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Biofuel Production and Water in the Southwest

WRRC Brownbag November 14, 2012

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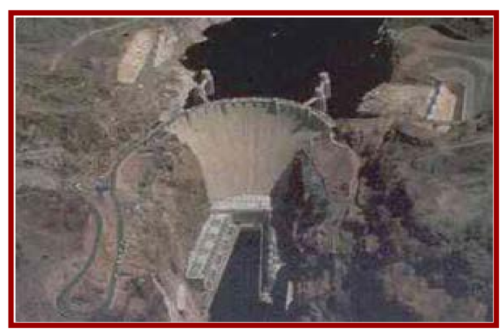
Where does on Energy Come From Currently?

Where do we get our current energy?

Oil

Coal

Nuclear

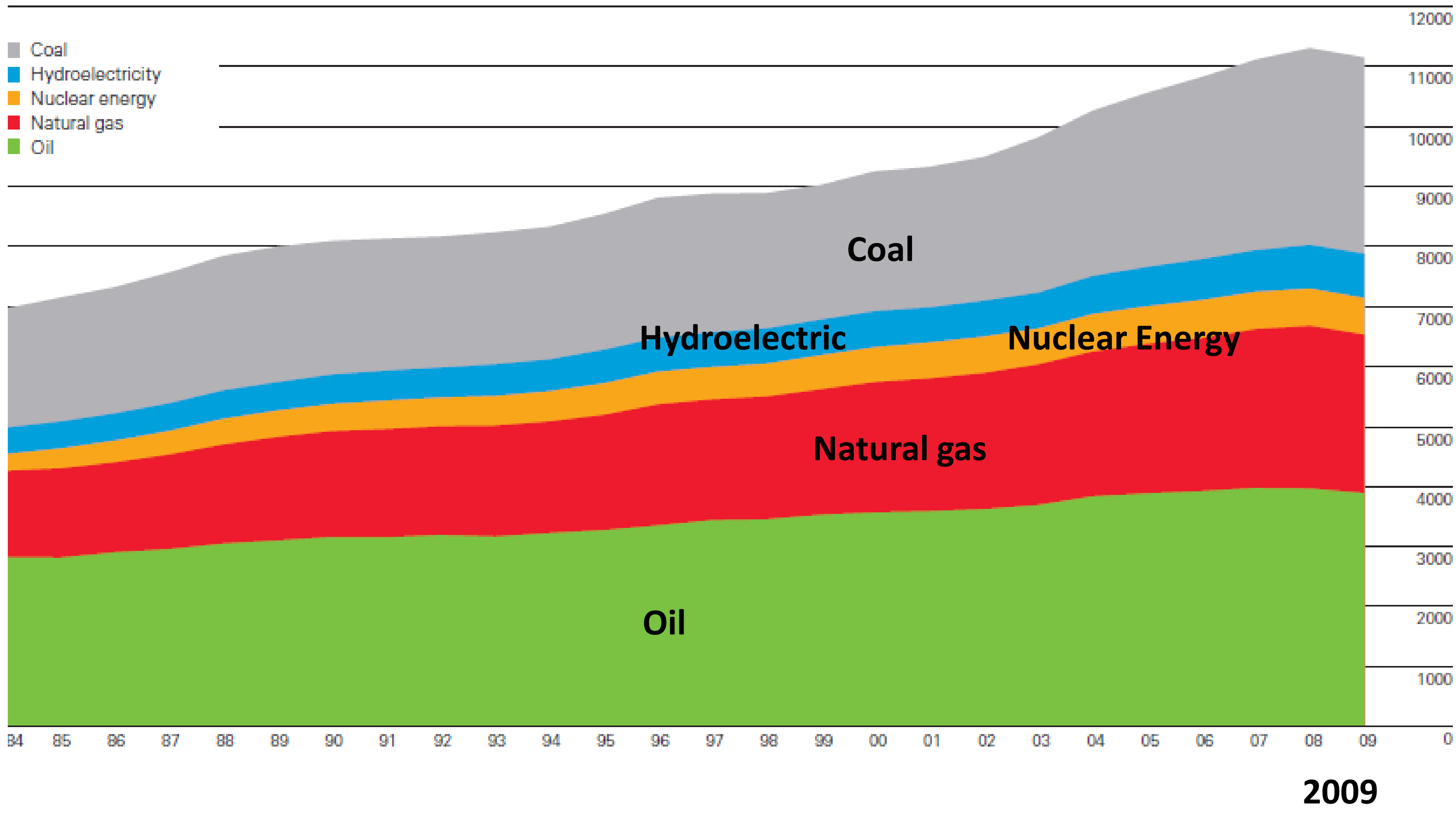


Hydroelectric

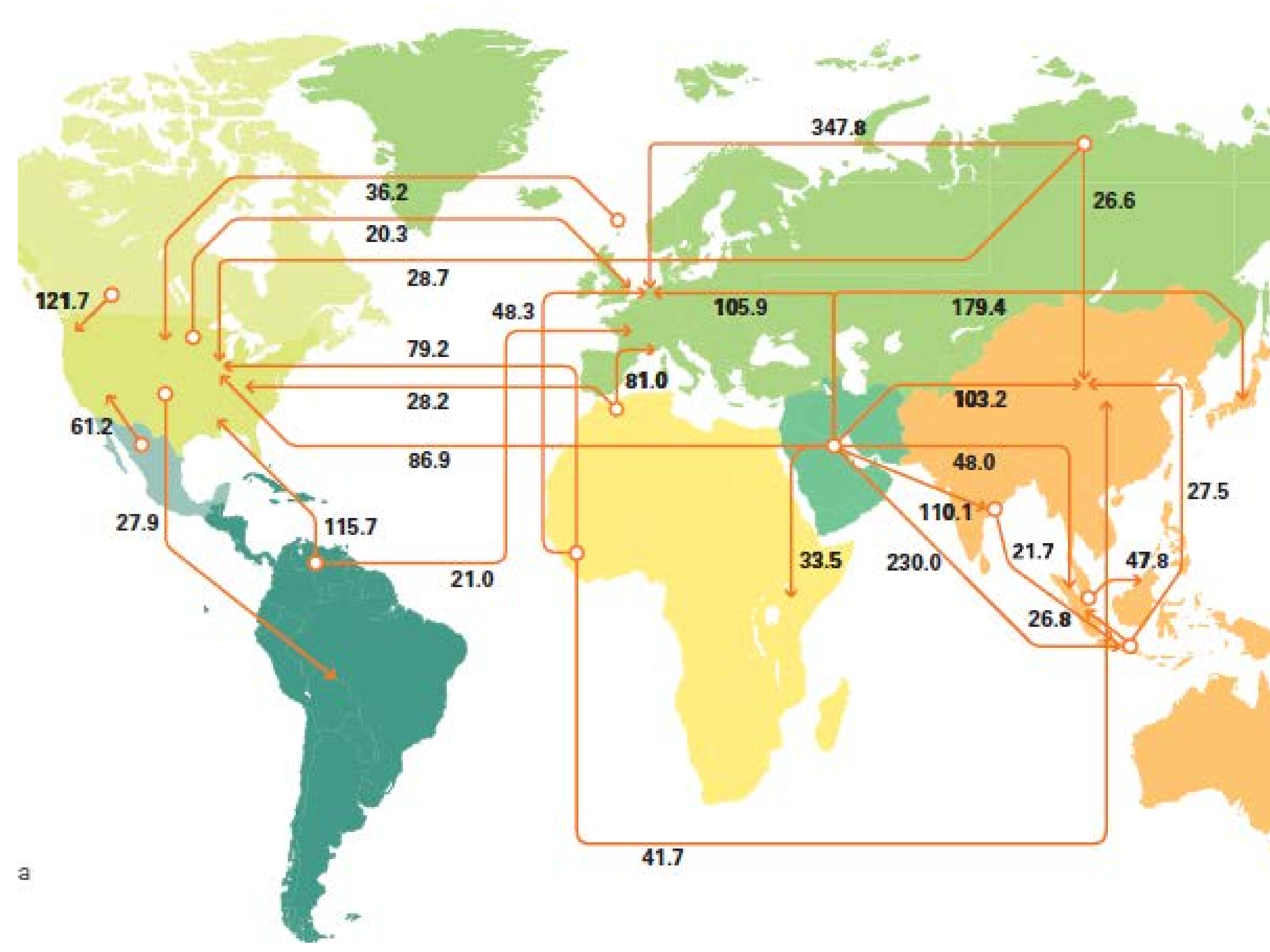
Natural Gas

World Consumption

(Millions tonnes of oil equiv)

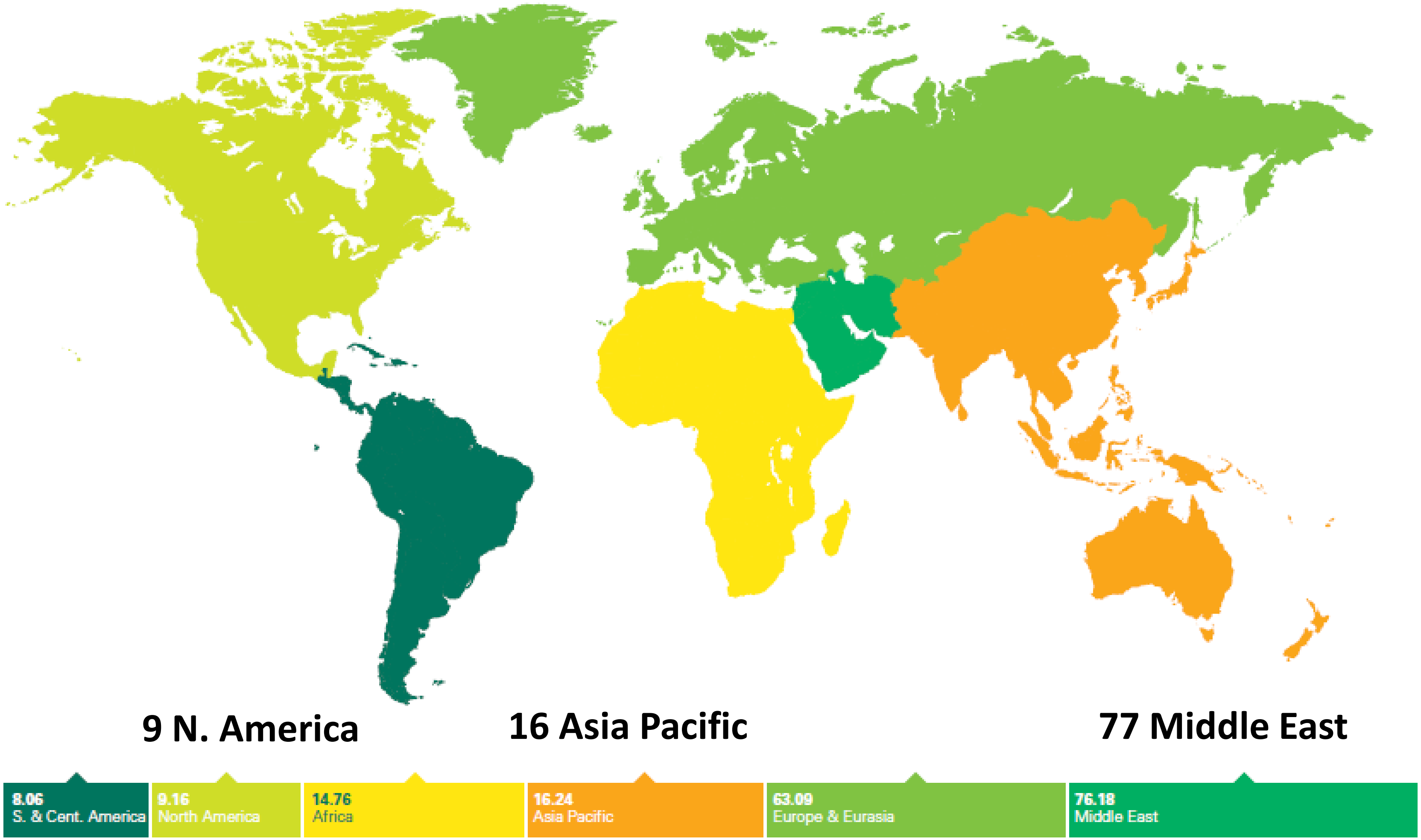


Where are the Largest Reserves of Oil and Natural gas?


