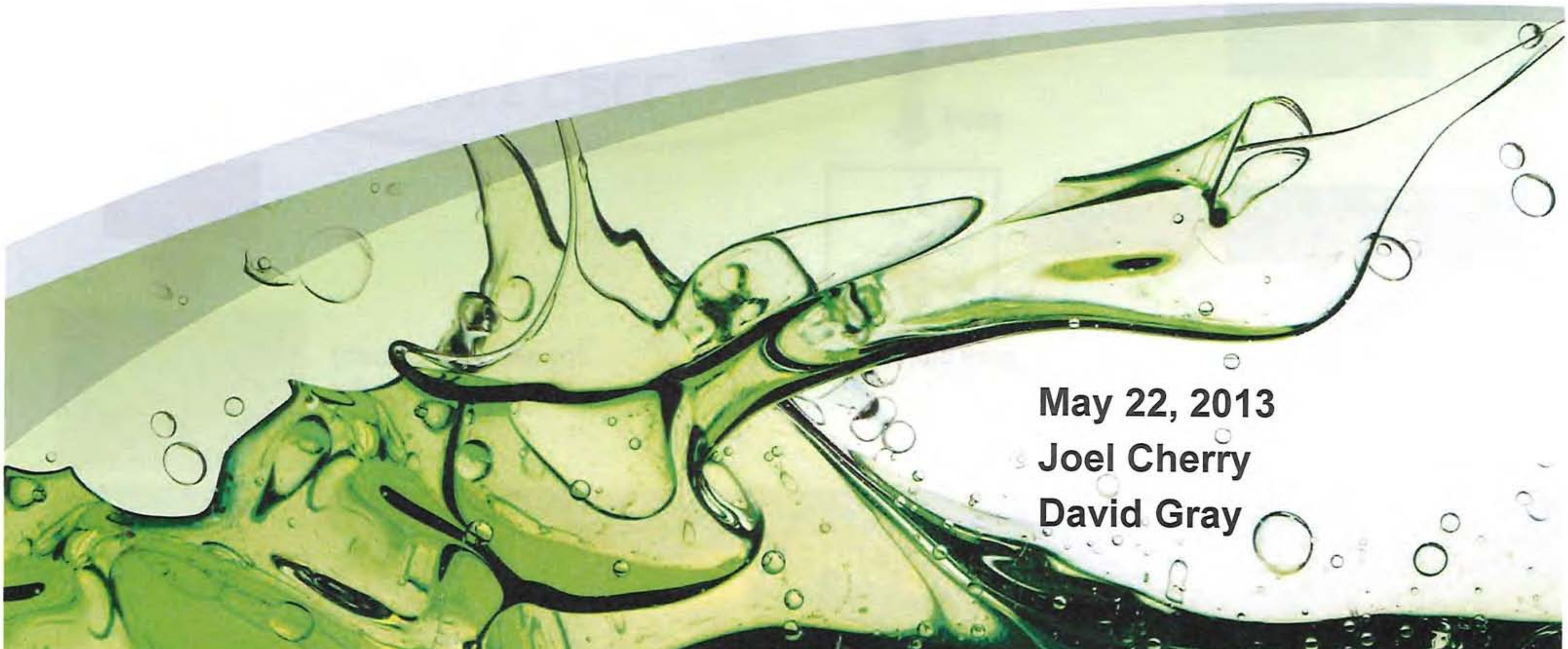
AMYRIS

2013 DOE Bioenergy Technologies Office (BETO) IBR Project Peer Review

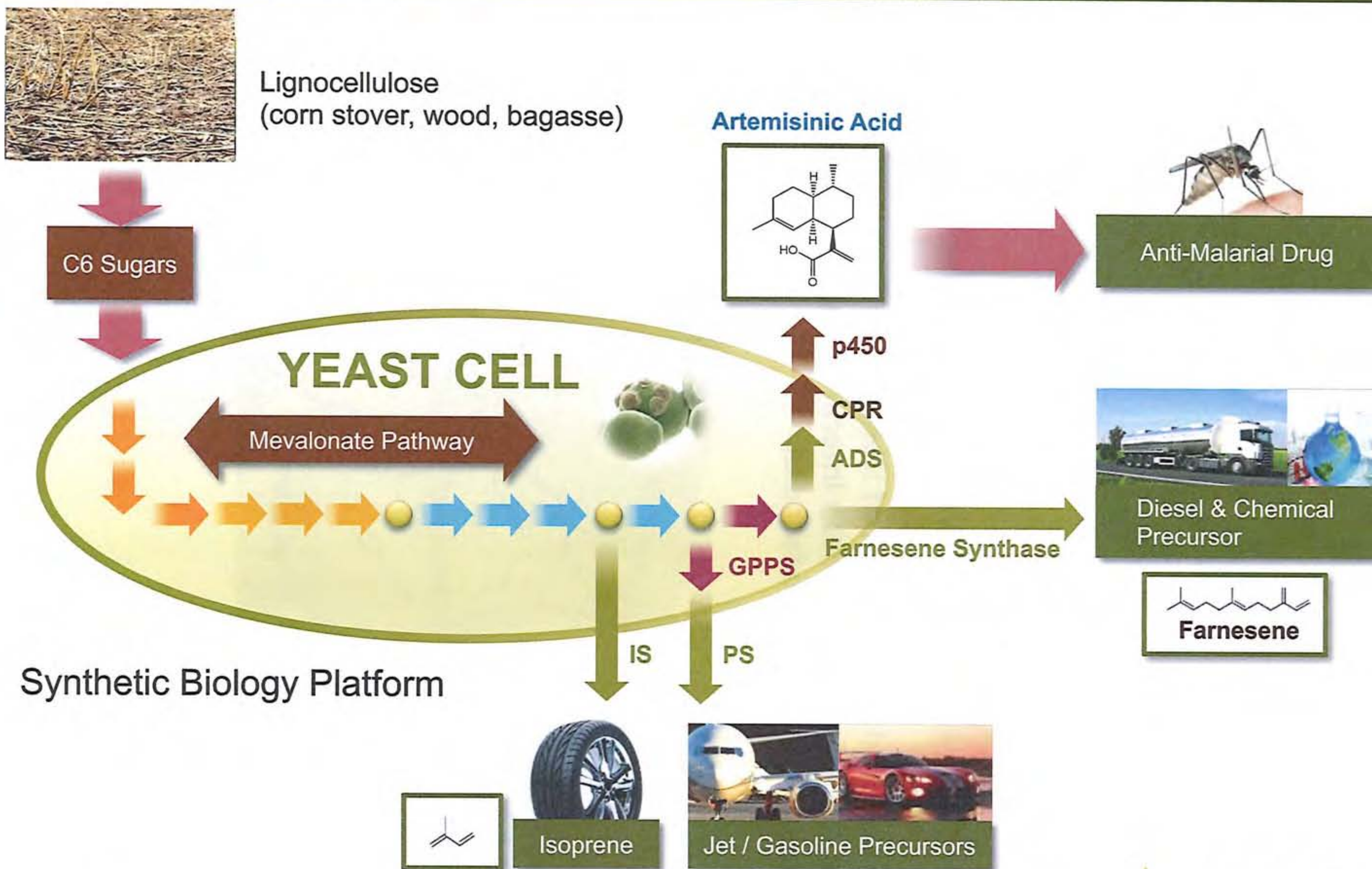
Scale-up and Mobilization of Renewable Diesel and Chemical Production from a Common Intermediate using US-based Fermentable Sugar Feedstocks



