



**Next generation algae extraction and fractionation technology:**  
*Helping move algae biofuels from “potential” to “practice”*

Brian L. Goodall, Puneet Chandra and Tom Czartoski  
*SRS Energy, Dexter, Michigan*



A Purification & Separations Technology & Service  
Company

# Outline



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- Who we are
- Algae extraction: The problems
- SRS AlgaFrac™ Technology
- Some results
- Technical readiness and conclusions

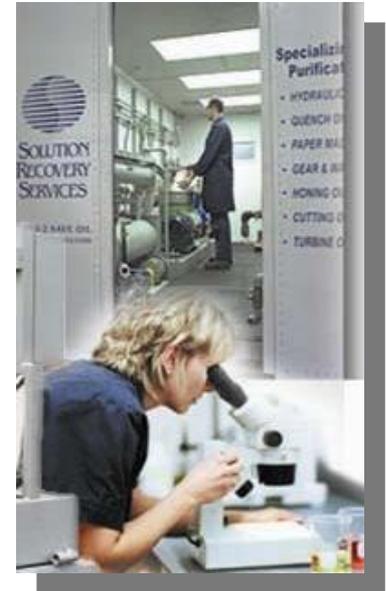
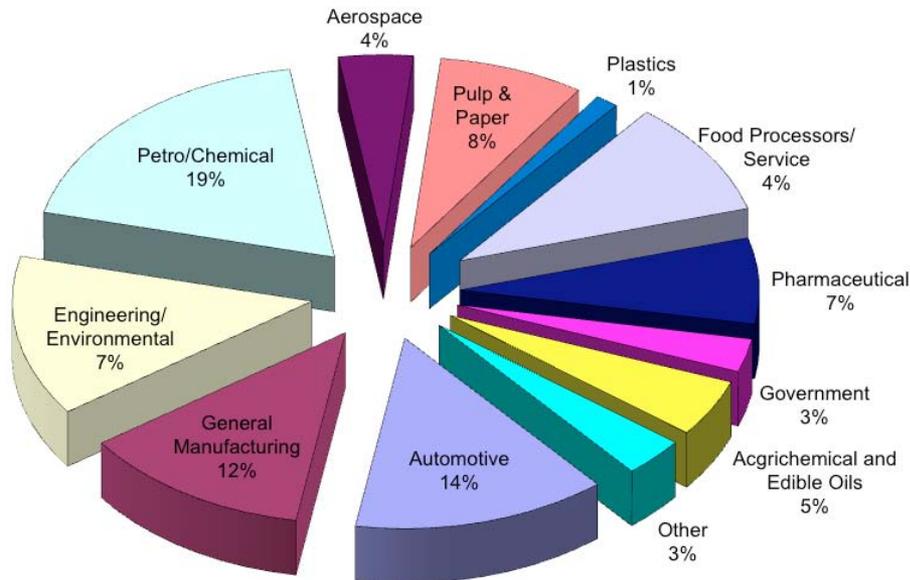
# Market Segmentation



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185 Employees ♦ \$55+ Million in Gross Revenues ♦ 8 Locations

Specializing in oil and water purification, separation and related services



**>4 years internally-funded, focused R&D on algae extraction and fractionation**

# The Algae Value Chain



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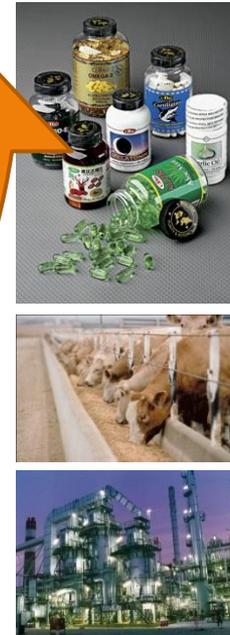
Growing



Extraction



Refining



HUNDREDS

FEW

HUNDREDS

NUMBER OF COMPANIES

- **Supercritical Carbon Dioxide**
  - *Currently prohibitively expensive for all but the highest value applications*
- **Dry hexane extraction**
  - *Drying algae very energy intensive, low oil extraction efficiency*
- **Cell disruption techniques; e.g. microwave, ultrasound, osmotic degassing, and electric field disruption**
  - *Marginally effective, these techniques require extensive capital equipment and extract only vascular lipids*
  - *In our hands algae cell lysis not required and insufficient to effectively extract oil*

# THE TECHNOLOGY: ALGAFRAC™



ALGAFRAC™ EXTRACTION &  
FRACTIONATION

# Benefits of Wet Fractionation



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## *Building on SRS's core strengths:*