347.8
36.2
26.6
20.3
28.7
121.7
48.3
105.9
179.4
79.2
81.0
103.2
28.2
61.2
86.9
48.0
27.5
110.1
27.9
115.7
21.7
47.8
33.5
230.0
21.0
26.8
41.7
a

Natural Gas Reserves

(trillion cubic meters)



9 N. America

16 Asia Pacific

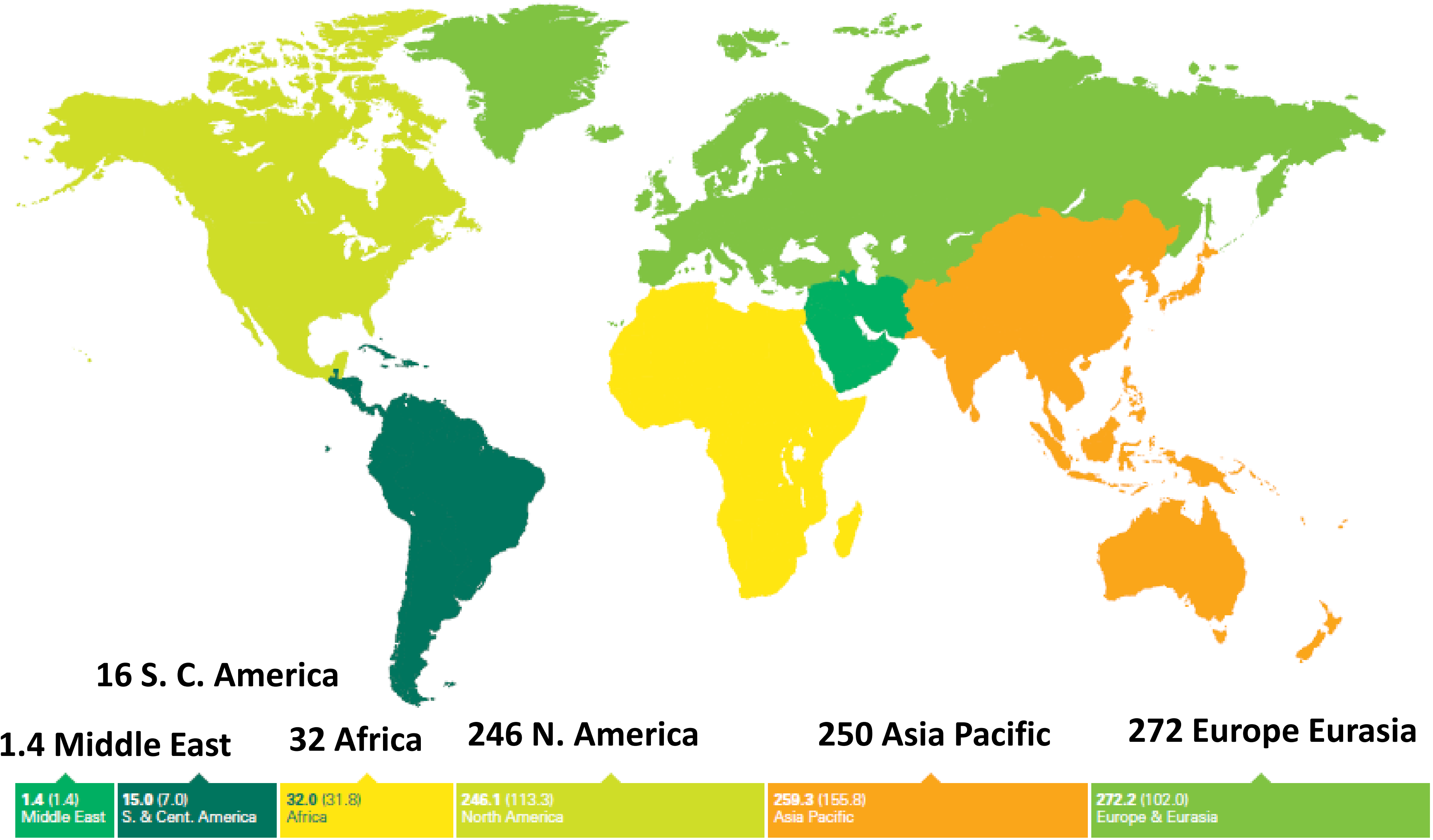
77 Middle East

8 S. C. Ame

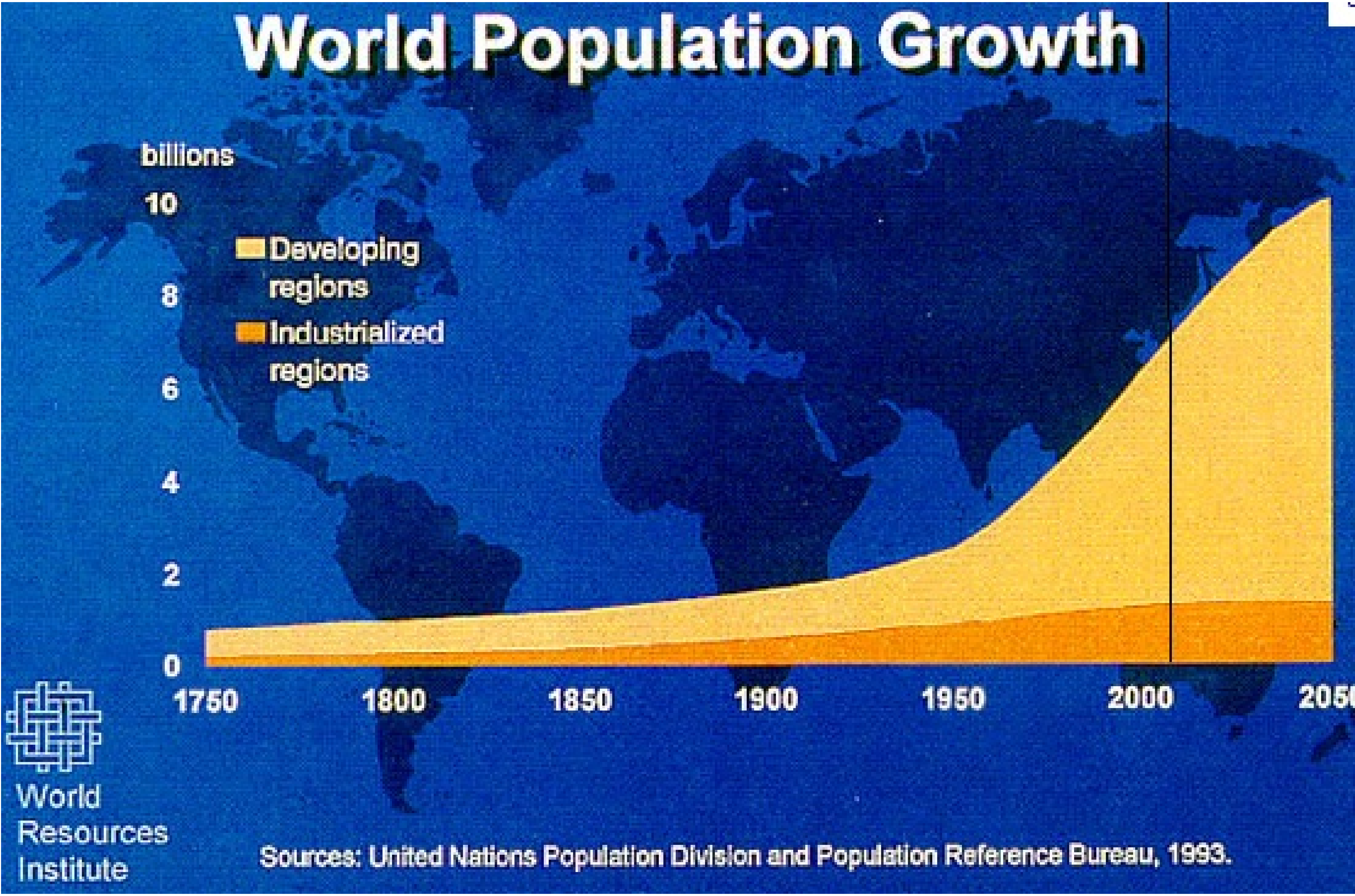
15 Africa

62 Europe and Eurasia

Coal Reserves

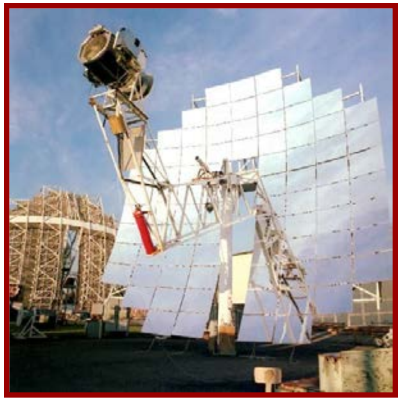


Energy and Water Demand is also influenced by?


World Population Growth
billions
10
8
6
4
2
0
Developing regions
Industrialized regions
1750
1800
1850
1900
1950
2000
205
World Resources Institute
Sources: United Nations Population Division and Population Reference Bureau, 1993.

Sources of Renewable Energy?

