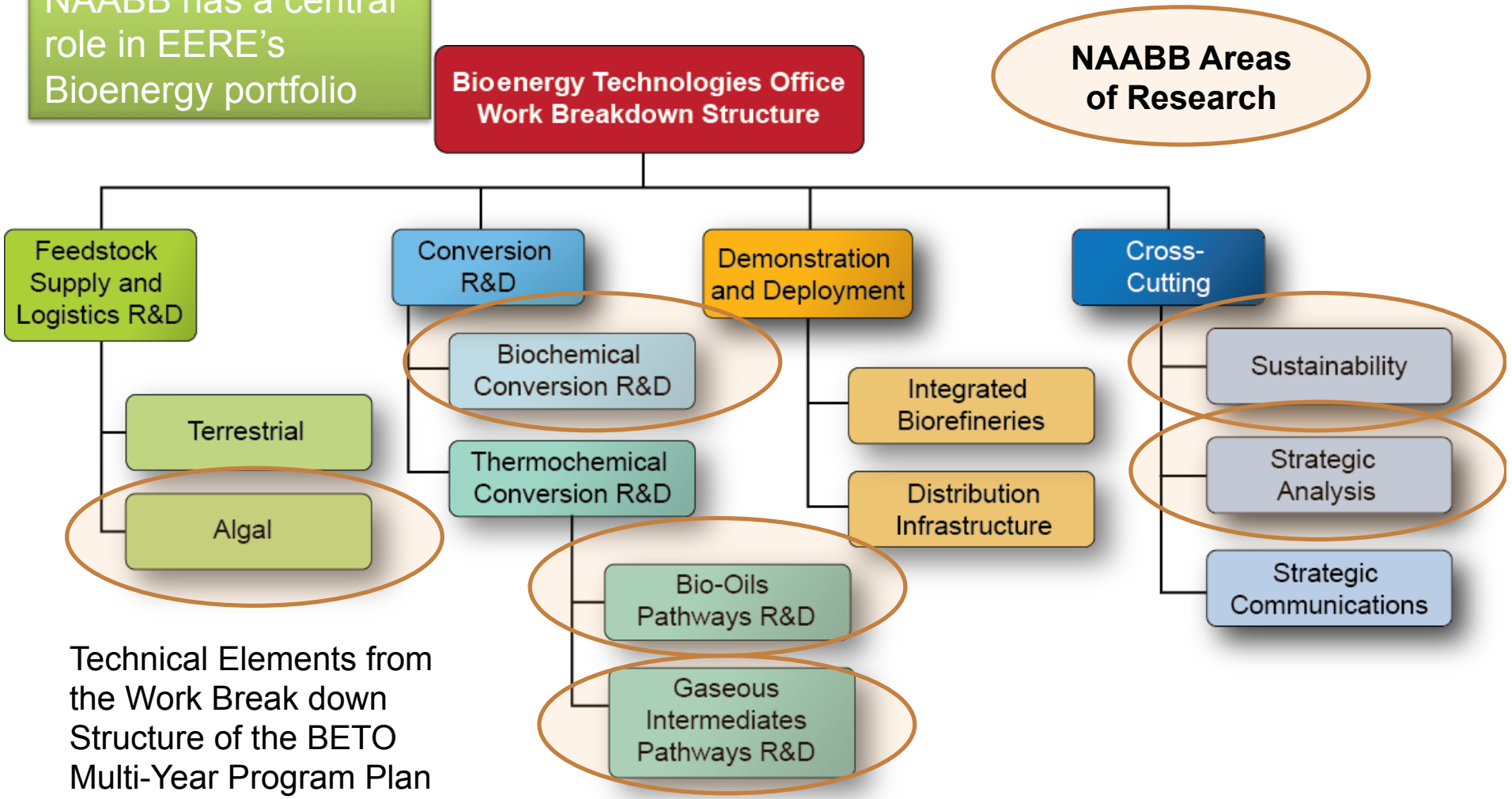
Peer Review
3 – Relevance
4 – Critical Success Factors
5 – Future Work and Summary