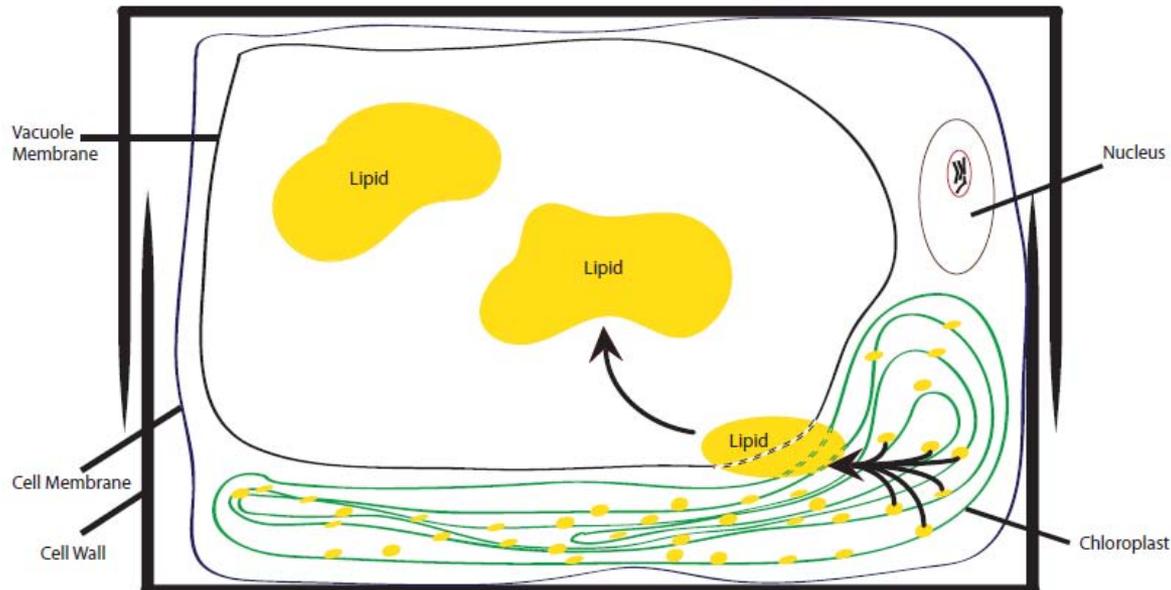
- > 90% lipid recovery
- 70-80% net energy
  - No thermal drying required for extraction
  - Modest temperature and pressure
- Cost effective & scalable
  - Operating Cost: \$0.16 – 0.24\*/gallon of oil
  - Compatible with existing refinery infrastructure
- Protein rich and sugar-rich co-product fractions
- Proven effective on multiple algae species:
  - >400 samples studied to date

# The Extraction Problem



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- **PROBLEM: Distribution of lipids throughout the algae cell**
  - *Drying of biomass too energy intensive/costly*
  - *Simple solvent extraction has limited efficacy*
  - *Lysing of the cell walls only allows access to part of the lipids (vacuole lipids) potentially available*