May 22, 2013

Joel Cherry
David Gray

Amyris:
A renewable products company focused on high-impact products

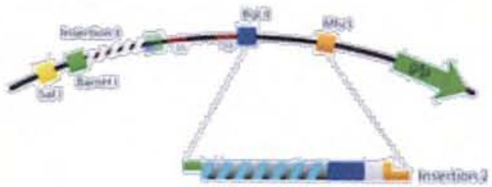


Synthetic Biology Platform

Technology: Industrializing Synthetic Biology

Traditional Construction

1 Planning



2

Manual Construction

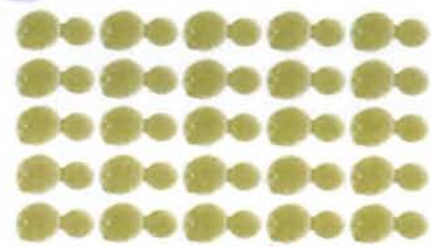
3 **20 strains/week**

Amyris Construction

1

2 Robotics Platform

3 **350 strains/week**



AMYRIS

Completed and operating plant in Brotas, Brazil

Amyris Brotas Production Facility

AMYRIS

Integration, by pipeline

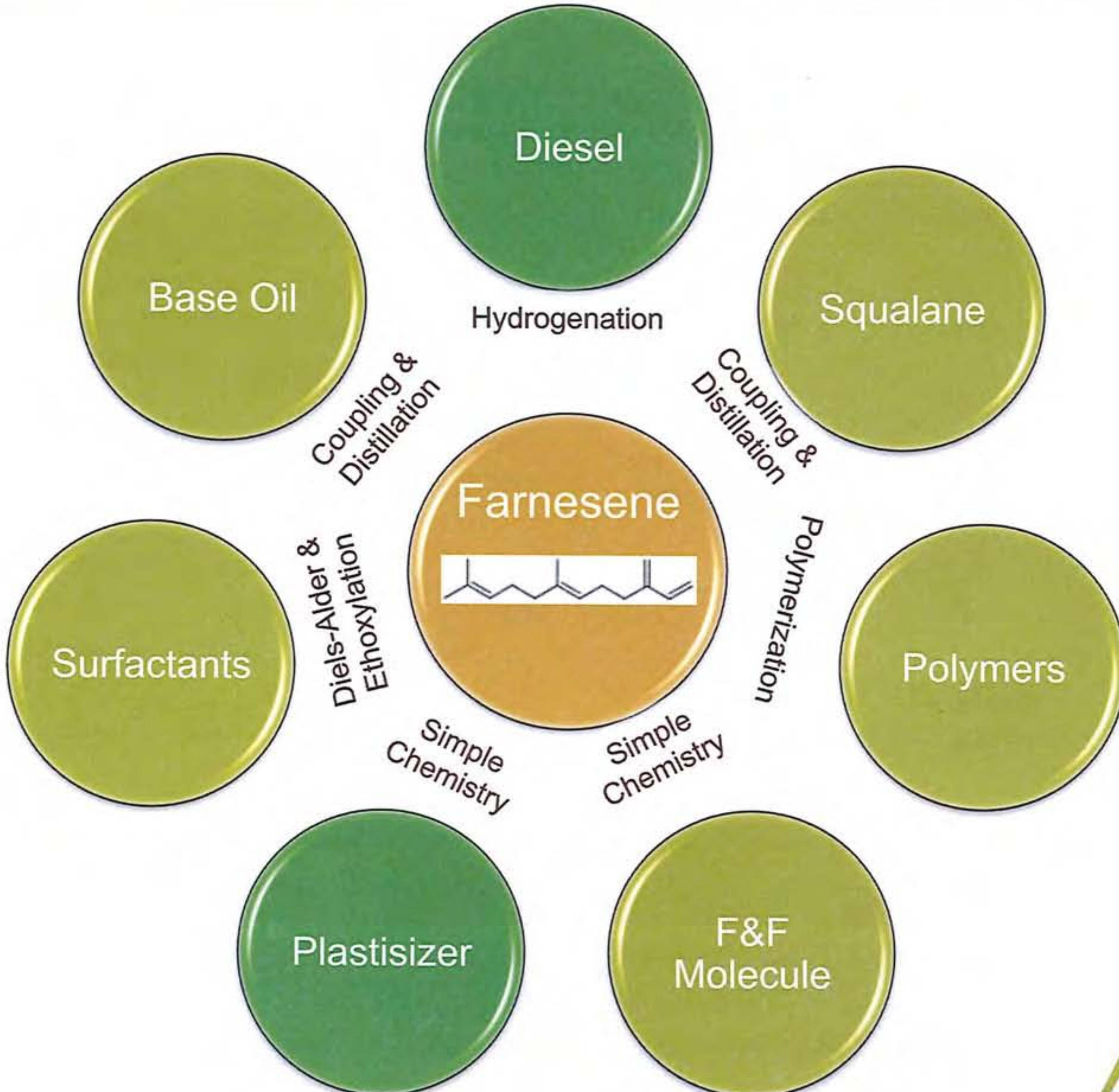
AMYRIS

Amyris Brotas plant operating to plan, producing farnesene

First Biofene™ tanker shipment
27 December 2012

AMYRIS

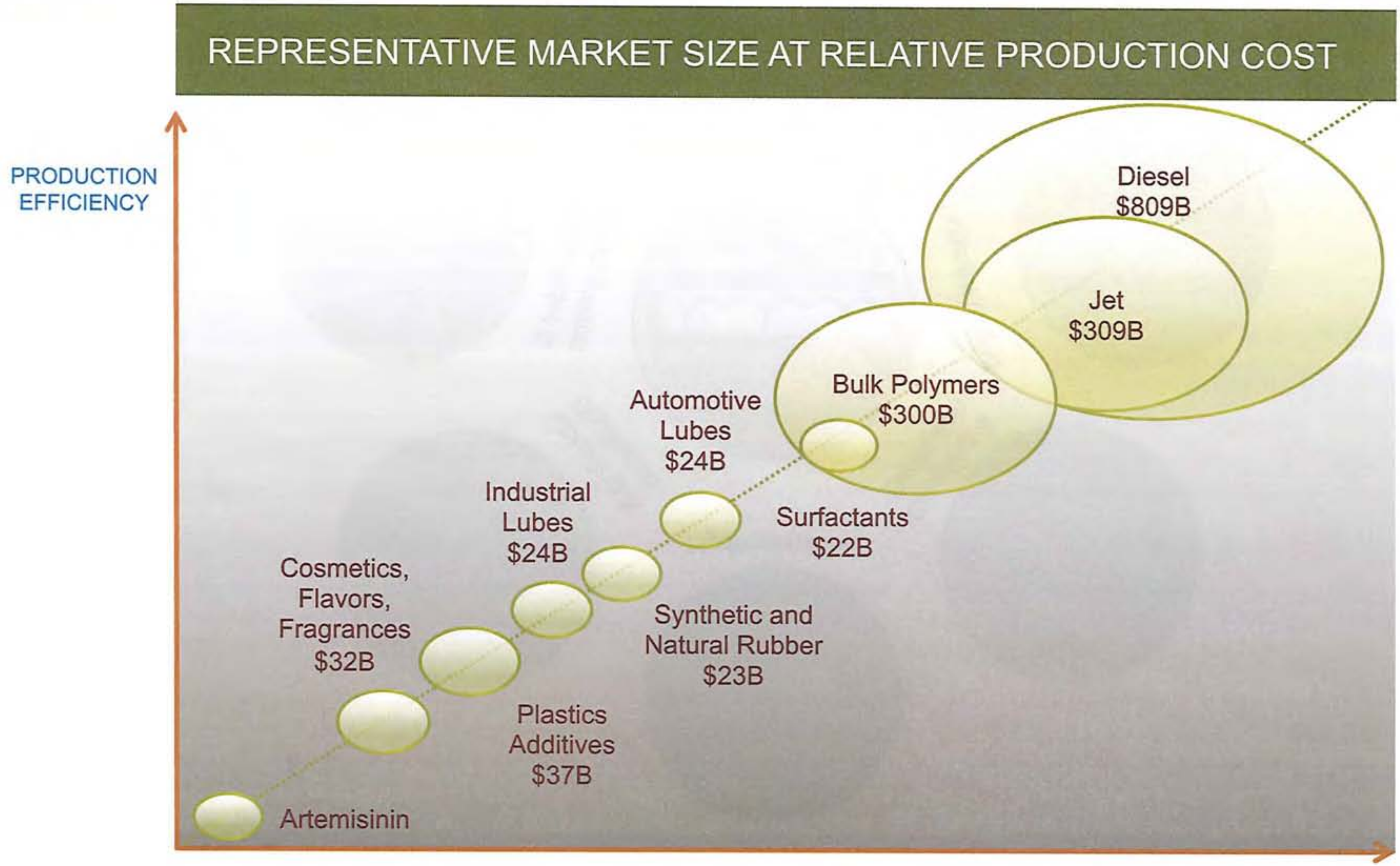
Farnesene: a chemical feedstock for known chemistry



AMYRIS.