John Holladay and José Olivares

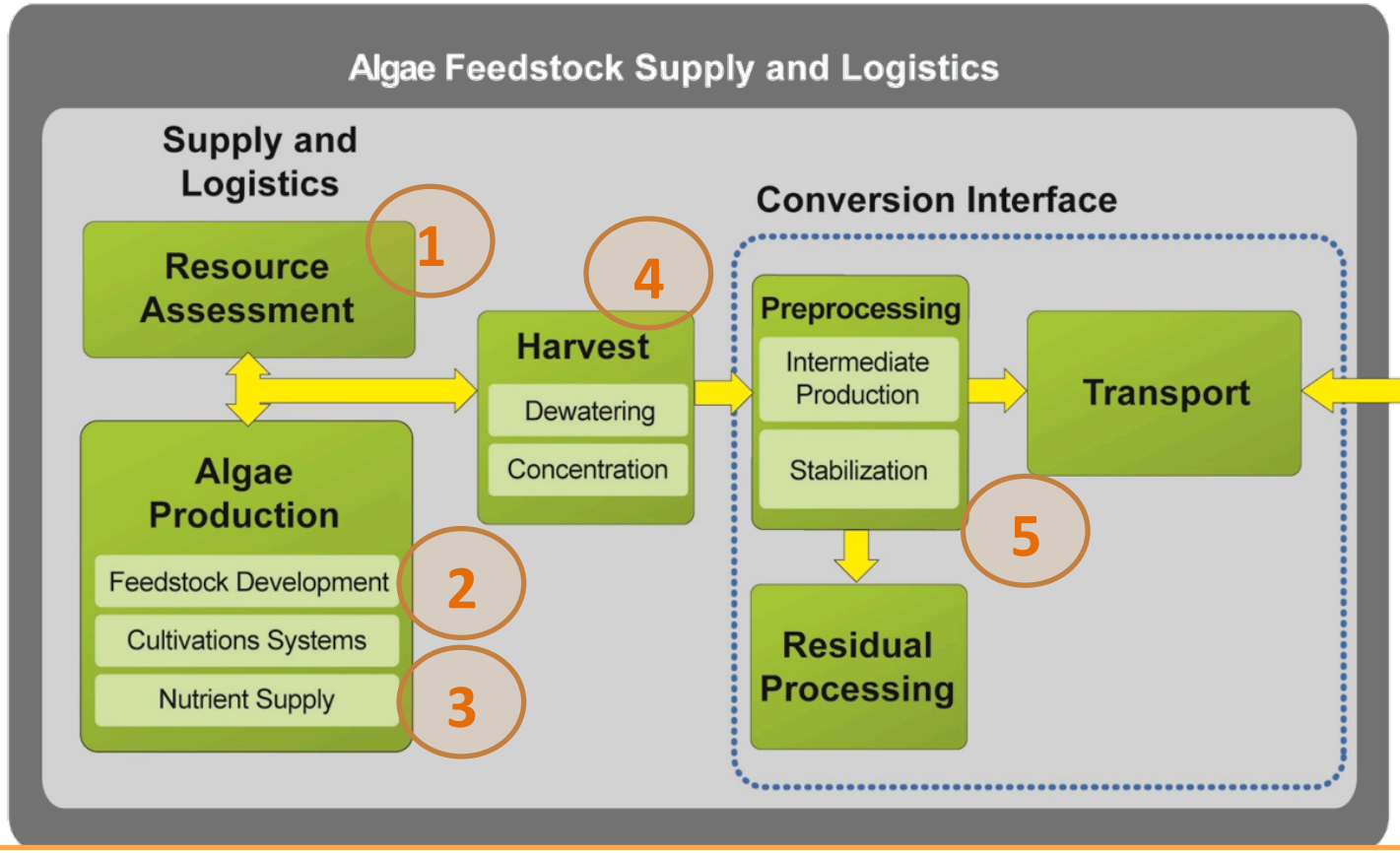
3- Relevance

NAABB has a central role in EERE's Bioenergy portfolio



Technical Elements from the Work Break down Structure of the BETO Multi-Year Program Plan (MYPP)

3- Relevance



From the BETO Multi-Year Program Plan (MYPP)

NAABB has…

1. Provided a detailed resource assessment through the AISIM BAT Module
2. Brought five new strains through the value chain (including outdoor cultivation)
3. Demonstrated the ARID cultivation (heat management) and low nutrient cost
4. Evaluated three new harvesting systems at larger scale
5. Combined extraction with conversion technology to reduce cost and demonstrated with NAABB produced algae (with high and low lipid content)

3- Relevance

National Alliance For Advanced Biofuels and Bio-products

ASPEN

Economic Sustainability

- Profitability
- Efficiency and productivity

APA

FARM

Social Sustainability

- Social acceptability
- Social well-being
- Energy security and external trade
- Rural development and workforce training

CGE

From the BETO Multi-Year Program Plan (MYPP)

BAT

GREET

Environmental Sustainability

- Climate
- Soil quality and agronomics
- Water quality and quantity
- Air quality
- Biological diversity

AISIM = NAABB Algae Integrated Simulation System

BAT	Biomass Assessment Tool	PNNL
GREET	Greenhouse gases, Regulated Emissions, and Energy Use in Transportation	ANL
FARM	Farm-level Algal Risk Model	TAMU
APA	Applied Production Analysis	NMSU
CGE	Computable General Equilibrium Global Simulation Model	TAMU
ASPEN	Aspen Tech Modeling Software	Various

Measures of Sustainability Generated by AISIM

- Risk Adjusted Profit
- Prob. of Success
- CAPEX/OPEX
- GHG Emissions
- Net Energy
- Land Use
- Marginal Cost
- Water Use Needs

AISIM Model covers elements from each of the sustainability pillars and provides an unique data set of algal sustainability that was not previously available

3- Relevance

- **NAABB is working to move technologies into commercial application through effective technology transfer…**
  - Capturing and licensing intellectual property
  - Peer review publications (as well as presentations)

NAABB team members have authored more than 65 original peer-reviewed research publications, filed 33 invention disclosures, spun one new company out, forged several international alliances, created a new peer-review research journal titled "Algal Research" established a new annual technical conference titled "International Conference on Algal Biomass, Biofuels and Bioproducts

4 - Critical Success Factors

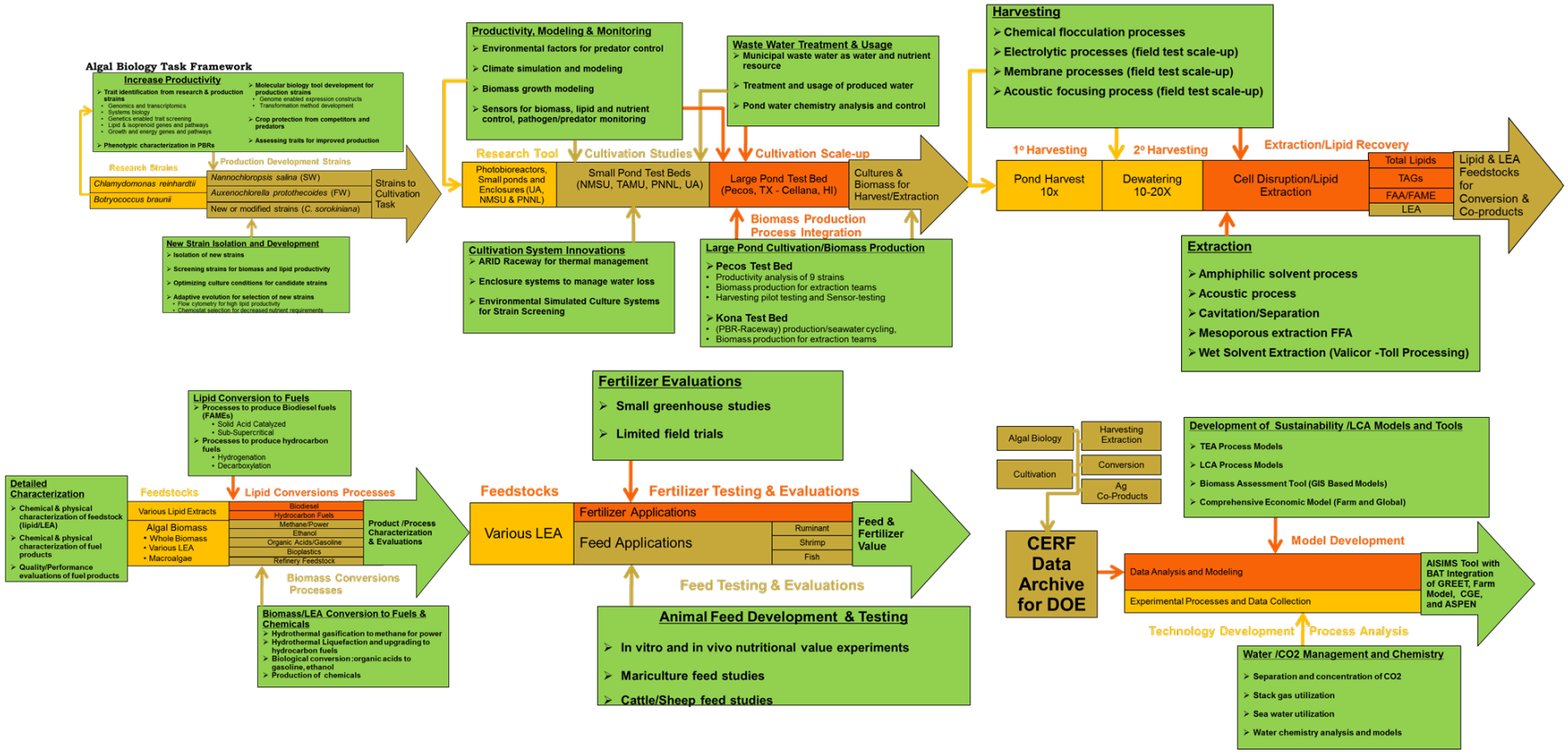
National Alliance For Advanced Biofuels and Bio-products