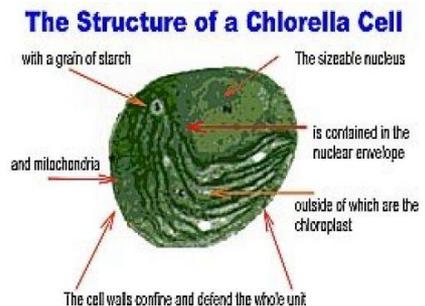


# The SRS Energy Solution

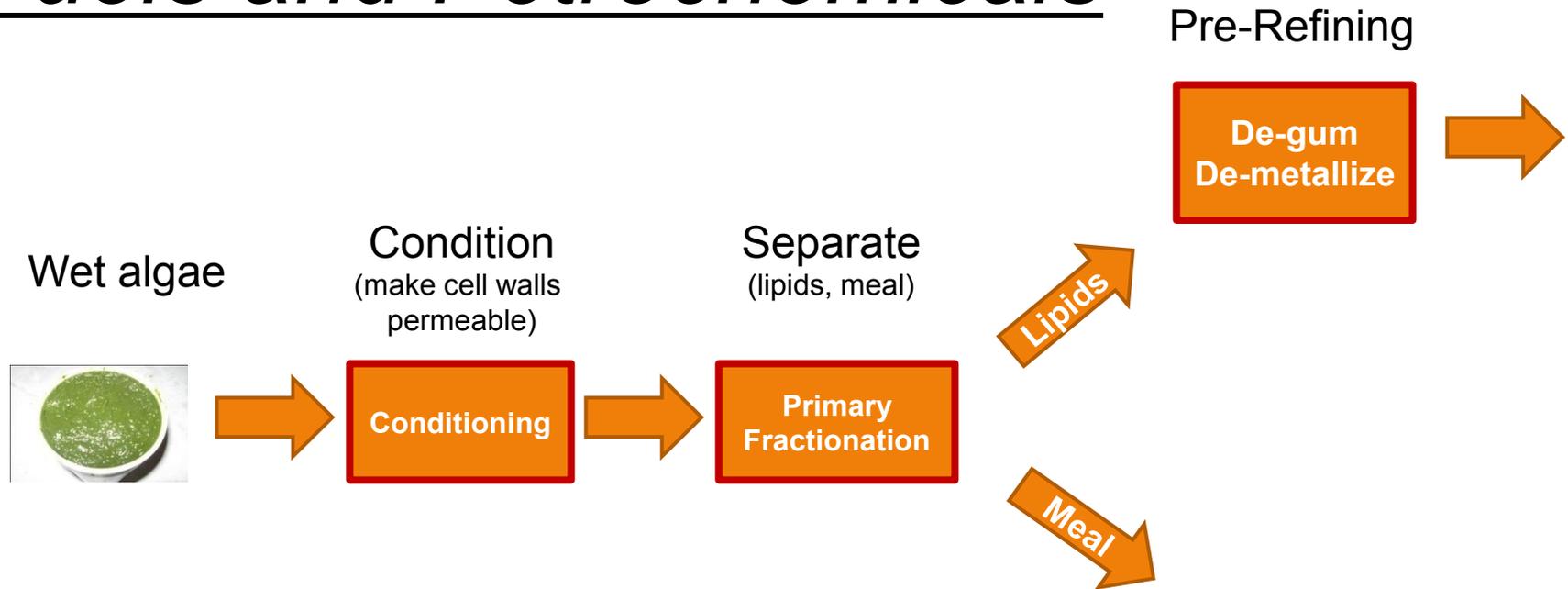


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- **PROBLEM: Distribution of lipids throughout the algae cell**
  - *Drying of biomass too energy intensive/costly*
  - *Simple solvent extraction has limited efficacy*
  - *Lysing of the cell walls only allows access to part of the lipids (vacuole lipids) potentially available*
- **SOLUTION: Cause permeability of cell walls/membrane**
  - *Enables access to ALL contained lipids from WET biomass (energy efficient)*
- **BONUS: Permits effective fractionation of the biomass**
  - *Allows optimization and tailoring to meet clients needs*
  - *Maximizes value proposition*



## Fuels and Petrochemicals

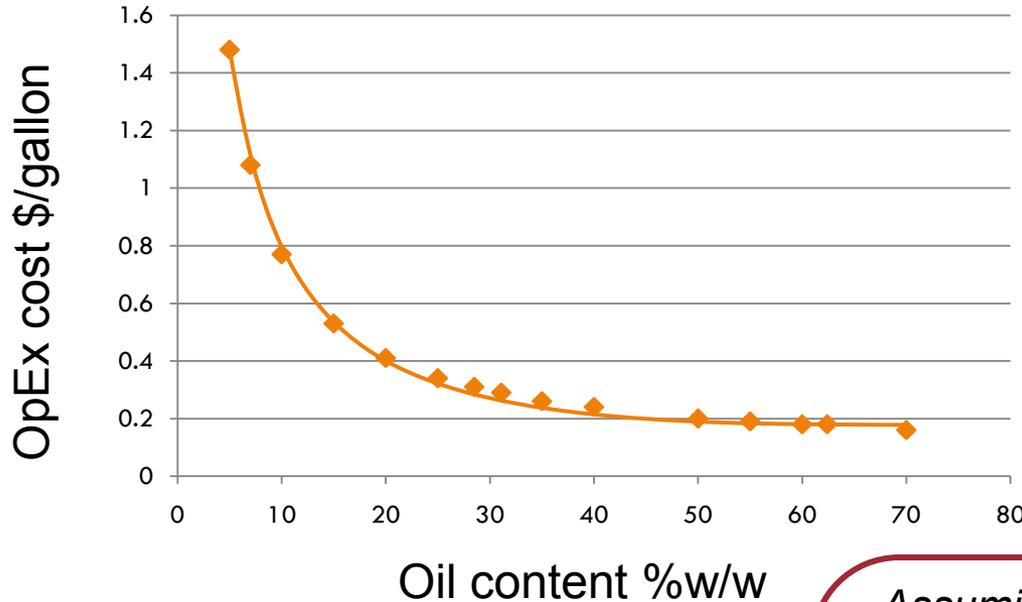


**Variants/options for each step (conditioning, fractionation) selected on the basis of customer and product needs**

# Extraction Costs



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*Cost-lowering developments:*

- *continuous processing*
- *alternative solvent system*

*Assuming:*

- *100MM gallons per annum*
- *10% solids*
- *38% oil extracted*
- *Dry biomass co-product*
- *10 year capital cost recovery*