Renewable Energy Technologies

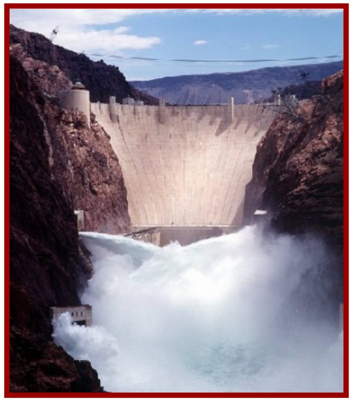


Solar Thermal

Wind

Biomass

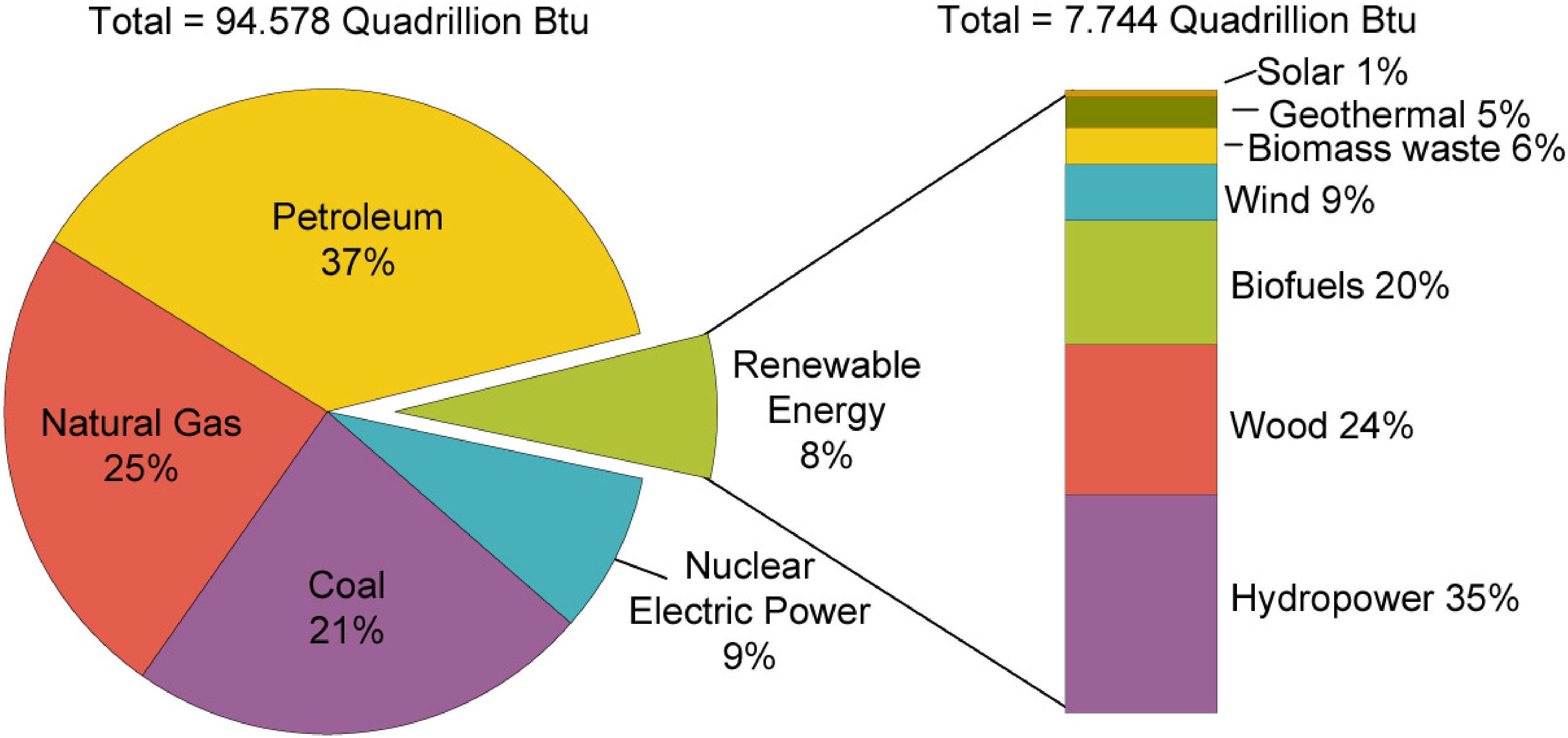
Photovoltaic



Hydroelectric

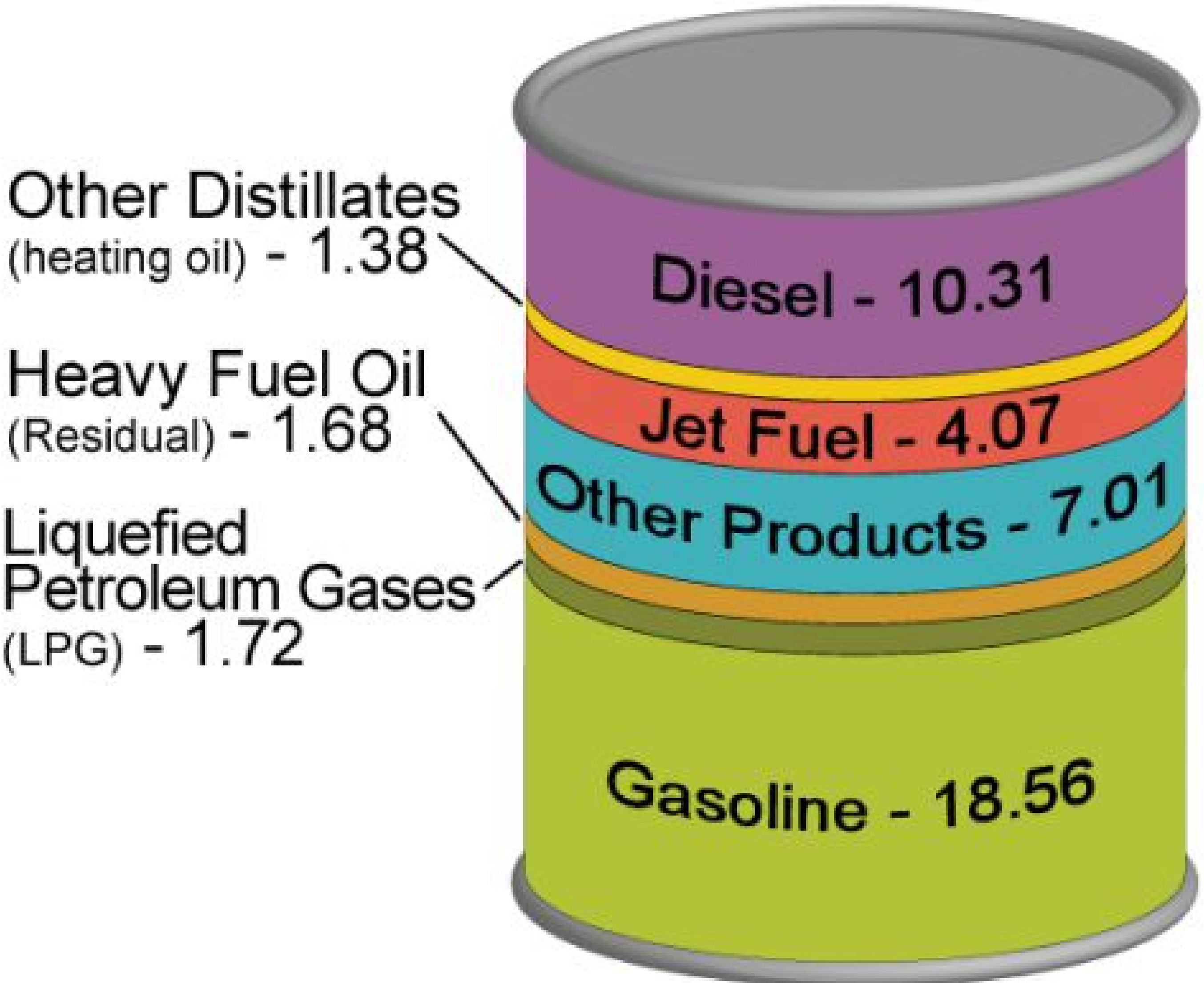
Geo Thermal

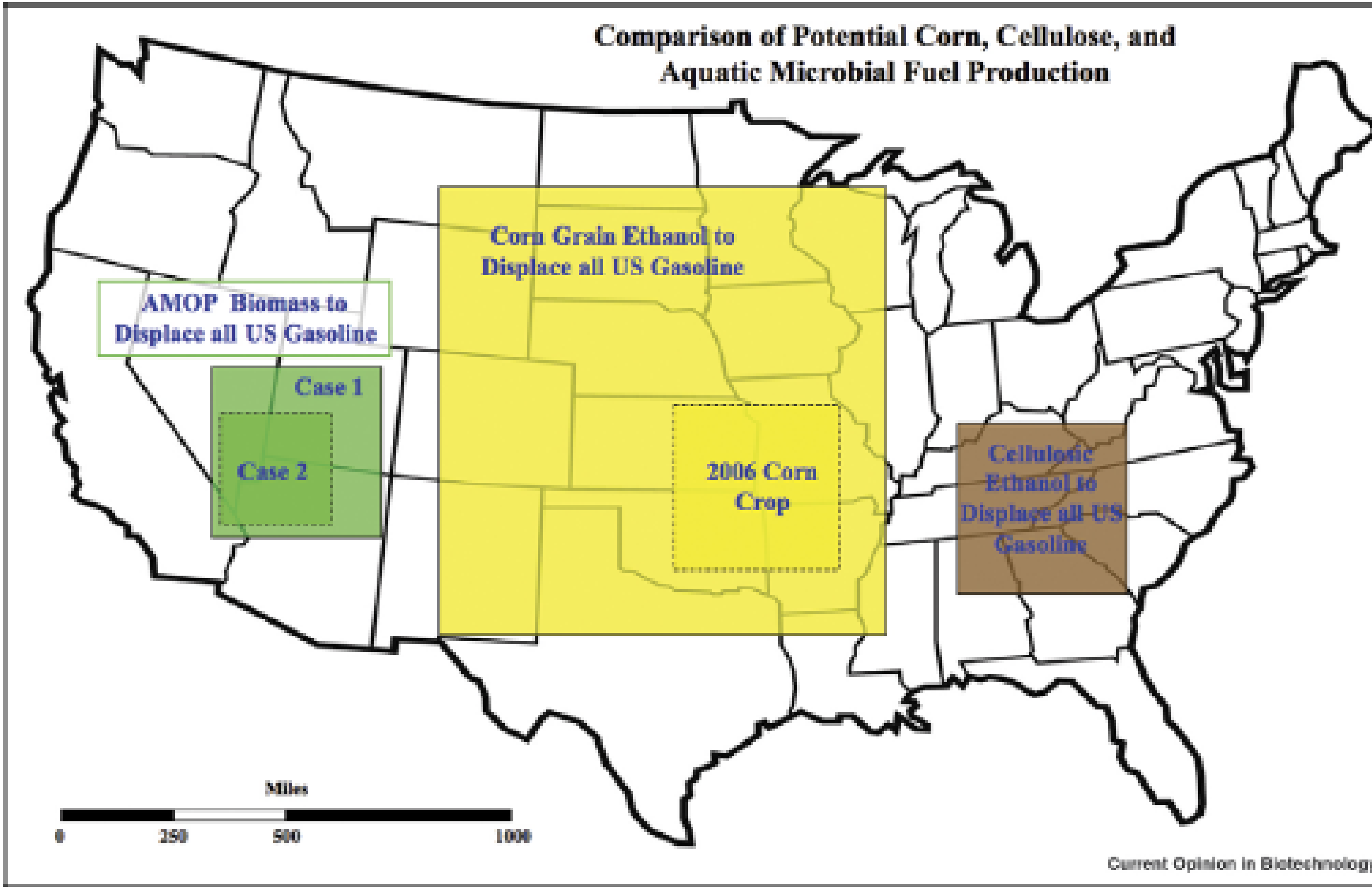
U.S. Energy Consumption by Energy Source, 2009