- **Technical Critical success factors**
  - Improve Biomass Productivity
  - Improve Extraction-Conversion Yield
  - Improve Cultivation-Harvesting Efficiency
- **Market and Business Critical Success Factors**
  - Combinations in reductions in CAPEX and OPEX needed in even the best scenarios
- **Top challenges (technical and non-technical) for achieving successful project results**
  - Combined 80 individual projects and 40 members into a unified consortium that address critical barriers
  - Developed Frameworks and Matrices that clearly communicate to each individual PI their role in the NAABB team structure
- **Demonstrate that success of the project advances the state of technology and positively impacts the commercial viability**
  - NAABB has taken the baseline technology, in which no combination of reduction of CAPEX and OPEX could led to commercial success to scenarios in which modest improvements have economic viability

4-Critical Success Factors

National Alliance For Advanced Biofuels and Bio-products

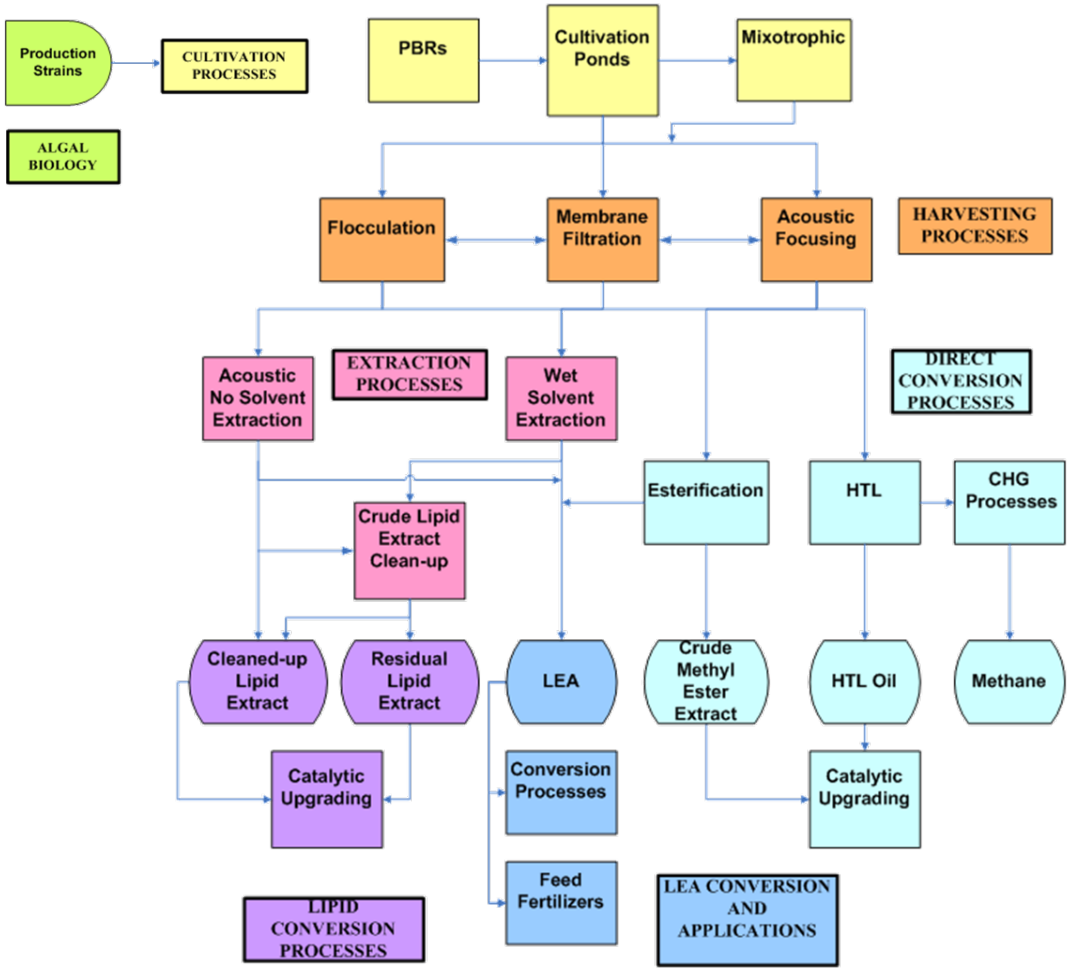
NAABB developed a framework that laid out the goals and format of the consortium so that each member clearly understood their role