**Total cost (OpEx + CapEx) per gallon <\$0.50/gallon**  
**Energy use < half that of dry hexane extraction**

# THE RESULTS (EXAMPLES)

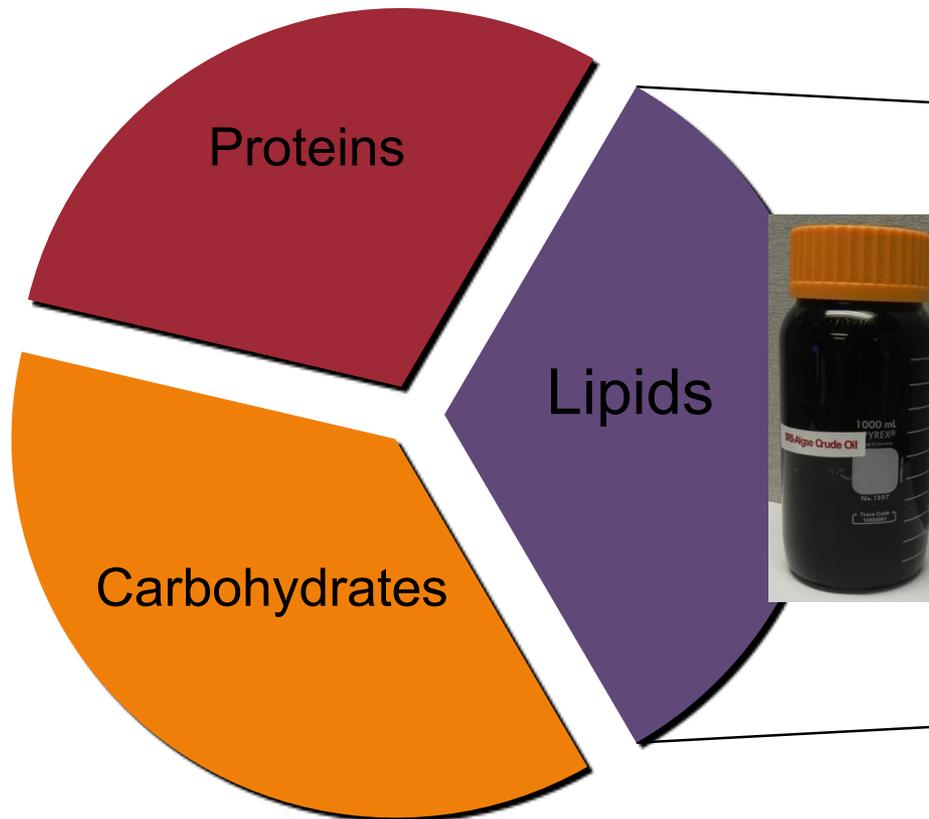


ALGAFRAC™ EXTRACTION &  
FRACTIONATION

# Phototrophic Algae: *Example A*

## Ash-Free Composition

ALGAFRAC™

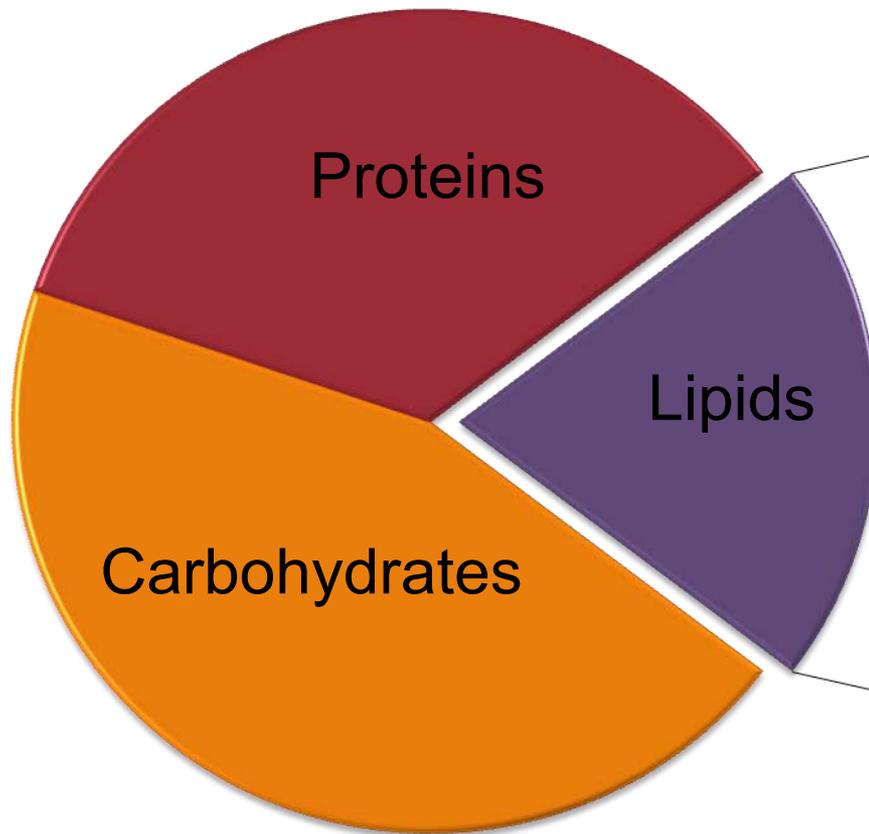


	% By Weight
C12:0	0.00
C14:0	3.56
C14:1	0.04
C16:0	44.32
C16:1n7	34.67
C18:0	0.72
C18:1	1.14
C18:2	2.44
C18:3	0.54
C20:0	0.06
C20:1	0.00
C20:2n6	0.06
C20:4n3	4.31
C20:5n3	6.52
C22:0	0.04
C22:1	0.16
C24:0	0.03
C26:0	1.11
C26:1	0.28