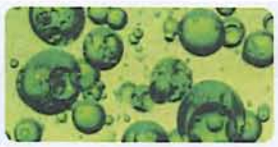
General Overview

Expansion of addressable markets with technology improvement



AMYRIS

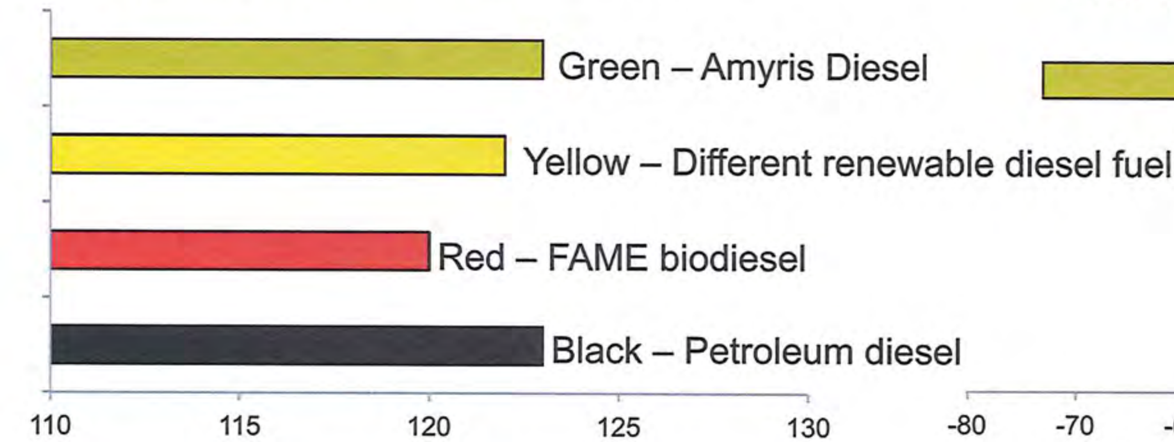
Farnesene Value Creation through Diversified Product Slate

		Products	Customers & Partners
Fuels		Diesel Jet	TOTAL, Mercedes-Benz, MAN, GE Aviation, BR, Cummins, EMBRAER, Azul
Lubricants		Base Oils Industrial Lubricants Passenger Car Motor Oil	cosan, novvi
Home & Personal Care		Surfactants Other Ingredients	P&G, wilmar, method detox your home
Polymers & Plastic Additives		Oxygen Scavengers Fene-Based Liquid Polymers	M&G Gruppo Mossi & Ghisolfi, kuraray
Flavors & Fragrances		Ingredient #1 Ingredient #2	Givaudan, IFF, Firmenich
Cosmetics		Squalane	NIKKOL, CENTERCHEM, INC., Laserson