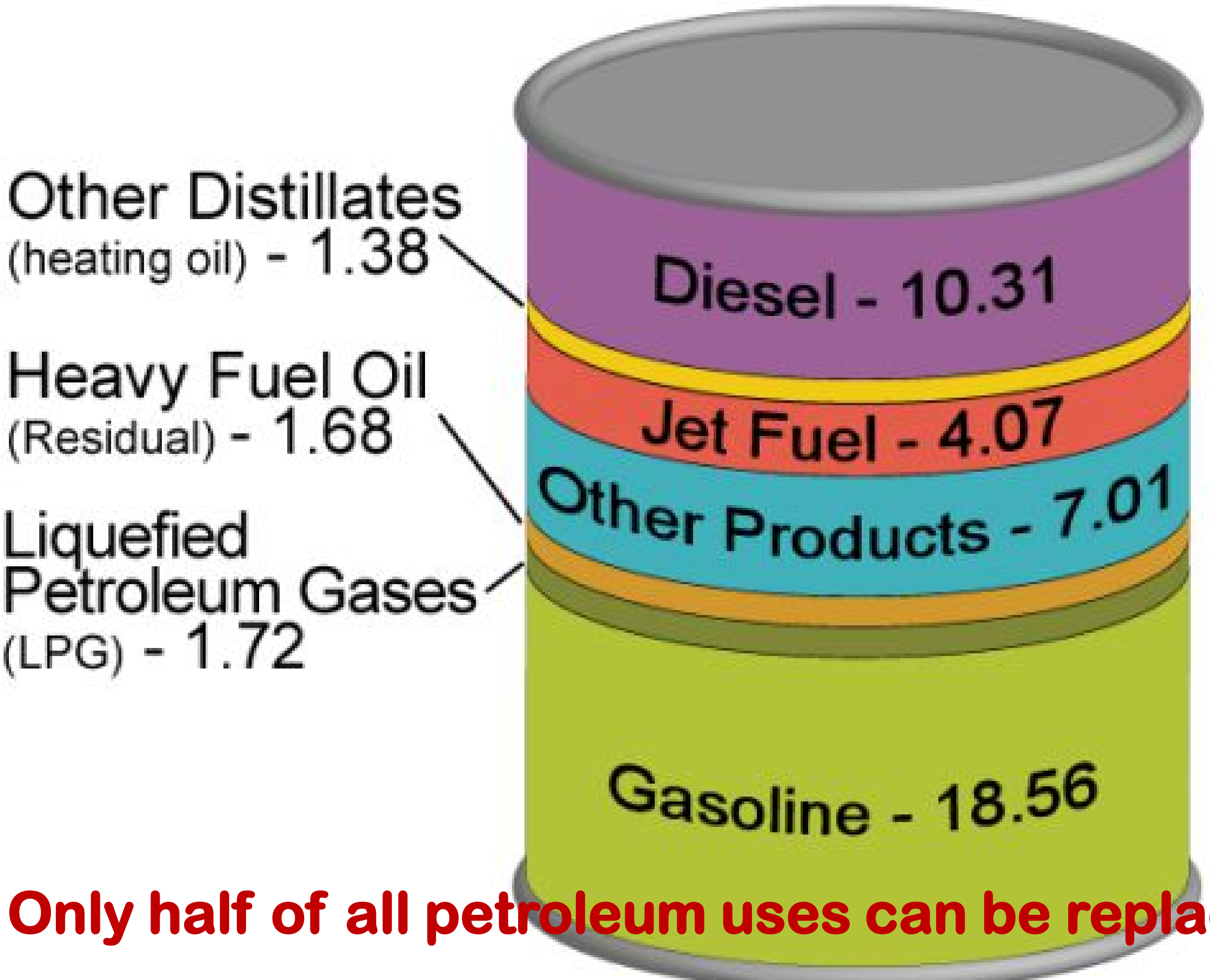
Note: Sum of components may not equal 100% due to independent rounding.
Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 1.3, Primary Energy Consumption by Energy Source, 1949-2009 (August 2010).

Products Made from a Barrel of Crude Oil (Gallons)




Comparison of Potential Corn, Cellulose, and Aquatic Microbial Fuel Production
Corn Grain Ethanol to Displace all US Gasoline
AMOP Biomass to Displace all US Gasoline
Case 1
Case 2
2006 Corn Crop
Cellulosic Ethanol to Displace all US Gasoline
Miles
0
250
500
1000
Current Opinion in Biotechnology

Products Made from a Barrel of Crude Oil (Gallons)



Only half of all petroleum uses can be replaced by ethanol

Other Products ?

What about Algae?

From the NRC prepublication copy of: *Sustainable Development of Algal Biofuels in the United States, (*2012)

…production of algal biofuels to meet even 5% of U.S. transportation fuel needs could create unsustainable demands for energy, water, and nutrient resources…

Foundation for Estimating Algal Biofuel demands for Land, Water, N,P

Assumptions

1. Objective: Satisfy 5% of US demand for transportation fuel
2. Oil demand in US = 6.9 BBL/yr or ~1B MT/yr
3. 2/3 of petroleum demand is for transport
4. 30% of algal CDW can be converted to biofuel

Parameters

1. Algal productivity is 10 g/m^2-d
2. Y_N = 16 g dry algae/g N consumed (data)
3. Y_P = 115 g dry algae/g P consumed
4. Cost of nitrogen—$1.1/kg N
5. Phosphorus—$3.3/kg P

What is the Land requirement for algal biofuel production?

Assumptions and parameters

1. Algal productivity is 10g CDW/m^2-day
2. Biofuel mass is 30% of CDW (reminder)
3. Objective is to produce 3.3×10^7 MT of biofuel per year (1.1×10^8 MT algal CDW/yr)

Results of analysis

1. Surface area requirement is ~11,747 mi^2 (25,000 km^2; 7.5M acres) for production of 5% of transportation fuel
2. This is 10% bigger than Maryland
3. And about 20% bigger than Lake Erie.

How much Water would we lose to evaporation in Tucson?

Assumptions and parameters

1. The pan evaporation rate in Tucson is 80 inches per year.
2. The precipitation rate is about 12 inches per year, for a net evaporation rate of 68 inches or 5.67 feet/yr.
3. Representative value of water in the Southwest is $125/acre-foot.
4. Required surface area is 7.5 million acres

Results of analysis

1. Rate of water loss due to evaporation is ~ 43 million AFY.
2. This is about 2.6x the average flow in the Colorado River.
3. Δ cost for biofuel production would be $5.4B/yr ($0.56/gal biofuel produced)
4. Water requirement is >1,450 gallons/gallon biofuel.

What are the N&P Demands for a significant Algal Biofuels industry?

Assumptions and Results

1. Annual demand for biofuel is 3.3 x 10^7 MT/yr (0.97B gal/yr—5% of demand for transportation fuels)

2. Y_N is 16g algae dry weight/g N
3. Y_P is 115g algae dry weight/gP

4. Δ demand for N: 6.3 x 10^6 MT N/yr—~ half of the nitrogen use in agriculture—cost equals $6.9B/yr or $0.71/gal biofuel.
5. Δ demand for P: 8.7 x 10^5 tons P/yr—17% of total phosphorus fertilizer use in US—cost equals $2.9B/yr or $0.31/gal.

Is Wastewater an alternative source of N,P?

Assumptions and parameters

1. Wastewater N content—40 mg/L as available N
2. Wastewater P content—3 mg/L as P
3. Wastewater production rate—100 gpcd
4. Cost of N as fertilizer is $1.1/kg
5. Cost of P as fertilizer is $3.3/kg

Results of analysis

Nitrogen first:

1. Population equivalent to provide 6.25 x 10^6 MT of nitrogen/yr is 1.14 billion people (3x US popn)
2. Reminder—Cost savings is $6.9B/yr, or $0.71/gallon of fuel.

Phosphorus second:

1. Population equivalent to provide 8.7 x 10^5 MT P/yr is 2.12 billion people (≈popn of China & India)
2. Cost savings is $2.9B/yr, but only $0.31/gallon of fuel

Can we use Wastewater Instead of a Commercially valuable Water Resource?

Assumptions and parameters

1. There are 3.26×10^5 gal/AF.
2. Biofuel development requires 42.6 MAFY (reminder)
3. Per capita rate of wastewater generation is 100 gpcd.

Result of analysis:

1. Population equivalent to generate 1.4×10^{13} gal/yr of treated wastewater is 426 million.
2. This is 1.15x the US population

Summary—Value and Limitations of Wastewater in Biofuels industry

Category	Result
N-sufficiency (5% industry demand)	Population equivalent—1.14 billion
N-value	$6.9B/yr or $0.71/gal
P-sufficiency (5% industry demand)	Population equivalent—2.12 billion
P-value	$2.9B/yr or $0.30/gal
Water sufficiency	Population equivalent—426 million
Water value	$5.4B/yr or $0.56/gal

- Overall conclusion—use of effluent for water algal biofuels industry could make a substantial cost difference—were there enough to go around.

What is UA doing to help solve the problem?

Algae to Biofuels

Sweet Sorghum to Ethanol, butanol, other bio-oils

Current Research Topics

- Productivity yield – 10 g/m^2 day – new reactor strategies
- Nutrient affects on lipid yield
- Wastewater and Recycled water studies
- Nutrient recycle
- Life cycle assessment
- Results shown today are for salt water Nannochloropsis species algae

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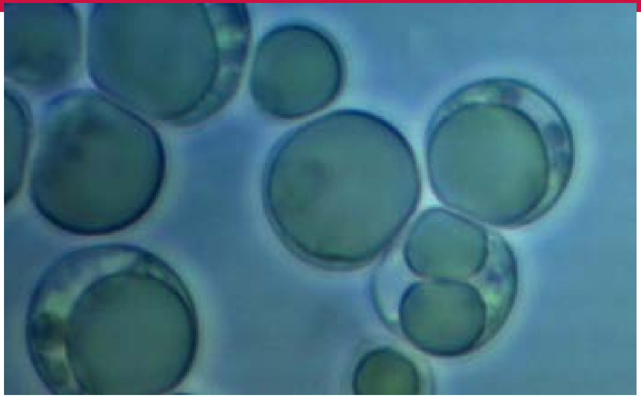
Why microalgae??



1. High oil content
2. Fast growth rate and high biomass yield
3. Grow in arid land and wastewater
4. Not interfere with food security concern
5. Less GHGs emission
6. Grown in non-arable land and industrial flue gas as carbon source

NAABB

National Alliance For Advanced Biofuels and Bio-products

DISCOVERY
Feedstock Logistics

Pacific Northwest National Laboratory — Proudly Operated by Battelle Since 1965
AXI — An Allied Minds Company
Los Alamos National Laboratory — EST. 1943
Donald Danforth Plant Science Center — Discover • Enlighten • Share • Nourish
UC Davis Energy Institute
USDA
Brooklyn College is CUNY
AgriLIFE Research — Texas A&M System
What Starts Here Changes The World — The University of Texas at Austin
The University of Arizona
Targeted Growth, Inc.
Solix — Algae to Energy
UCLA
Diversified Energy
University of Washington
HR BioPetroleum

DEVELOPMENT
Harvesting

Inventure
Kai BioEnergy — Tomorrow's Energy Today
The University of Arizona
Solix — Algae to Energy
Pacific Northwest National Laboratory — Proudly Operated by Battelle Since 1965
Clarkson University — defy convention
Donald Danforth Plant Science Center — Discover • Enlighten • Share • Nourish
Iowa State University
Catilin
Los Alamos National Laboratory — EST. 1943
AgriLIFE Research — Texas A&M System

DEPLOYMENT
Fuel Conversion & Coproducts

AgriLIFE Research — Texas A&M System
NM State
Terrabon
UC San Diego — Local Impact, National Influence, Global Reach
Kai BioEnergy — Tomorrow's Energy Today
Palmer Labs — where new ideas come to life
Iowa State University
Penn — University of Pennsylvania
Los Alamos National Laboratory — EST. 1943
Eldorado Biofuels
Diversified Energy
HR BioPetroleum
UC Davis Energy Institute
NC State University
Pacific Northwest National Laboratory — Proudly Operated by Battelle Since 1965
UOP — A Honeywell Company
Genifuel Corporation
Colorado State University

