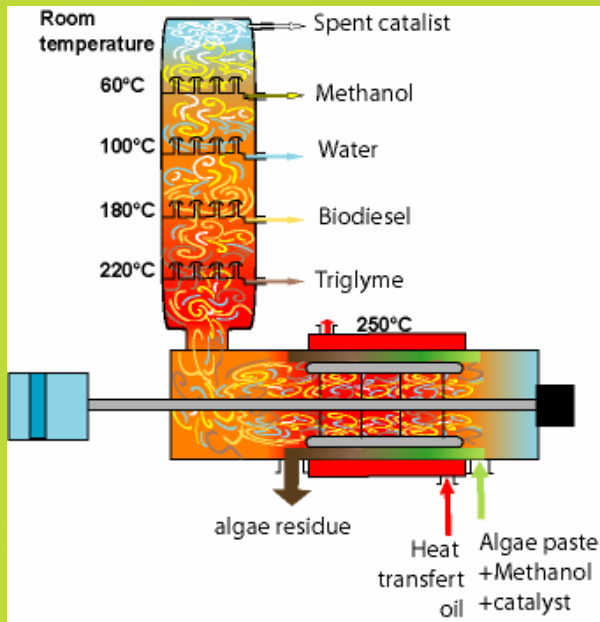
Dried flake
(algae does not have to be 100% dry)



Two pilot-scale conversion processes

1. Conversion to FAME biodiesel

Treat harvested algae directly in chemoreactor



FAME Biodiesel

By-product

Fertilizer

2. Conversion to Algae Crude for Jet Fuel

Treat to isolate algaenan

Pyrolysis

Liquid hydrocarbon-based Algae crude



Conventional refinery

Gasoline
 C_5-C_9

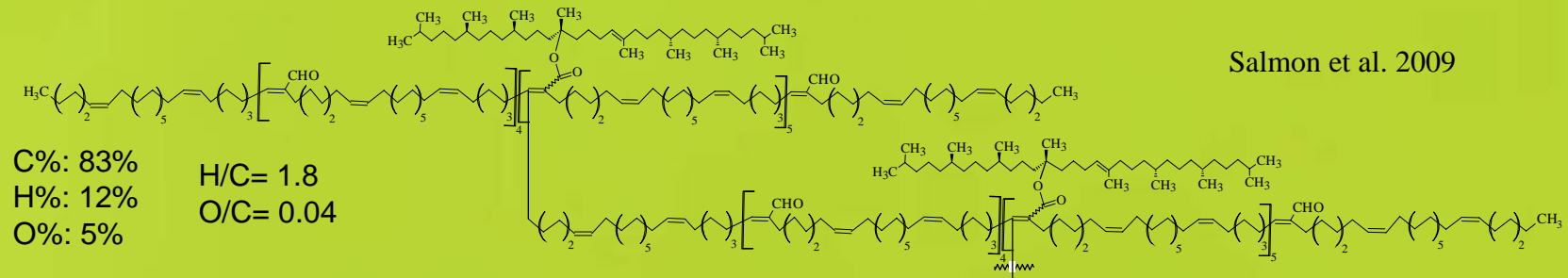
Kerosene
 $C_{10}-C_{15}$

Diesel fuel
 $C_{16}-C_{18}$

Lubricating oil C_{19+}

Etc...

What is algaenan?