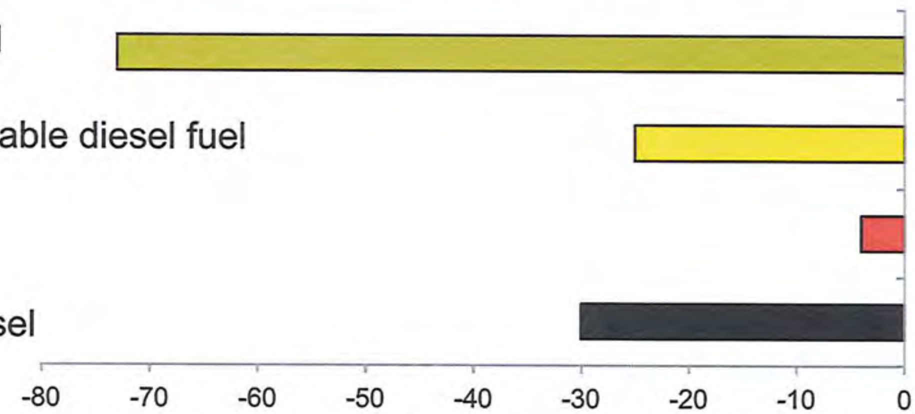
AMYRIS

Product performance is a key driver for diesel adoption

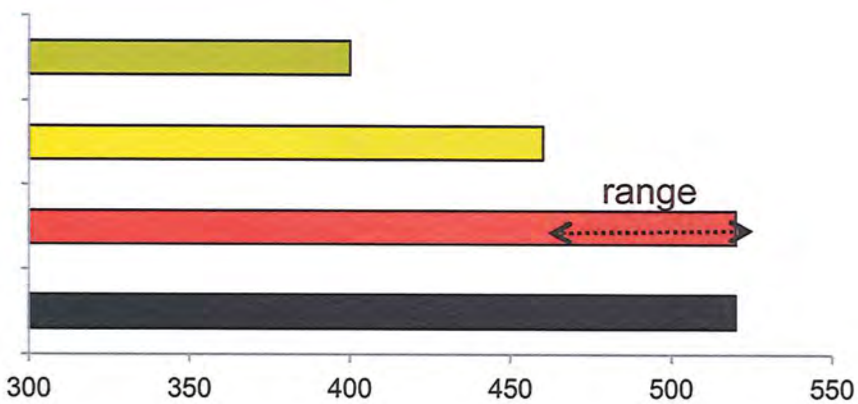
Energy Density (1000 x btu/gal)
Higher for increased fuel economy



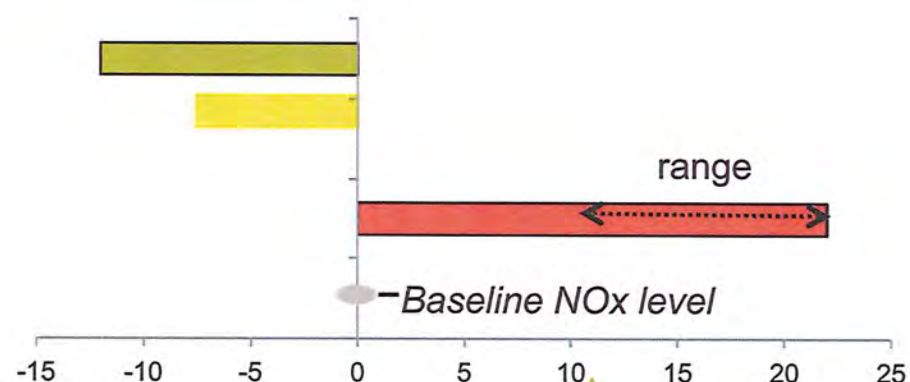
Cold Filter Pour Point (°C)
Lower for improved cold operation



Lubricity (μ)
Lower for decreased engine wear



Engine Emission Impact (NOx)
Lower for environmental and health benefits



AMYRIS

Amyris Fuels São Paulo Buses

- City buses in São Paulo, Brazil are fueled with Amyris renewable diesel derived from sugarcane (known locally as Diesel de Cana™)
- The buses run on a blend of Amyris renewable diesel, with the balance made up of biodiesel and petroleum diesel supplied by Petrobrás Distribuidora