Other NAABB Partner: Pratt & Whitney

U.S. Department of Energy

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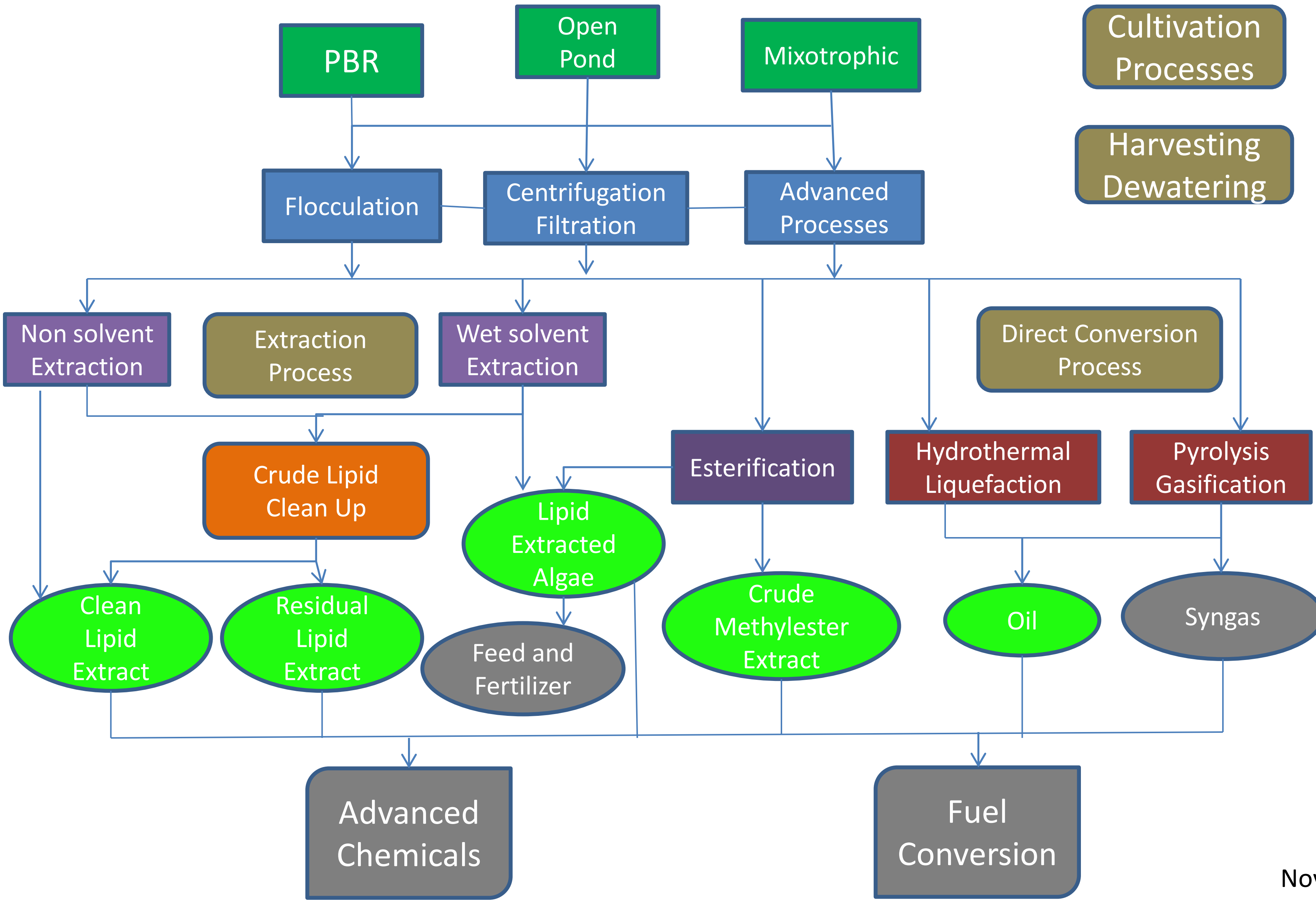

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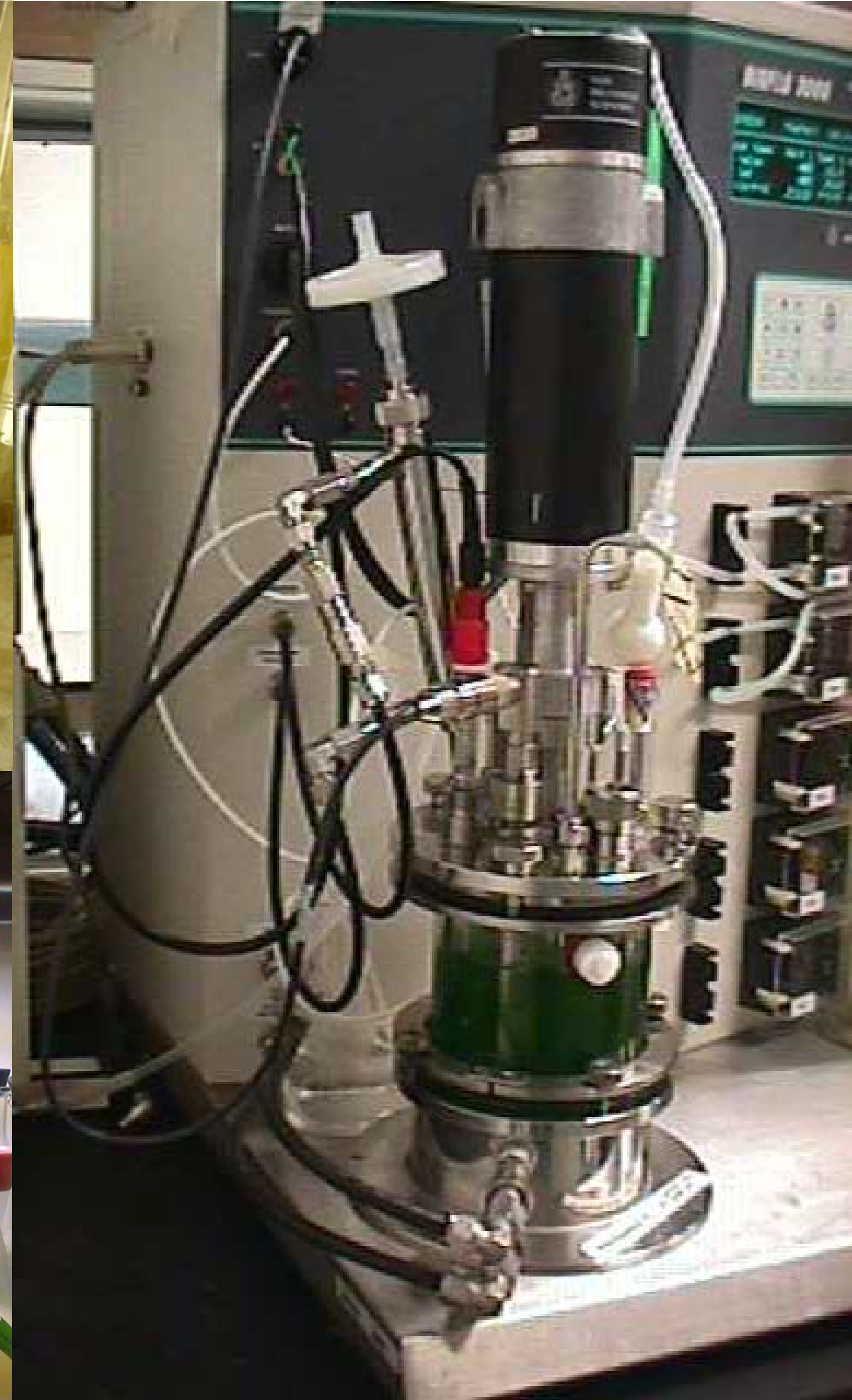