# Phototrophic Algae: *Example B*

## Ash Free Composition

ALGAFRAC™

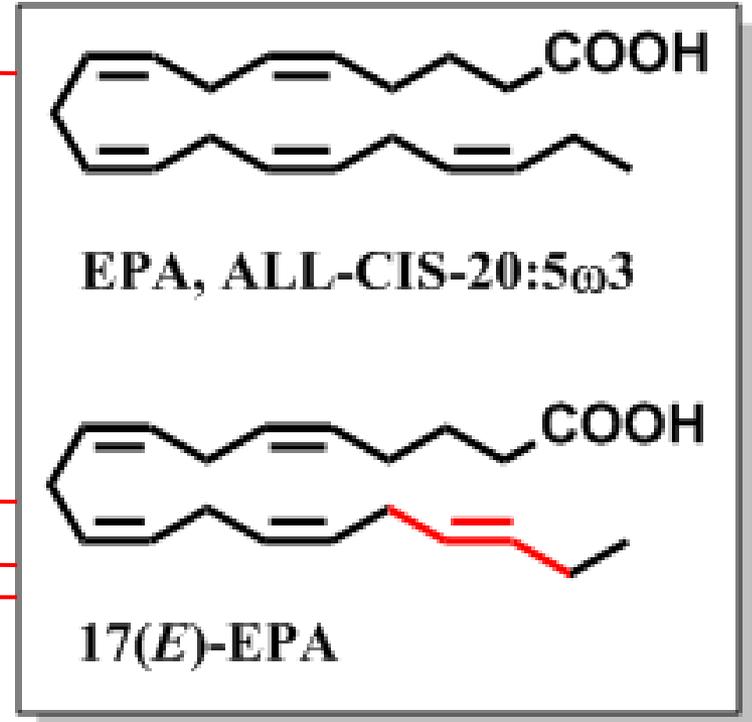
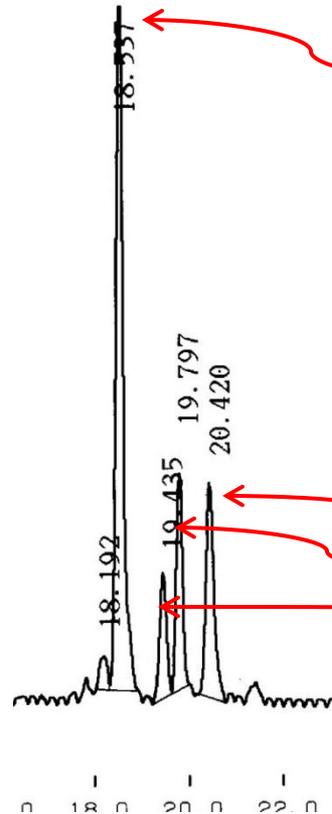


Fatty Acid Profile (w/w % of all fatty acids)	
C14:0	3.92
C14:1	0.28
C16:0	26.29
C16:1n7	26.89
C18:0	0.52
C18:1	3.12
C18:1	0.89
C18:2	2.44
C18:3	0.18
C20:0	0.08
C20:1	0.00
C20:2	0.26
C20:4n6	3.41
C20:3n6	0.27
C20:5n3	30.58
C22:0	0.16
C22:1	0.24
C24:0	0.10
C22:6	0.16
C24:1	0.21