4-Critical Success Factors

National Alliance For Advanced Biofuels and Bio-products

From the Process Framework we developed a Cross Cutting Matrix to examine all the ties between the six research areas (Framework)

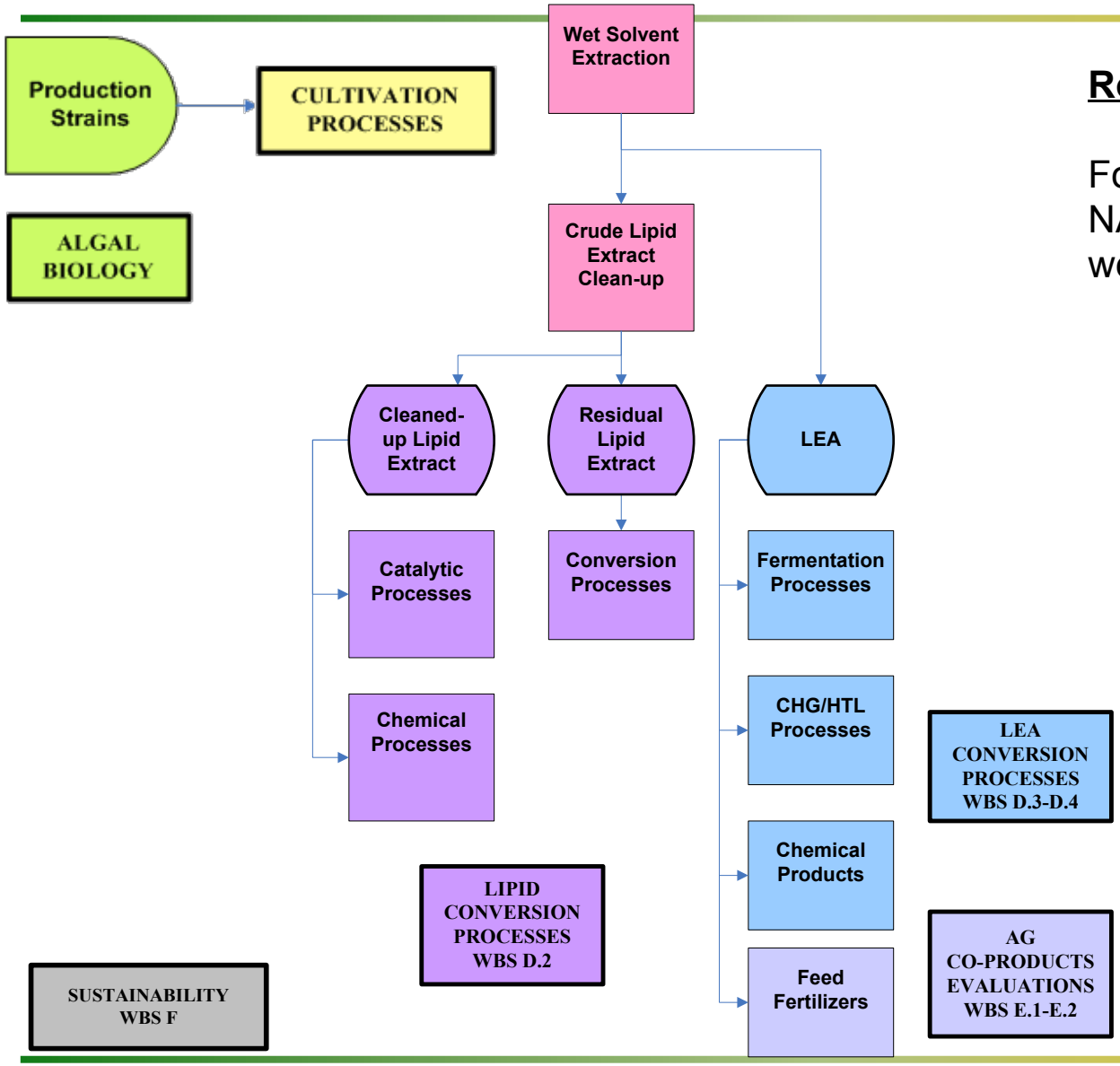


Role of Gap Analysis

Gap analysis of the matrix

- Allowed us to identify key cost drivers and how they impact technologies upstream and downstream
- We also learned where the consortium was missing key R&D elements