Traditional Raceway Design

UA ARID Raceway Design

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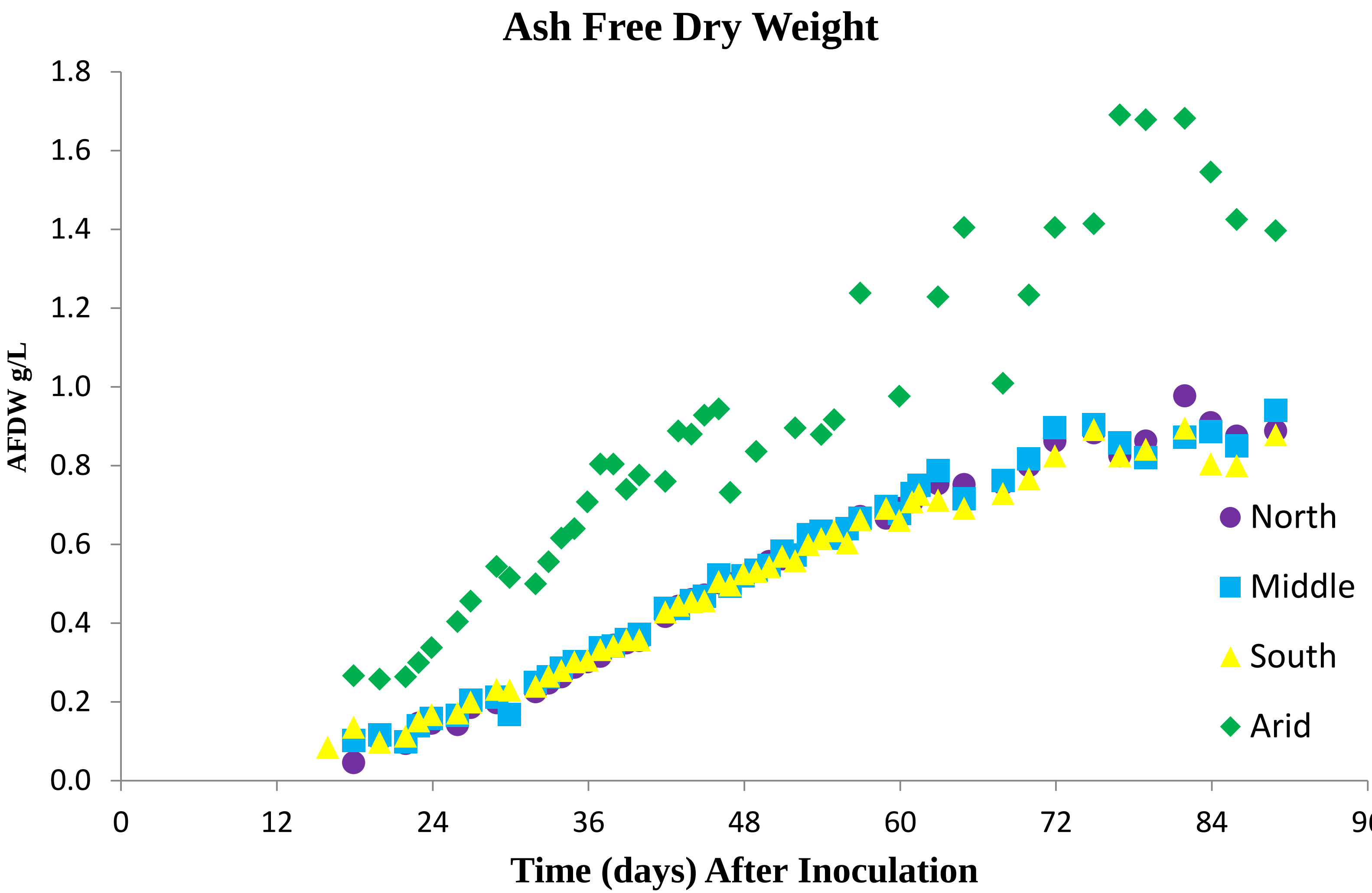
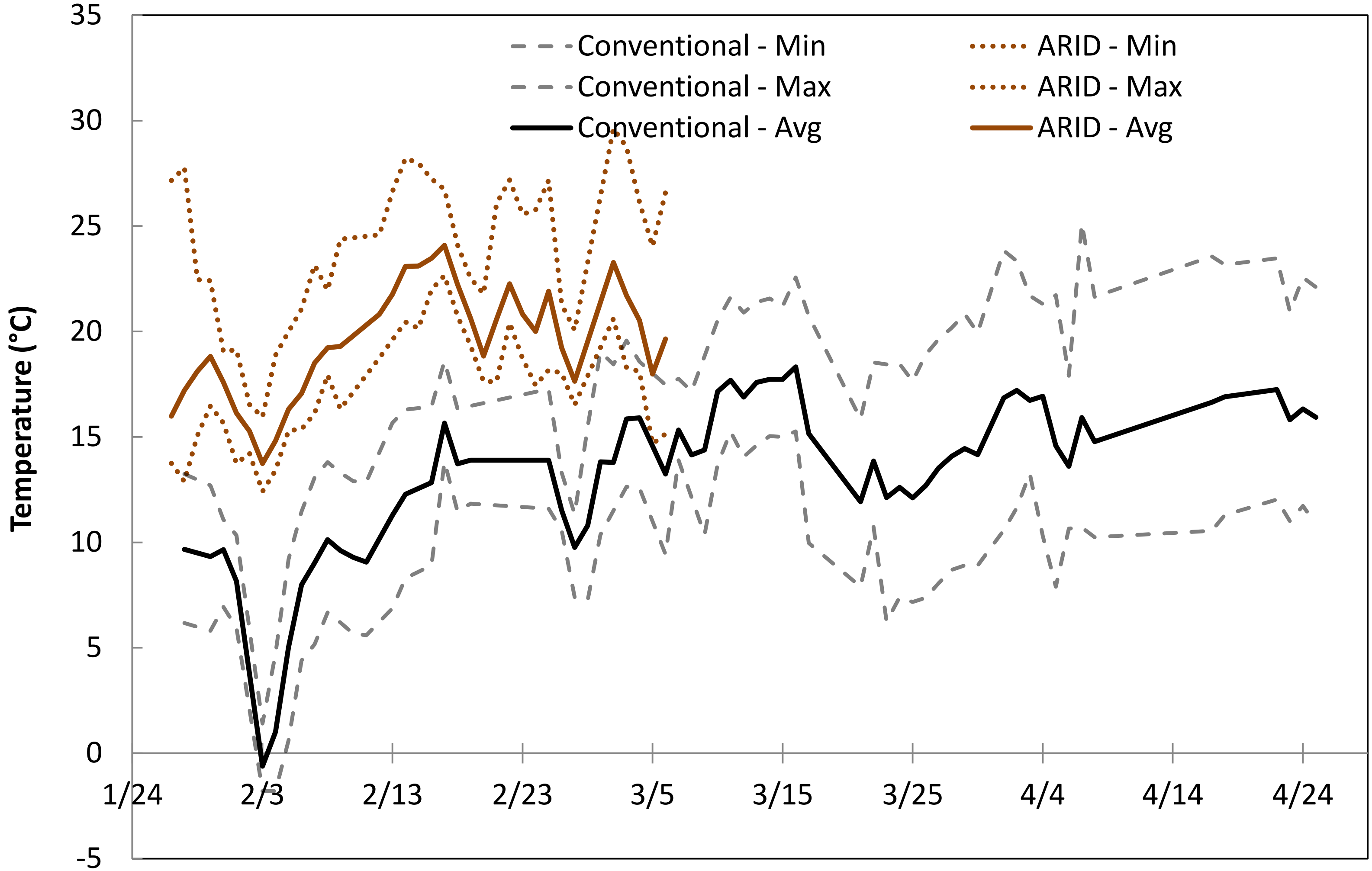
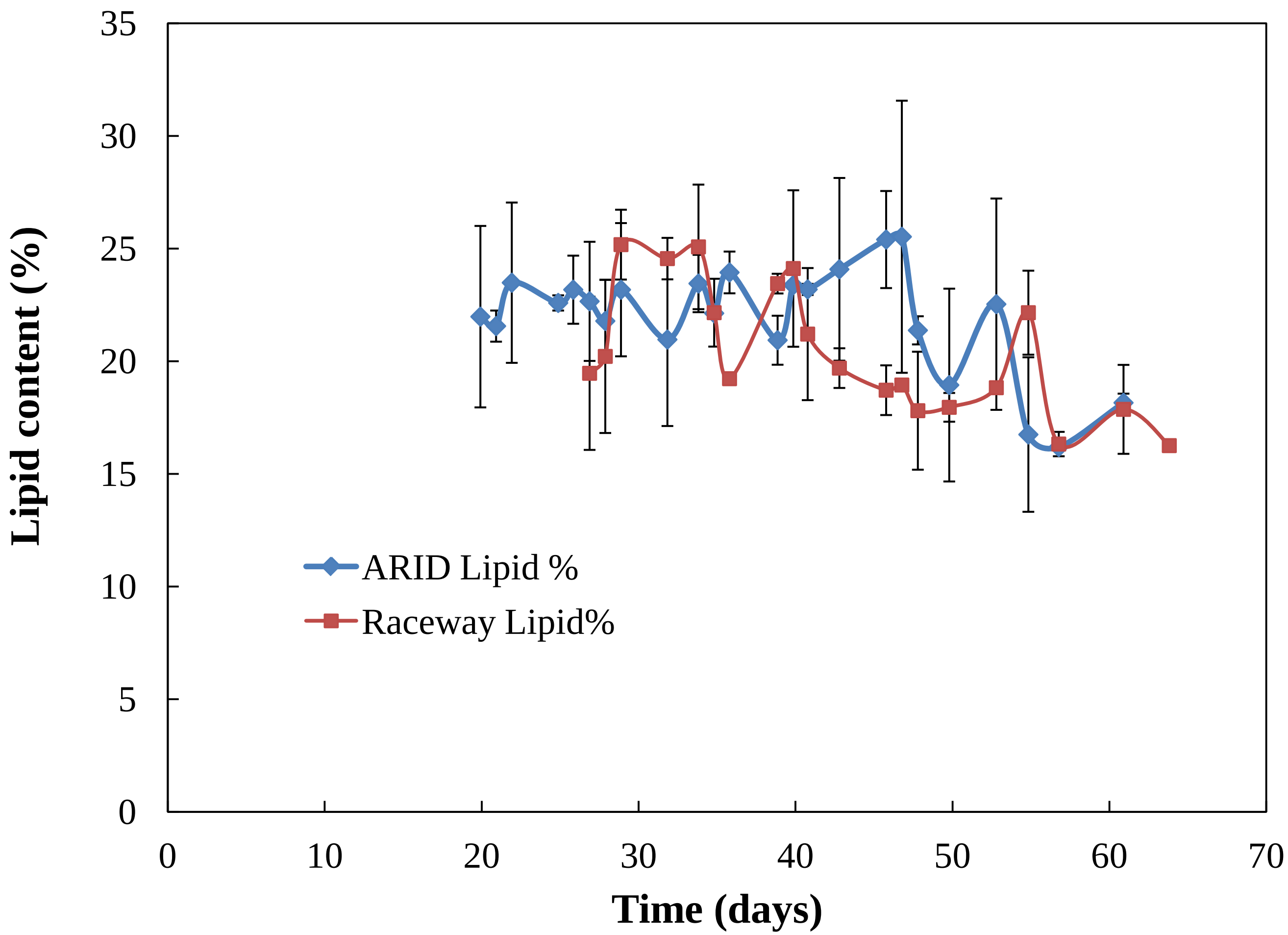
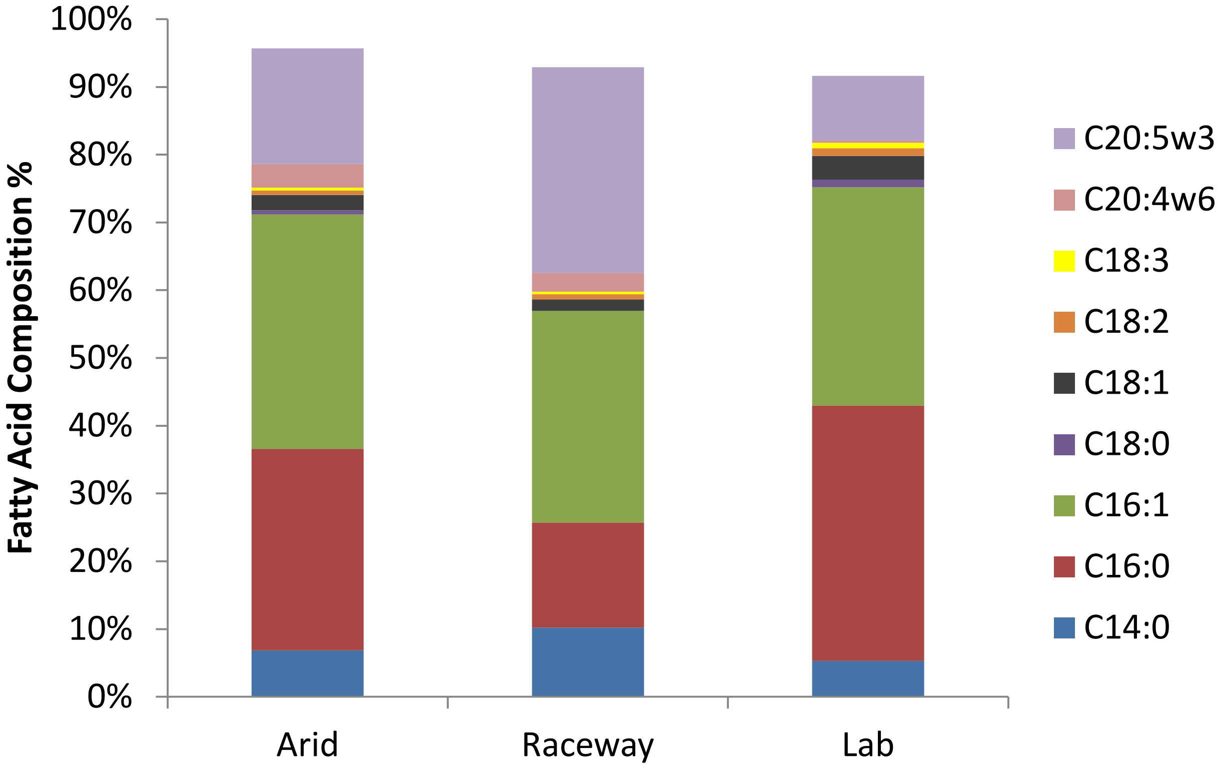