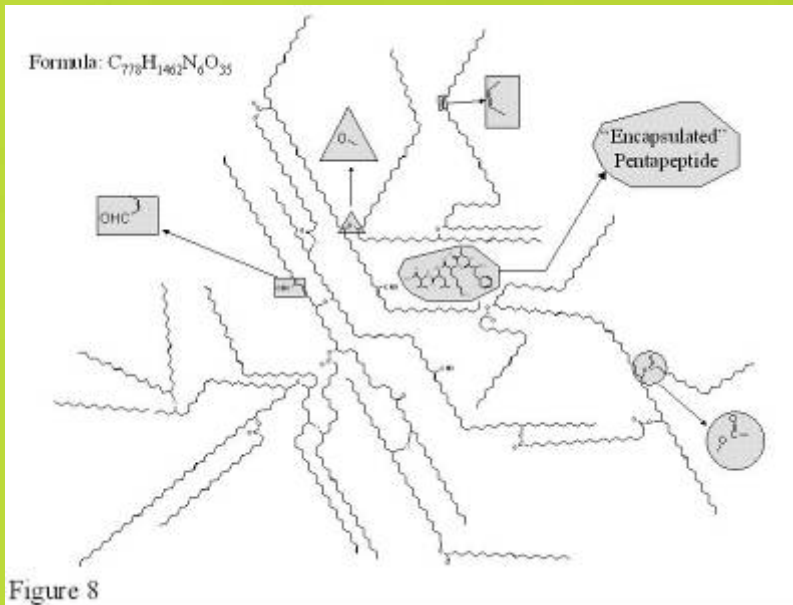


→ Aliphatic biopolymer containing ester and aldehyde functional groups

→ Resistant material :

Resistant to organic solvents, acid and basic treatments
Resistant to sedimentary processes like diagenesis

→ Fairly stable to temperature (< 300°C)
Precursor of petroleum



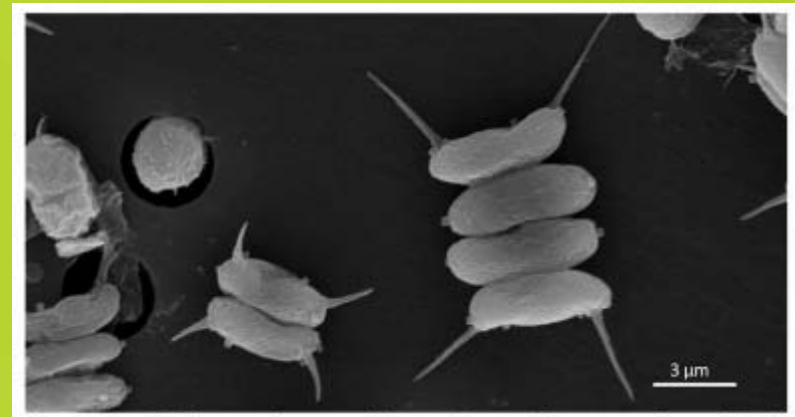
Zang 2001

C%: 76%
H%: 11%
O%: 10%

H/C= 1.7
O/C= 0.1



Algaenan at ODU algae farm: *Scenedesmus* / *Desmodesmus*



Desmodesmus in 2 and 4 celled cenobia form with terminal spines (VCERC progress report 2009)