4-Critical Success Factors

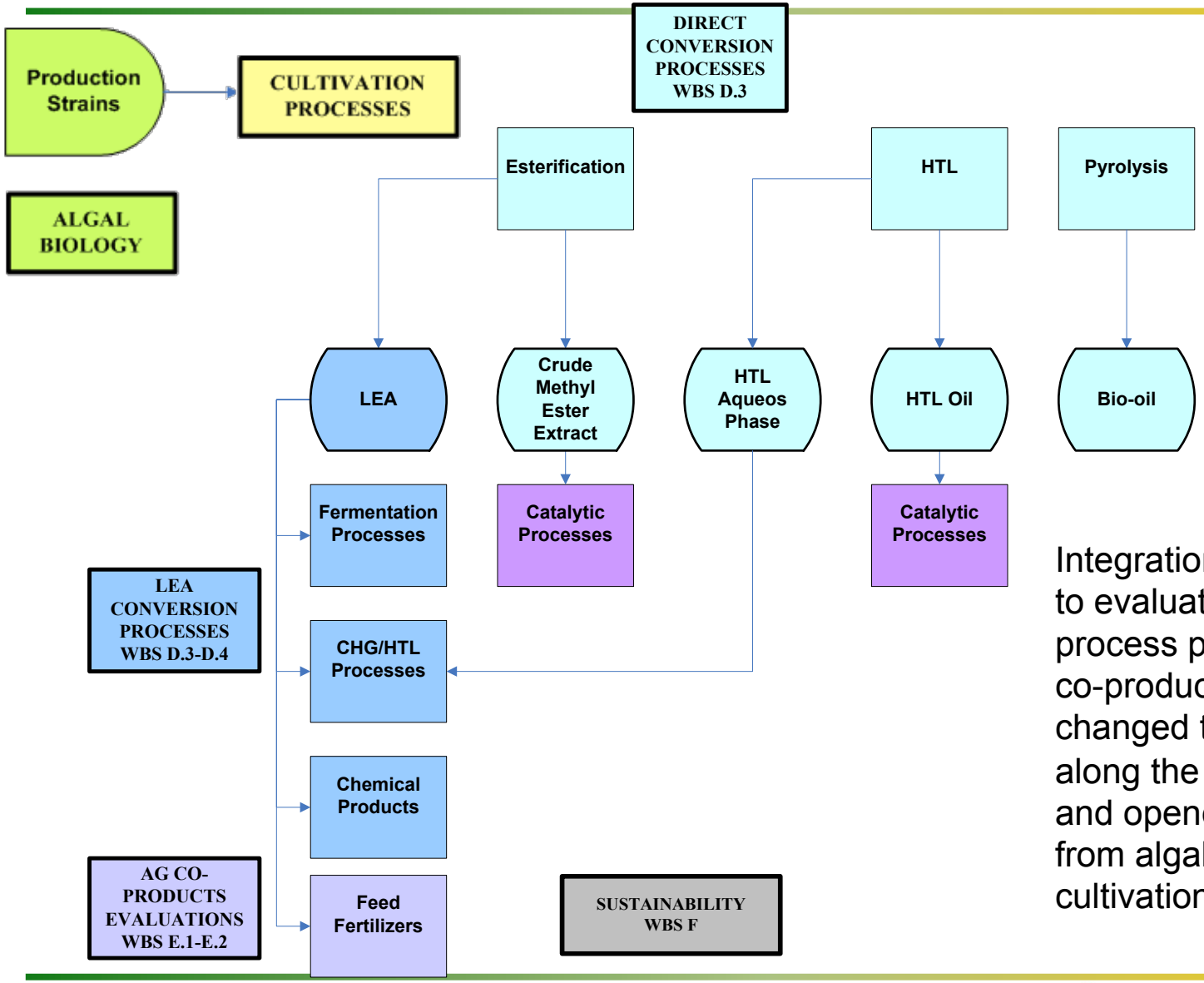


Role of Gap Analysis

For example, as we started NAABB, this is the model we were working toward…

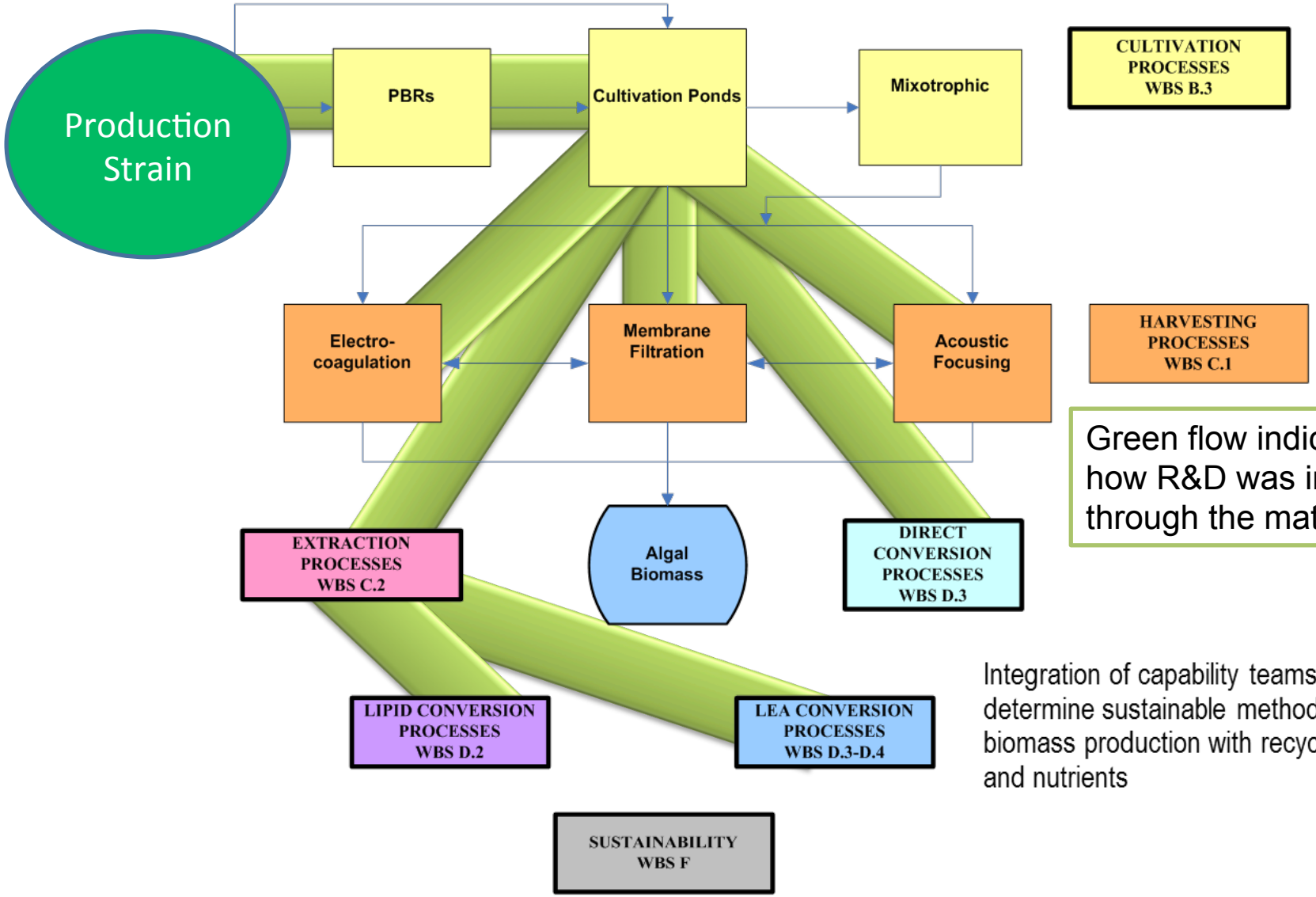
- Achieve high lipid efficiency
- Crude lipid extract clean-up proved too costly
- Through a gap analysis we added new technologies that combine extraction and conversion
- Similar analysis was done in the algal biology group to focus on traits and genes