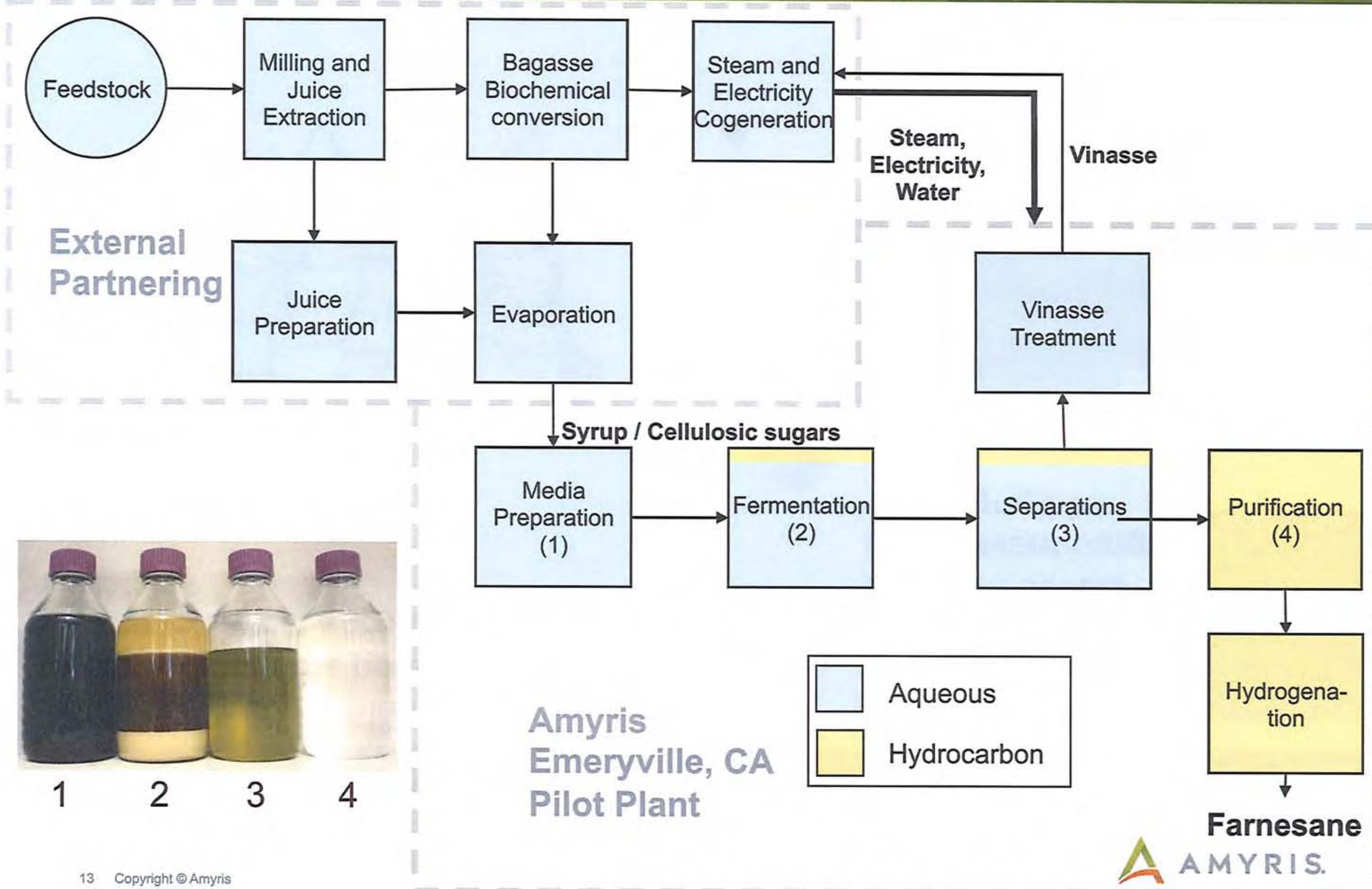
AMYRIS.

First Jet Flight Using Amyris Biofuel

- Project "Azul+Verde" ("a greener blue" in Portuguese) fueled an Embraer E195 jet operated by Azul with Amyris biofuel, 10% blend
- Jet flew from Campinas, Brazil, to Rio de Janeiro during U.N. Conference for Sustainable Development (Rio+20) in June 2012
- Amyris partnered with GE Engines, Embraer, and Azul Airlines
- Next test flight: Paris Air Show, June 2013

AMYRIS.

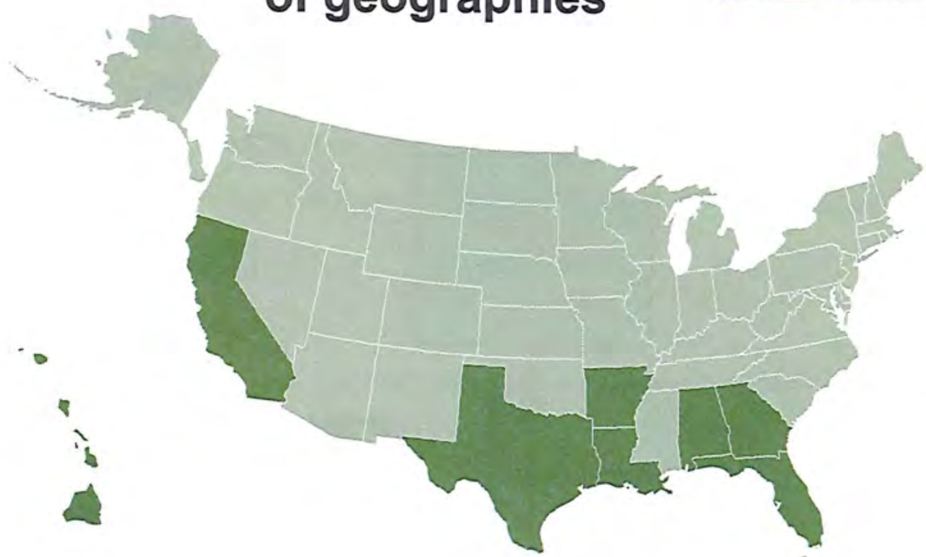
Project Description – Process Overview



IBR - potential for scaling sweet sorghum in the US

Projected geographies and yields indicate the potential for Ceres' sweet sorghum varietals