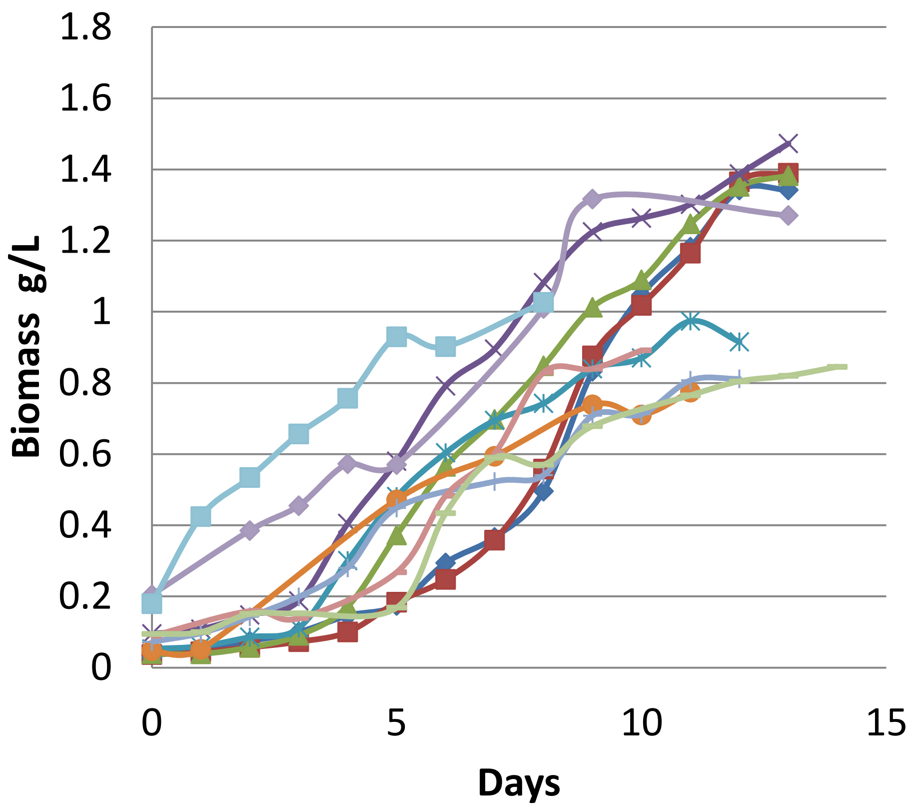

Conventional - Min
Conventional - Max
Conventional - Avg
ARID - Min
ARID - Max
ARID - Avg
Temperature (°C)
35
30
25
20
15
10
5
0
-5
1/24
2/3
2/13
2/23
3/5
3/15
3/25
4/4
4/14
4/24

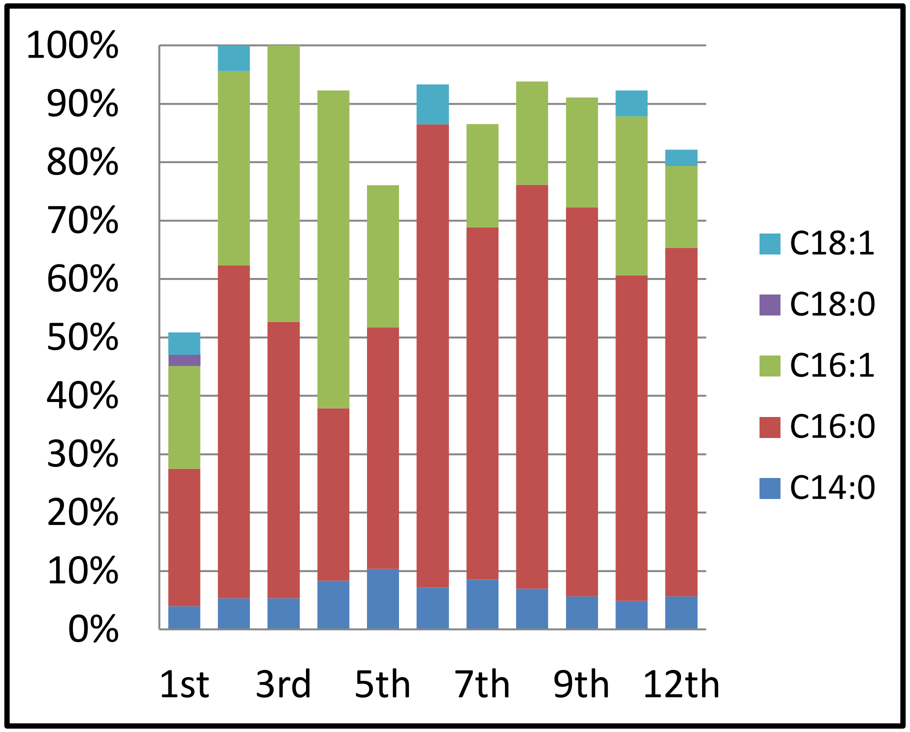
Lipid content vs time





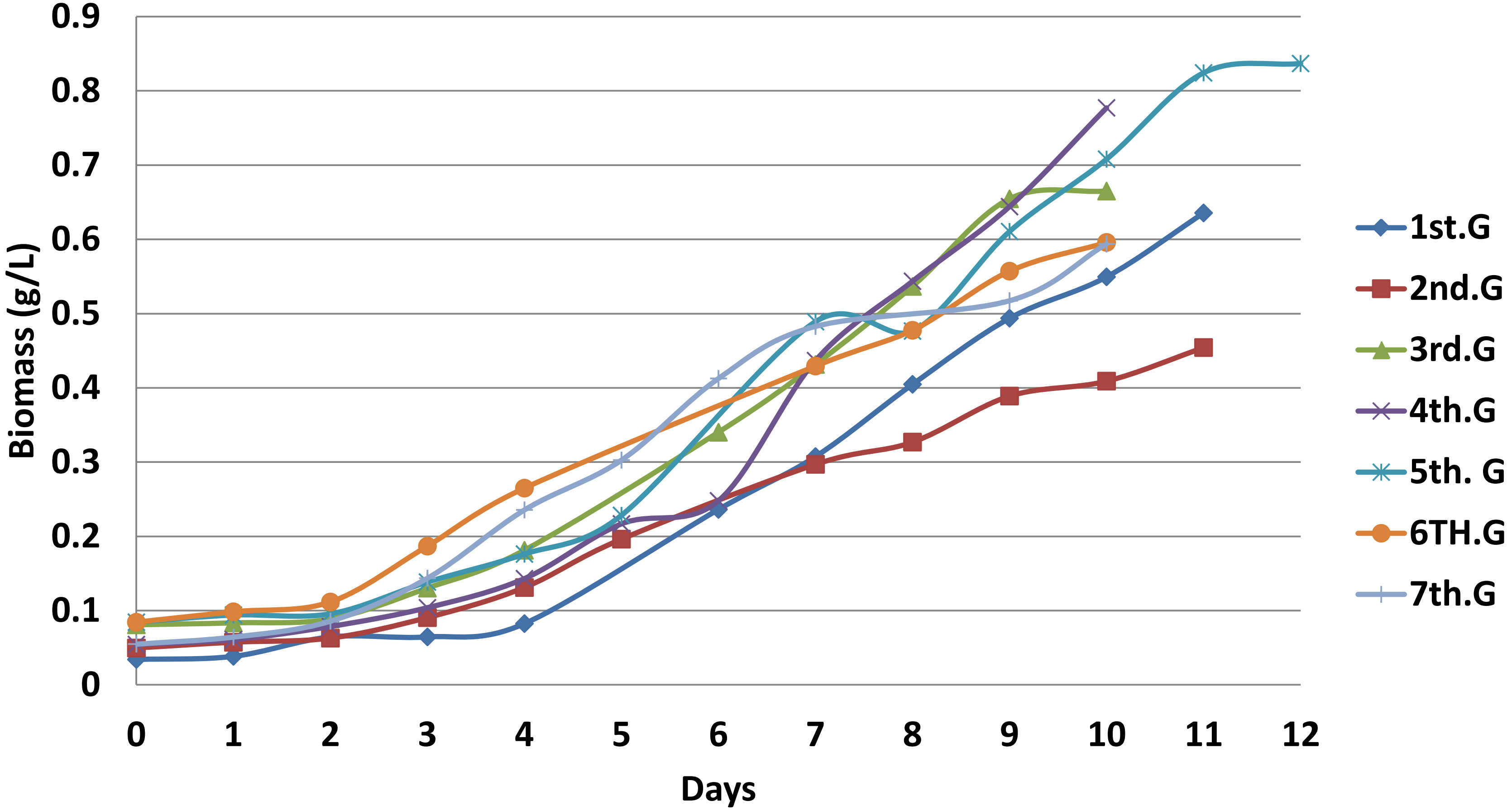
Fatty acid profile comparison at Stationary phase in three different culture systems