4-Critical Success Factors



Integration of capability teams to evaluate alternative process pathways for fuels, co-products and nutrient changed the requirement along the entire value chain and opened up new options from algal biology through cultivation and harvesting

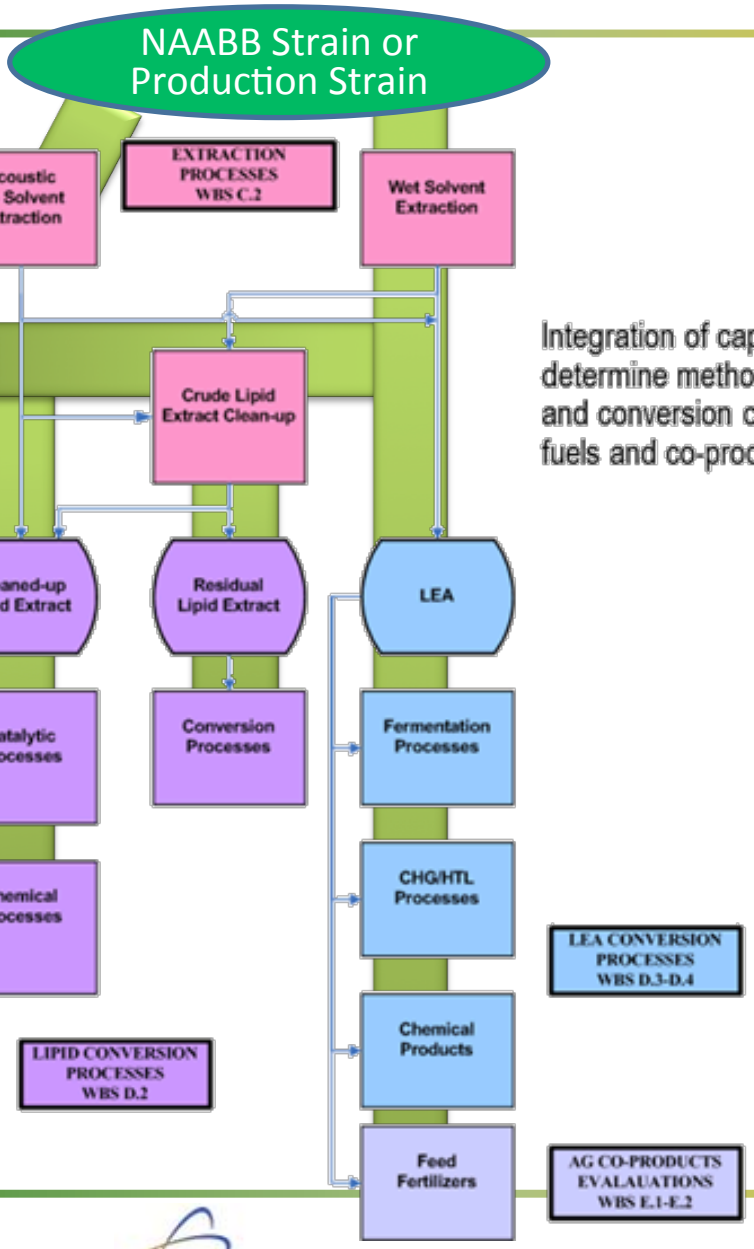
Cultivation/Harvesting/Water & Nutrient Recycling



Green flow indicates how R&D was integrated through the matrix

Integration of capability teams to determine sustainable methods for algal biomass production with recycle of water and nutrients

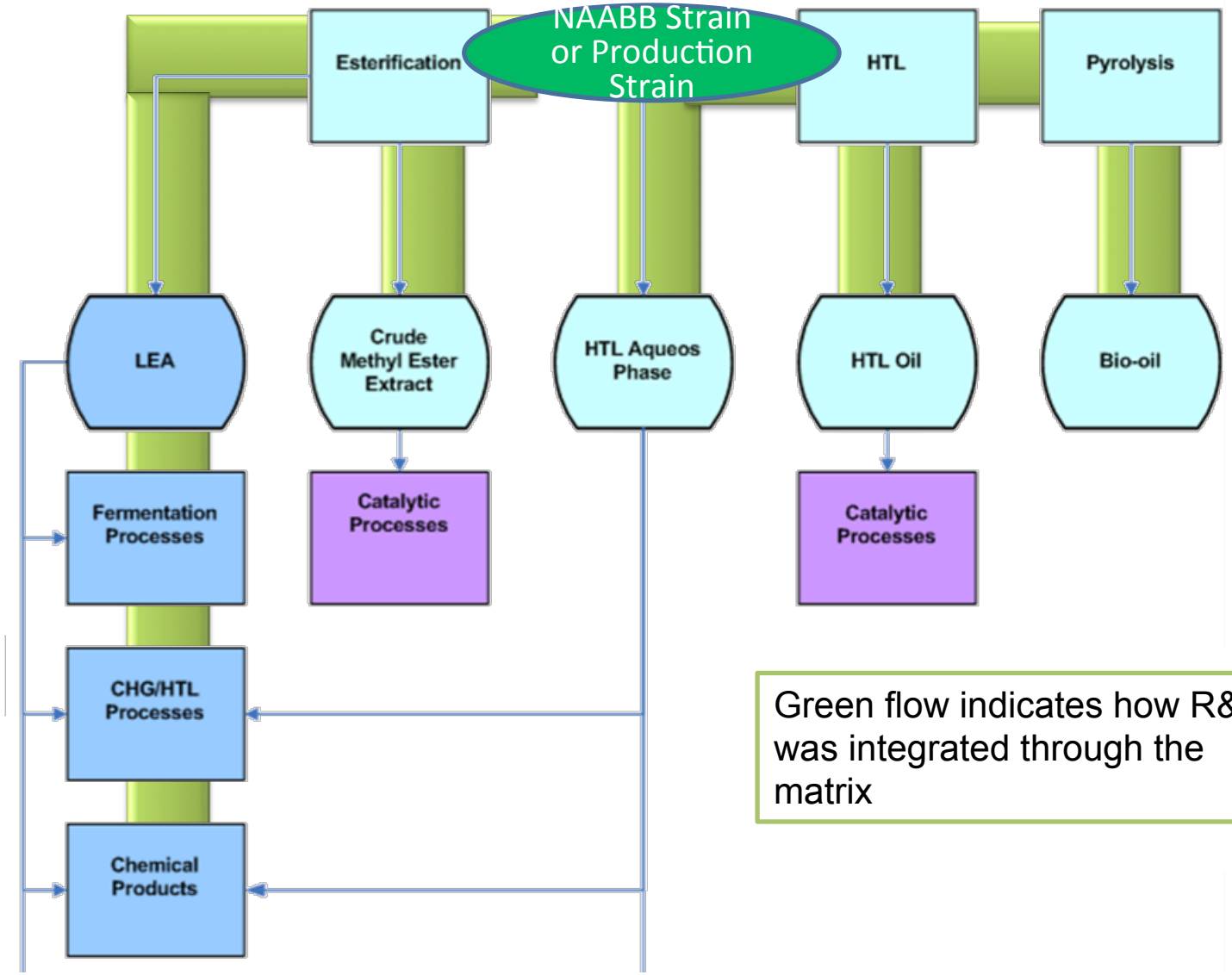
Extraction/Lipid Clean-up and Conversion