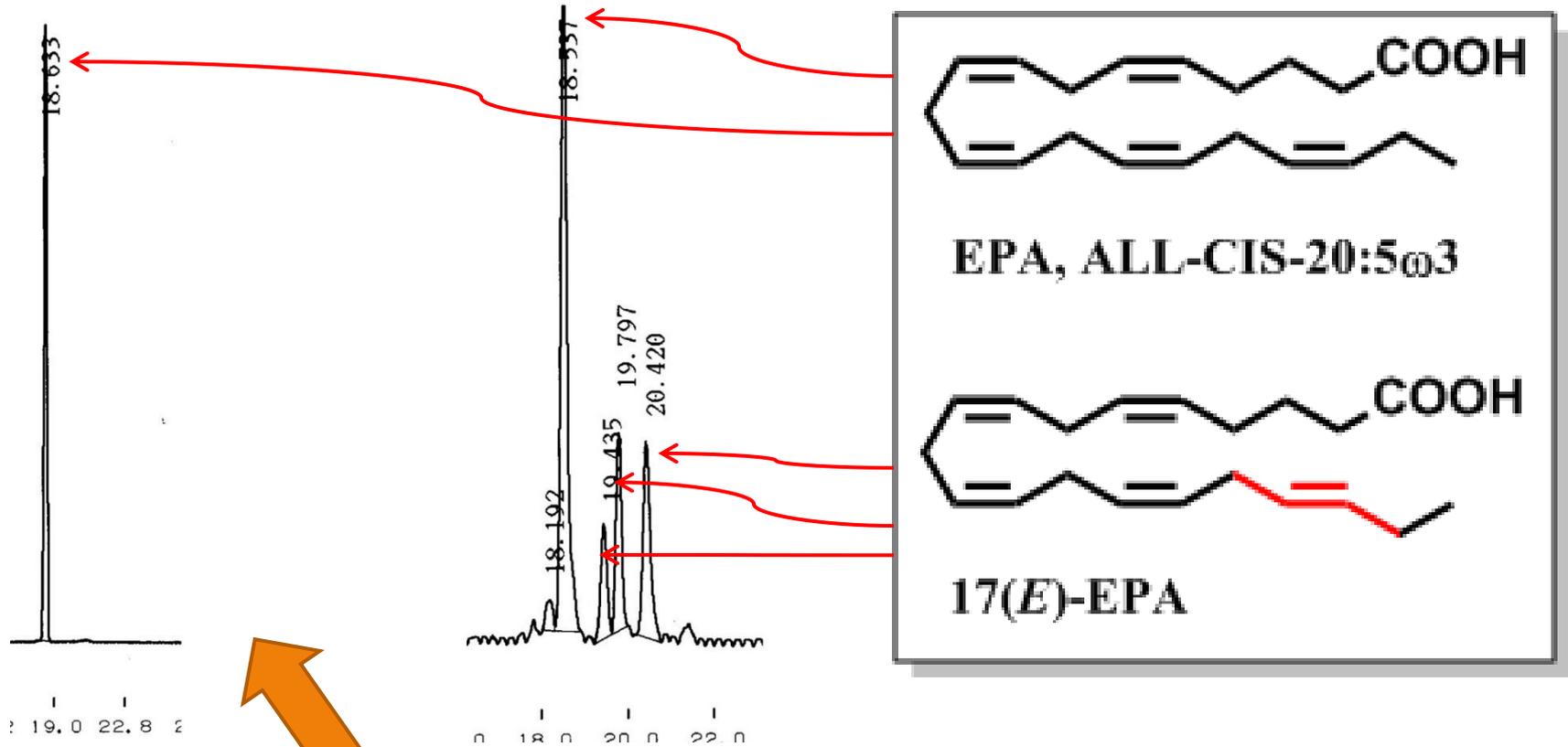
# EPA Quality is Paramount

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EPA very sensitive  
to isomerization  
(and oxidation)