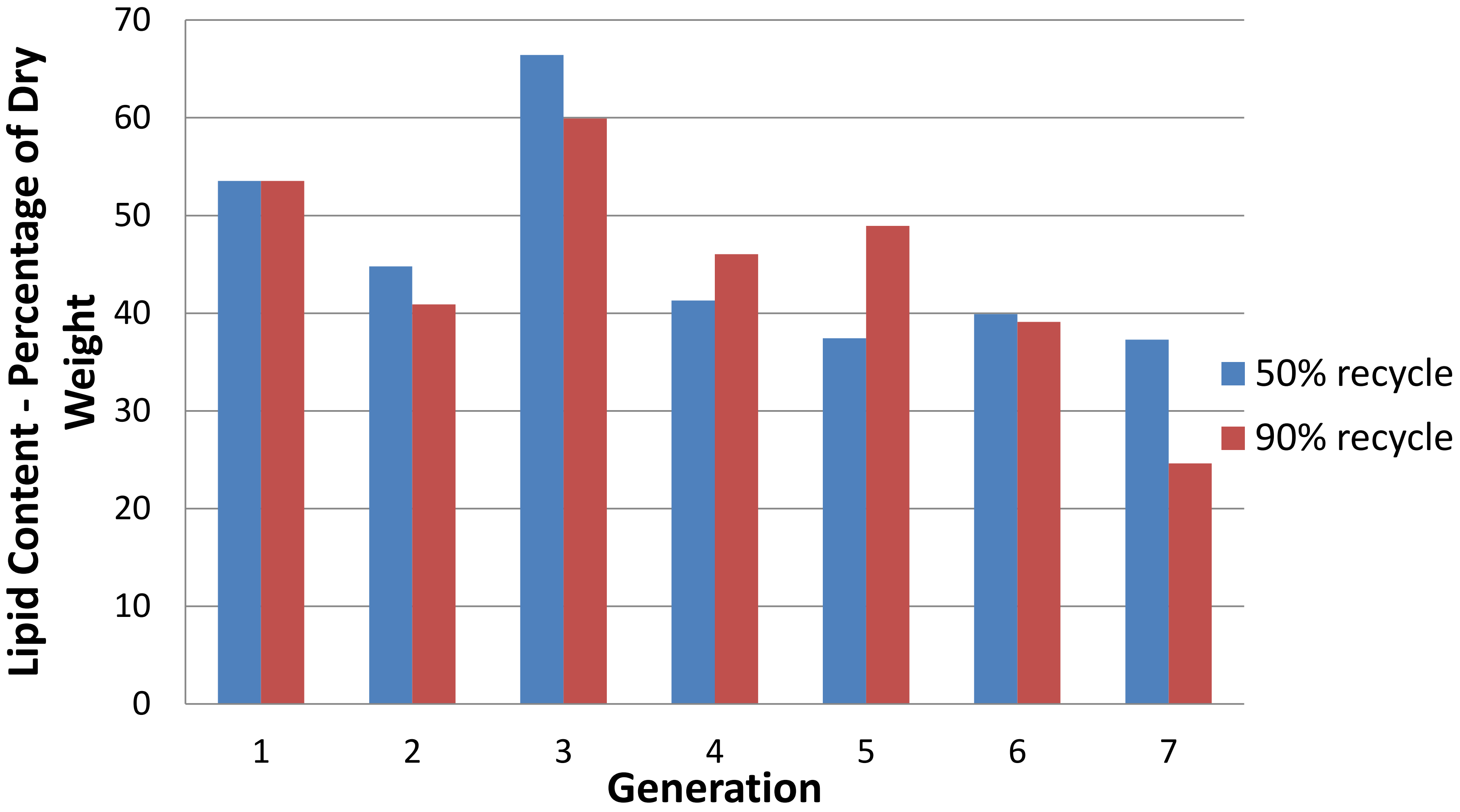


Productivity of *Nannochloropsis salina* with 50% Recycled Water

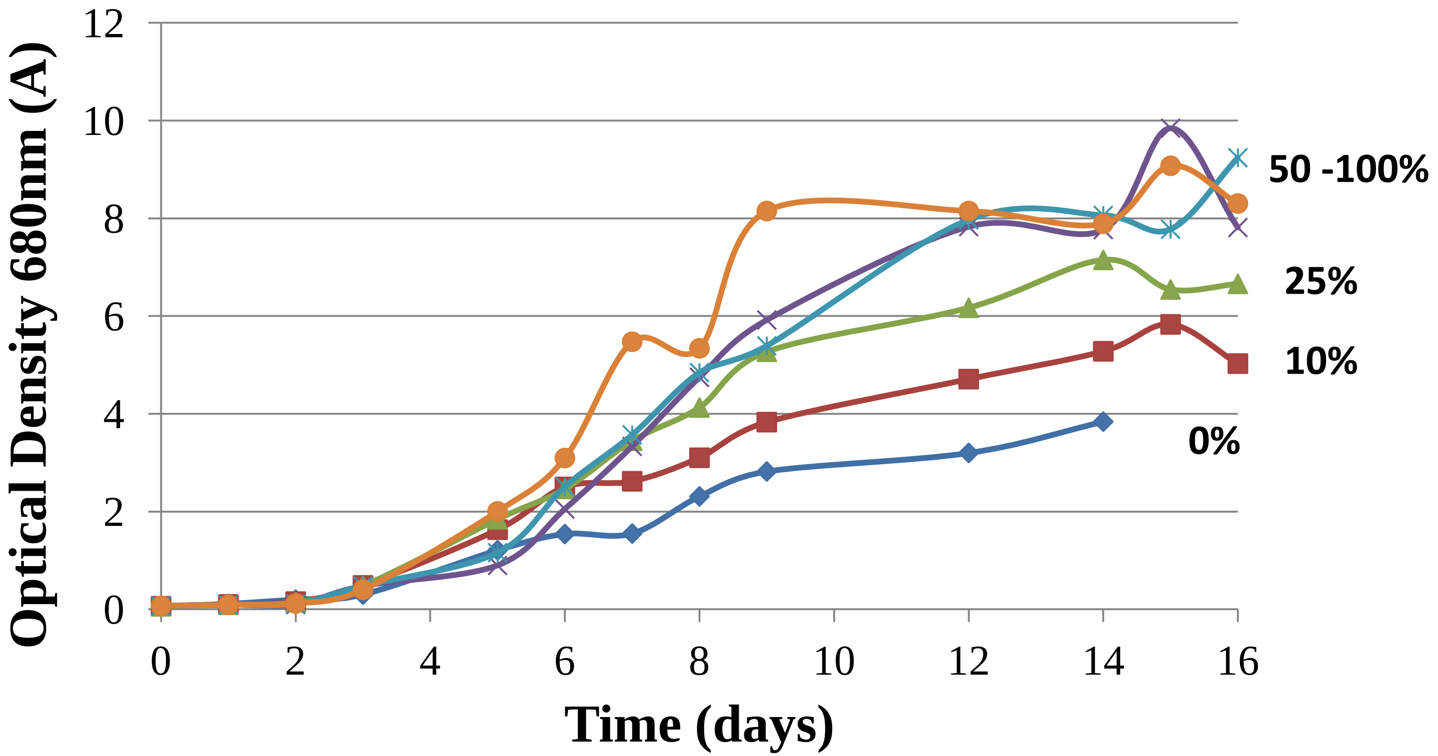
90% Water Recycle



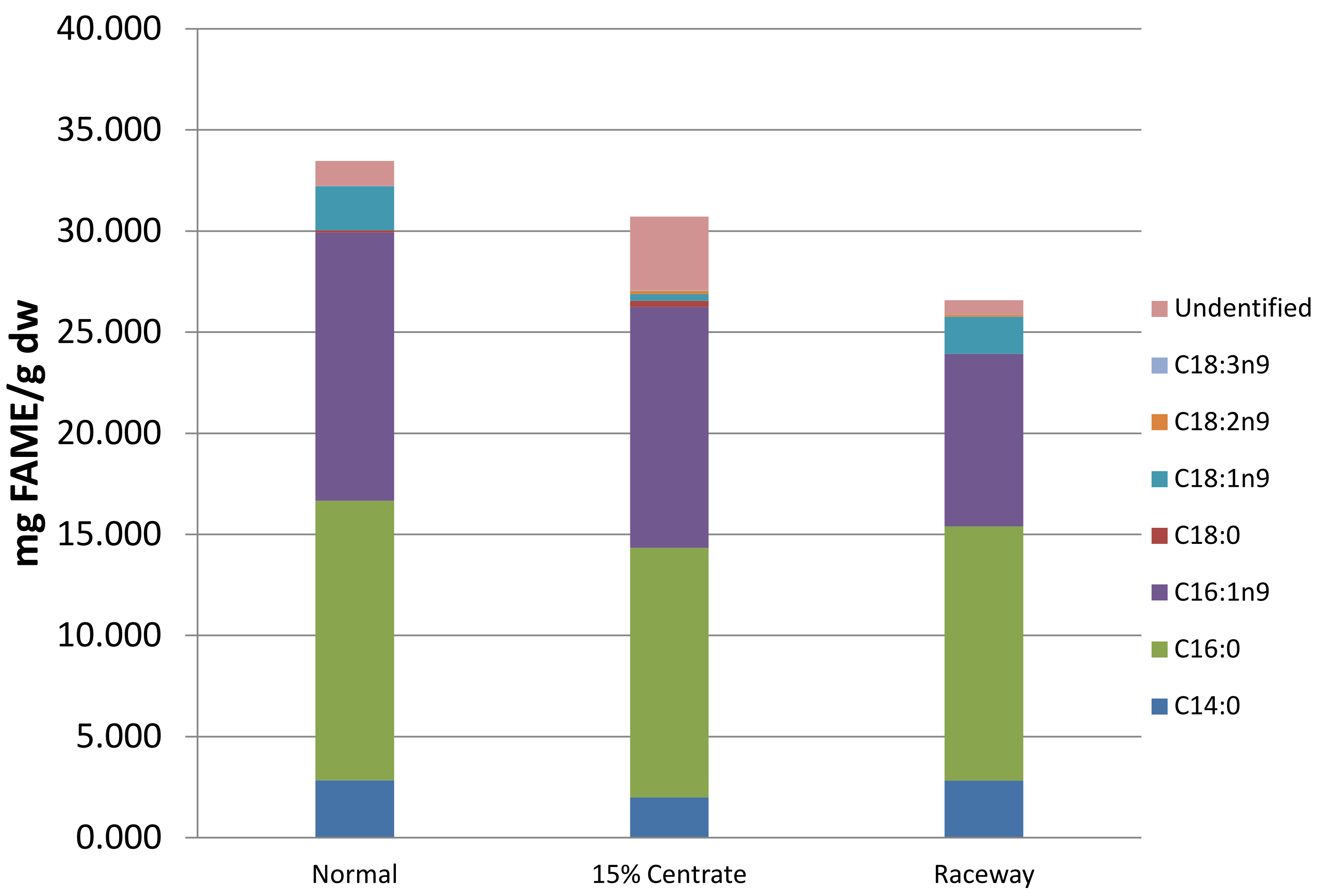
Lipid Productivity with Water Recycle



CCMP 1776 Growth Curve Using Different Percentages of Centrate in Normal Medium Minus N,P



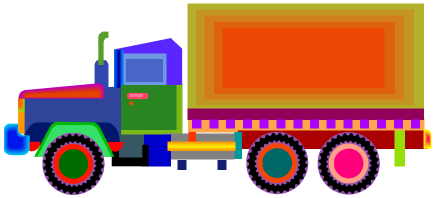
Comparative FAME profiles for control, 75% centrate and raceway

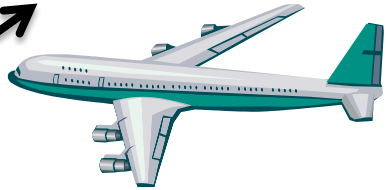


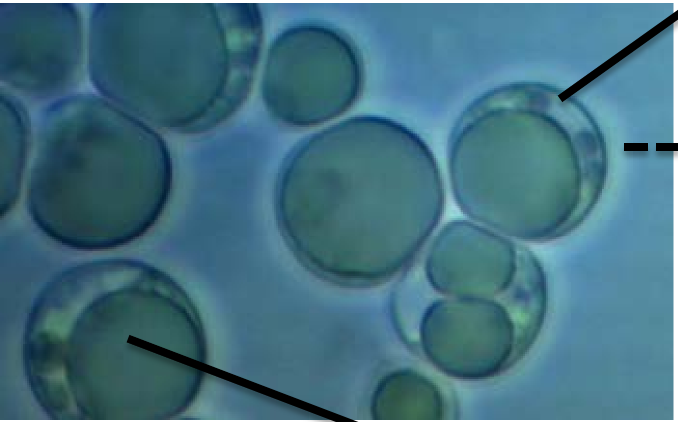
Research Conclusions

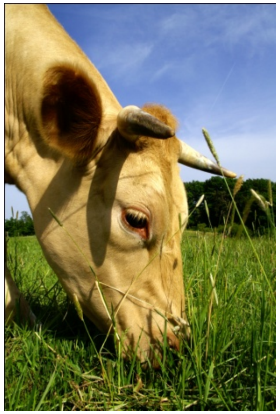
- Arid reactor system has potential to increase productivity from 10 g/m^2 day – long term cultivation studies required
- Water can be recycled 5 to 6 times with little affect on productivity – total water recycle
- Wastewater is advantagous to algal growth – need to supplement with some trace nutrients
- Combination of recycled water, wastewater or brackish and nutrient recycle required to have sustainable production of fuel from microalgae.

Food AND Fuel









UA Biofuels Team

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- Randy Ryan, CALS
- Donald Slack, Ag. and Biosystems Engr.
- Pete Waller, Ag. and Biosystems Engr.


Arizona
GEORGIA
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3. GK12 and RET Programs of the National Science Foundation $3.1M