Integration of capability teams to determine methods for lipid, extraction and conversion of lipids/ LEA fractions to fuels and co-products and nutrient recycle

Green flow indicates how R&D was integrated through the matrix

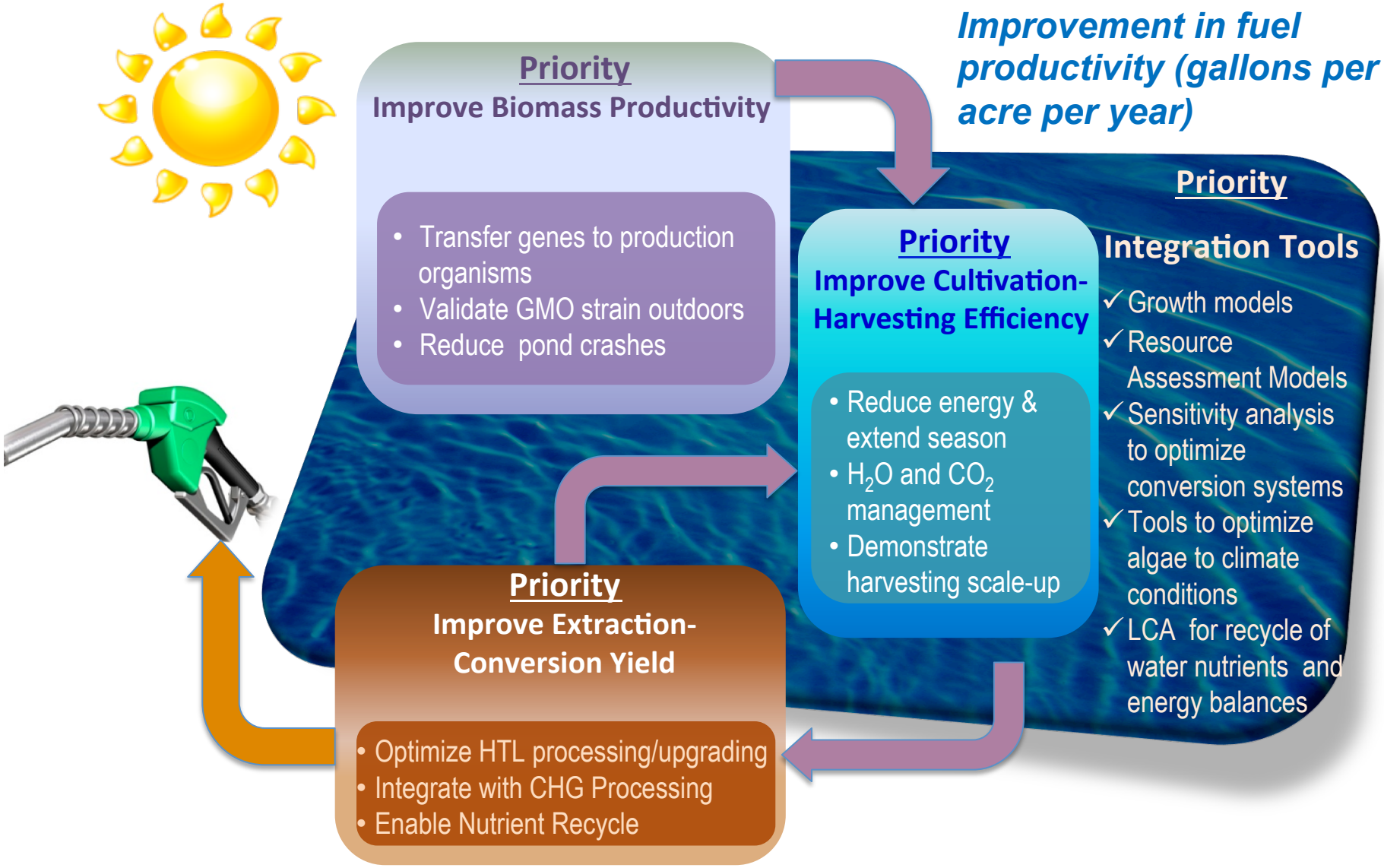
Direction Conversion to Fuels & Co-products



Green flow indicates how R&D was integrated through the matrix

4-Critical Success Factors

National Alliance For Advanced Biofuels and Bio-products



5. Future Work

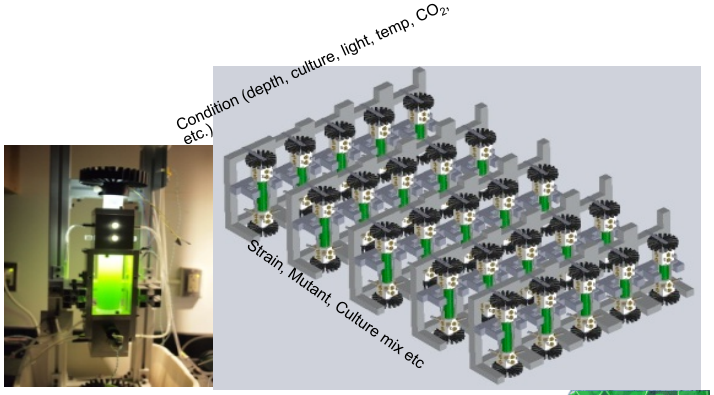
- **NAABB has successfully completed all of its DOE Milestones and Deliverables**
- **NAABB partners recently completed "wet research" portion**
- **Over the next 3 months we will continue to analyze data into the AISIM model and complete sustainability efforts**
- **The legacy of NAABB will be documented in our final report that detail improvements to the algal fuel enterprise**
  - A comprehensive evaluation of NAABB research
  - Aiming for a late summer public release
  - In addition:
    - Strains have been deposited in the UTEX library
    - NAABB partners are interacting with funding agencies and industry to carry forth the work initiated by EERE
    - Additional peer-reviewed publications (upstream, downstream and sustainability special topics in Algal Research)