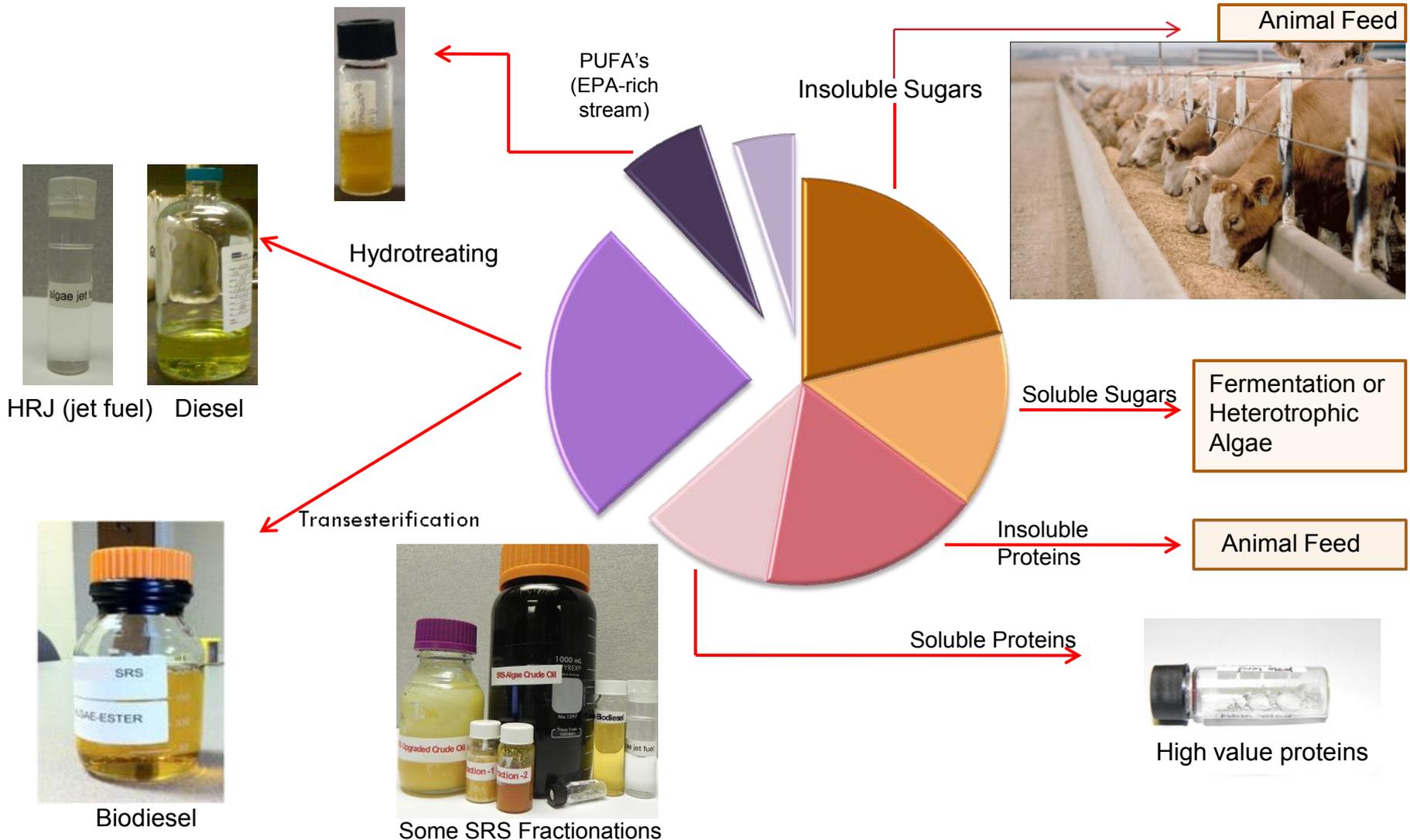


# EPA Quality after Extraction



**SRS Energy AlgaFrac™ process delivers high quality EPA**

# Upgrading to Products



# TECHNICAL READINESS

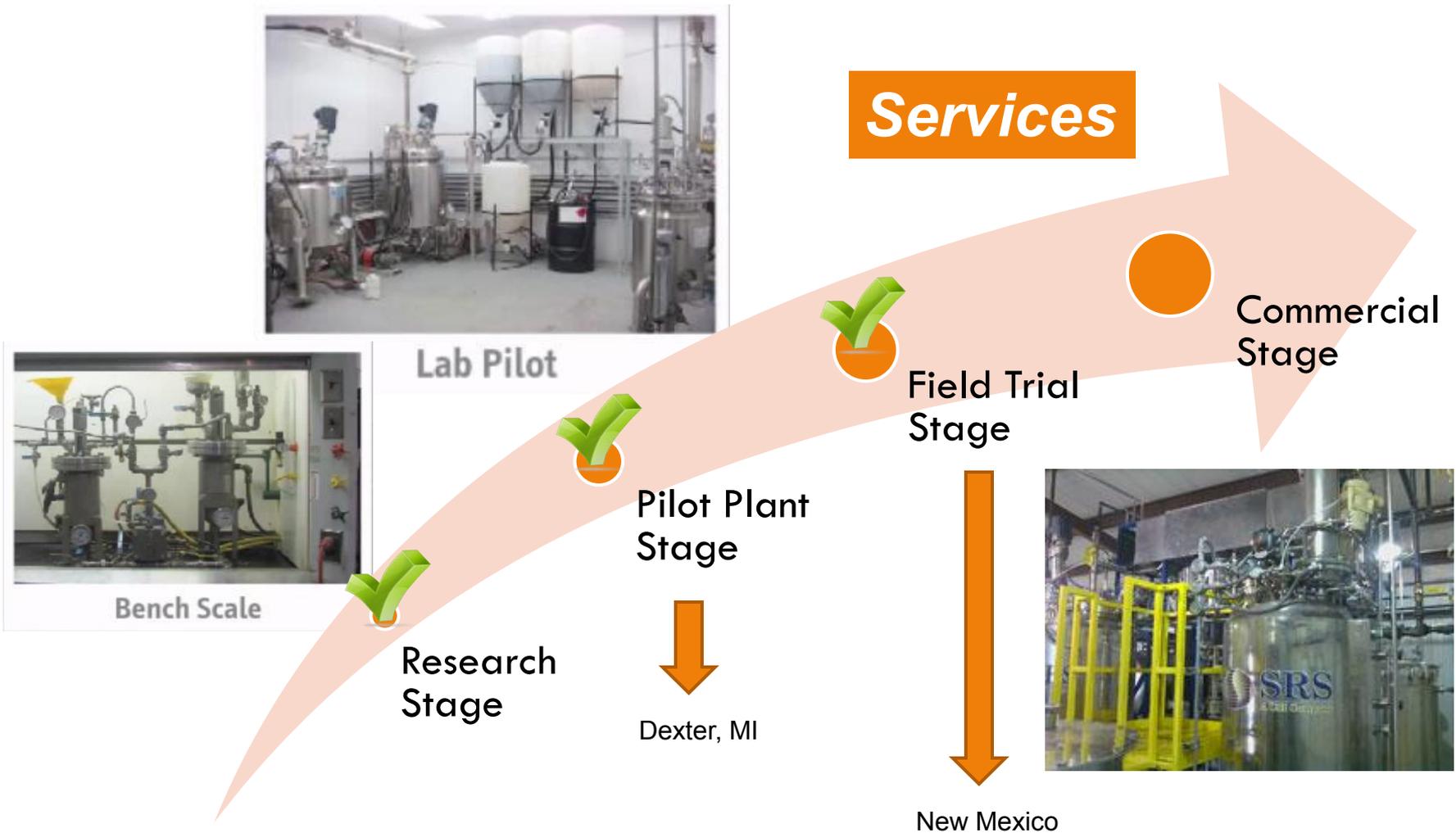


ALGAFRAC™ EXTRACTION &  
FRACTIONATION

# Technology Readiness



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# Proven Scalability



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- Field trial scale
  - ▣ Scale-up and pre-commercial field unit (about 100Kg/day)
    - New Mexico (CEHMM) - 07/09
  - ▣ On-site process validation and optimization
  - ▣ Data analysis



# Summary

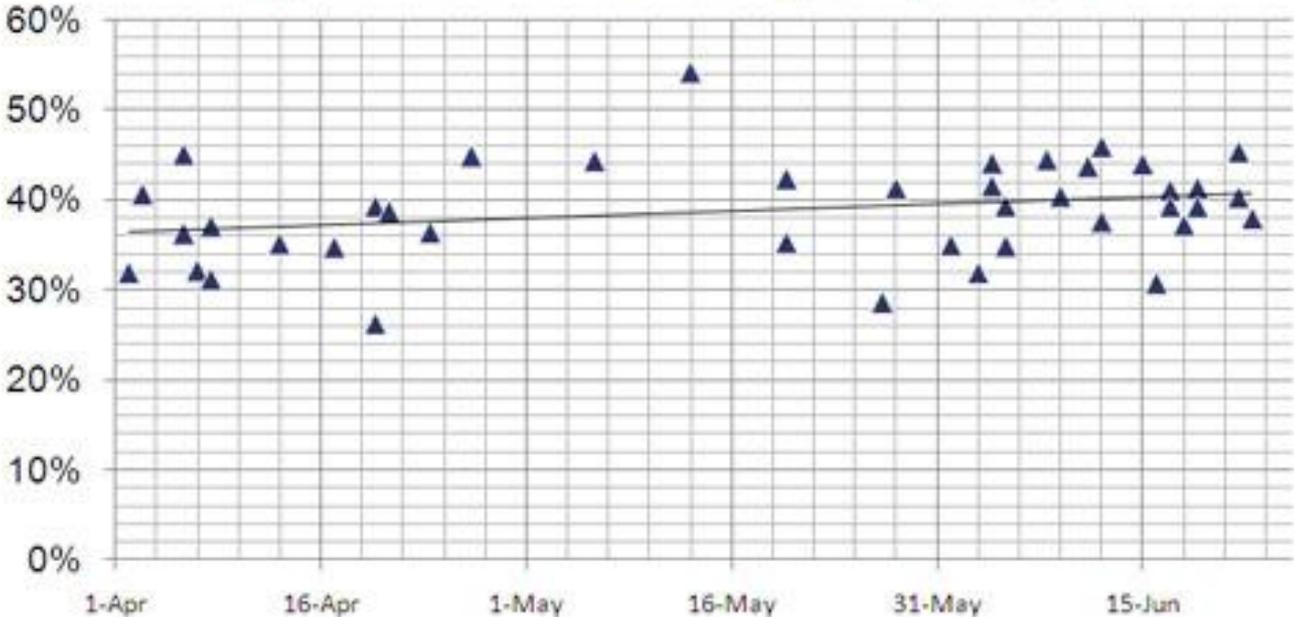
Unprecedented lipid yields can be achieved

- <30 to >60% w/w has been demonstrated (strain dependent).
- Typical “good” phototrophic biomass 30-40% w/w.

Extraction of lipid economically viable scalable

New developments horizon

Lipids Extracted as % of Algae Dry Weight



# Summary



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Unprecedented lipid yields can be achieved

- <30 to >60% w/w has been demonstrated (strain dependent).
- Typical “good” phototrophic biomass 30-40% w/w.

Extraction of lipids is economically viable and scalable

- Exact costs depend on scale, oil content, product slate.
- Proven at 100kg/day Pilot (2 years of operation).
- High value oils (e.g. EPA) have been extracted with high quality.

New developments on the horizon

- Gen II (no hexane) pilot unit (3Q2011) and continuous operation (4Q2011)

# Thank you!



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<http://www.solutionrecovery.com/algae/index.html>