Contain around **10 wt%** dry initial biomass of Algaenan





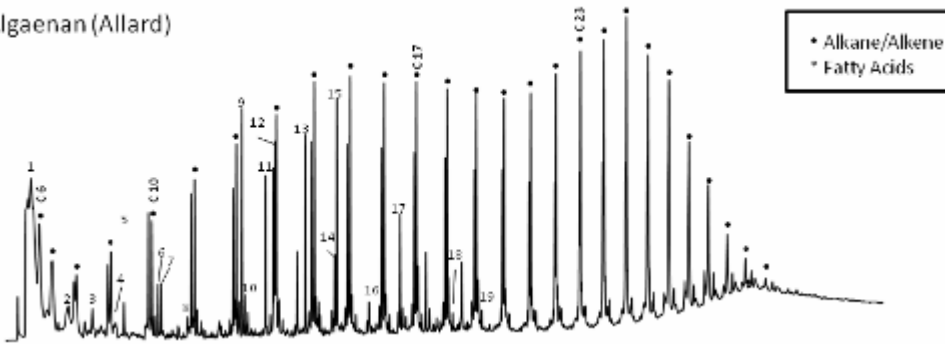
Isolation of Algaenan

Lab testing from literature data

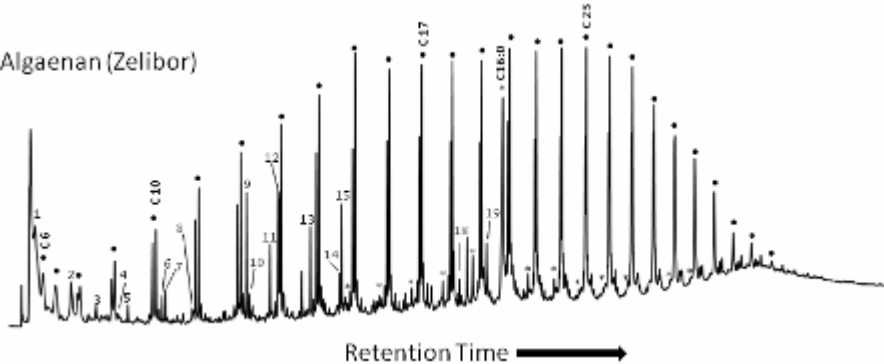


Flash pyrolysis/GC/MS

Algaenan (Allard)



Algaenan (Zelibor)



Peak Number	Corresponding Compound
1	1-Hexene
2	1-Heptene
3	2,6-Dimethyl-2-Heptene
4	3,7-Dimethyl-2-Heptene
5	3,6-Dimethyl Octane
6	4-Methyl-1-Decene
7	2,6-Dimethyl Nonane
8	Dodecadiene
9	2,6-Dimethyl Unidecane
10	2,5-Dimethyl-2-Unidecane
11	C14 Alkane Isoprene
12	C14 Alkene Isoprene
13	2,6,10-Trimethyl Dodecane
14	4,8,12-Trimethyl Trimethyl-1-ene
15	C16 Isoprene
16	4,11-Dimethyl Pentadecane
17	2,6,10-Trimethyl Pentadecane
18	5-Octadecene
19	1-Nonadecene

Resemble petroleum

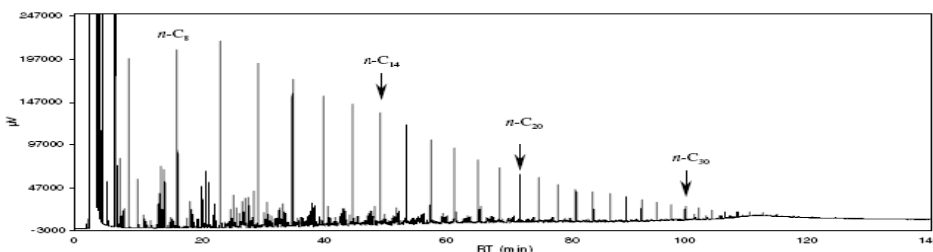


Fig. 1. GC trace of the total Safaniya oil.

=> Algaenan pyrolyzate contains essentially hydrocarbons



Where do we go from here?



1. Need to build a pilot pyrolysis reactor to further develop our innovative drop-in fuels from algae research.
2. Expand to a 10+ acre production facility (Algae Research Center) where we can demonstrate commercial viability.
3. Develop a business partnership with companies willing to commercialize the activity.
 - Algae to FAME biofuels + fertilizer
 - Algae to biofuels + wastewater cleanup
 - Algae to drop-in biofuels (FAME and Algae Crude)



Our perception of how we can work with USDA



1. Utilize USDA B&I Loan Guarantee Program in FY 2011/12 to establish a 25+ acre algae farm to produce algae-derived biodiesel for the Navy.
2. Utilize USDA RD assistance to develop a product rural farmers can license to produce, harvest, and convert algae to biodiesel and fertilizer
3. Work with other USDA research and development programs to advance algae-to-jet fuel and develop protocols and educational programs regarding the promise of algae for biofuels and rural development.



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