Summary

- **NAABB has expanded the state of technology for algal-based advanced fuels:**
  - Developed an algal biology tool box for new strain transformation
  - Demonstrated new strains in large outdoor ponds and have taken the material through the entire process
  - Validated the use of lower cost media and impaired water
  - Improved cultivation methods with improved heat management, CO_2 and low energy mixing
  - Demonstrated 3 innovative harvesting technologies at larger scale
  - Converted NAABB derived algae through to fuels that hit specs
  - Developed the most comprehensive data set available on ag-coproducts
  - Demonstrated strong cost savings by combining unit operations for extraction and cultivation
  - Completed 6 scenario models that carefully examine the algal enterprise
- **NAABB partners have demonstrated the value of doing work in a comprehensive consortium able to connect all aspects of the value chain**

NAABB Accomplishments (as of May 5, 2013)

- **Over 150 presentations at national and international conferences**
- **>65 scientific publications**
- **Five theses**
- **New Journal: ALGAL RESEARCH (by Elsevier)**
- **New Conference Series: *International Conference on Algal Biomass, Biofuels and Bioproducts***
- **Deposited 30 most productive algae strains into UTEX culture collection**
- **33 Intellectual Property Disclosures**
  - Molecular biology tools – 10
  - Cultivation – 5
  - Harvesting and Extraction – 7
  - Fuel conversion – 8
  - Co-products and other – 3
- **New company: *Phenometrics***



3rd International Conference on

Algal Biomass, Biofuels and Bioproducts

16 - 19 June, 2013 - The Sheraton Centre Toronto Hotel, Toronto, Canada

Supporting publication

Conference Chair

José A. Olivares

Los Alamos National Laboratory, Los Alamos, USA

Richard Sayre

Los Alamos National Laboratory, Los Alamos, USA

René Wijffels

Wageningen University, The Netherlands

Visit Journal home page:
www.elsevier.com/locate/algal

Visit conference website:
www.algalbbb.com

NABB Vision and Targets

National Alliance For Advanced Biofuels and Bio-products

The NAABB will develop technologies for cost-effective production of algal biomass and lipids, economically viable fuels and co-products, and provide a framework for a sustainable biofuels industry.

Process Economics Drivers

- < $2.10 /gal of lipid
- Operating cost
  $0.40/gal processing cost (oil)
- Capital Cost (Industry benchmarks for oil)
  $1/annual gallon installed capacity (biodiesel)
  $2/annual gallon installed capacity (green diesel)

Productivity Targets

- >50% lipid content at harvest
- >20 g/m^2/day productivity (open system)
- 5g dw/l yield (closed system)

Harvesting and Extraction Targets

- 5,000 gal/day processing for harvesting unit
- 15 gal/day lipid extraction capacity per unit

Co-product Targets

- LEA feed value $250-1000 /ton

Sustainability

- Reduced CO_2 Emissions
- Water usage: less than 0.75 gal H_2O / gal fuel
- Nutrient recycle
- LEA: 90% recycle nutrients
- Energy required for conversion is 10% or less of energy in fuel
- Energy Return on Investment (>> 1)

How did we do?

The NAABB will develop technologies for cost-effective production of algal biomass and lipids, economically viable fuels and co-products, and provide a framework for a sustainable biofuels industry.

$6.03 ($2.86 with reduction in CAPEX & OPEX)

$27 total capital/annual gal for entire process ($16 total capital/annual gal with reductions)

Process Economics Driv

< $2.10 /gal of lipid

- Operating cost
  $0.40/gal processing cost (oil)
- Capital Cost (Industry benchmarks for oil)
  $1/annual gallon installed capacity (biodiesel)
  $2/annual gallon installed capacity (green diesel)

Capture 59-85% of carbon in usable form

$1.6 total capital/annual gal for HTL extraction / conversion to crude

15 g/m^2/day open

Productivity Targets

- >50% lipid content at harvest
- >20 g/m^2/day productivity (open system)
- 5g dw/l yield (closed system)

demonstrated

Harvesting and Extraction Targets

- 5,000 gal/day processing for harvesting unit
- 15 gal/day lipid extraction capacity per unit

Co-product Targets

- LEA feed value $250-1000 / ton

LEA feed value $160 - $350 / ton

Sustainability

- Reduced CO_2 Emissions
- Water usage: less than 0.75 gal H_2O / gal fuel
- Nutrient recycle
- LEA: 90% recycle nutrients
- Energy required for conversion is 10% or less of energy in fuel
- Energy Return on Investment (>> 1)

Thanks

We gratefully acknowledge funding from EERE's Bioenergy Technologies Office

NAABB Agenda For Peer Review Meeting

Introduction to the NAABB Program and Team – *José A. Olivares*

1. **Approach: The NAABB Framework** – *Dan Anderson*
2. **Technical Accomplishments/Progress/Results from NAABB**
   - UPSTREAM Technologies – *Dick Sayre*
     - Algal Biology and Cultivation
   - DOWNSTREAM Technologies – *Kim Ogden*
     - Harvesting and Extraction; Conversion; Coproducts
   - SUSTAINABILITY Efforts (TEA/LCA) – *James Richardson*
     - Algal Integrated Simulation Modeling System
     - Sustainability Scenarios

Summary – *John Holladay*

3. **Relevance**
4. **Critical Success Factors**
5. **Future Work and Summary**

Click line to move to next presentation