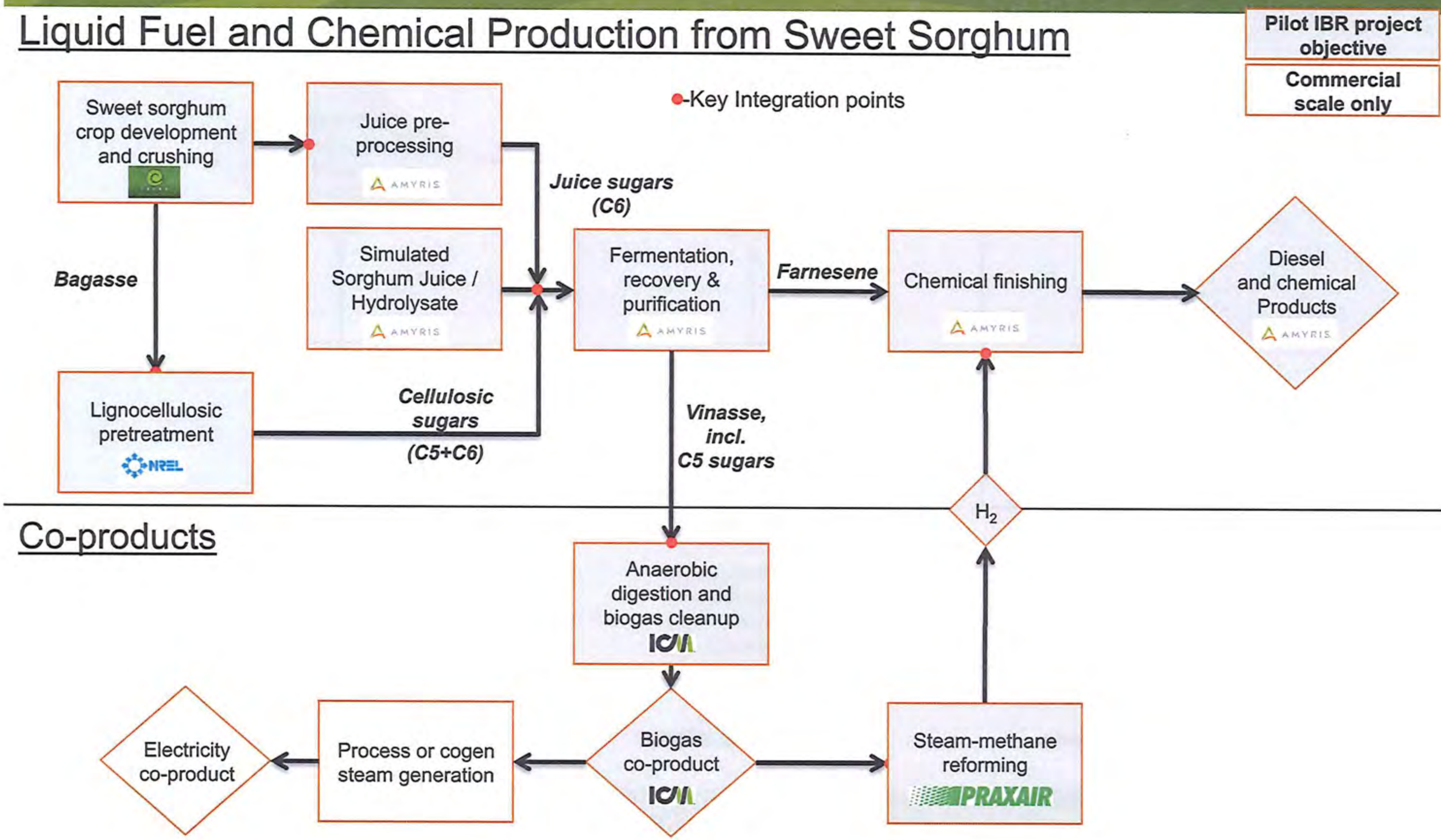
Ceres' planned and existing sweet sorghum trial footprint covers the relevant range of geographies



Project Overview

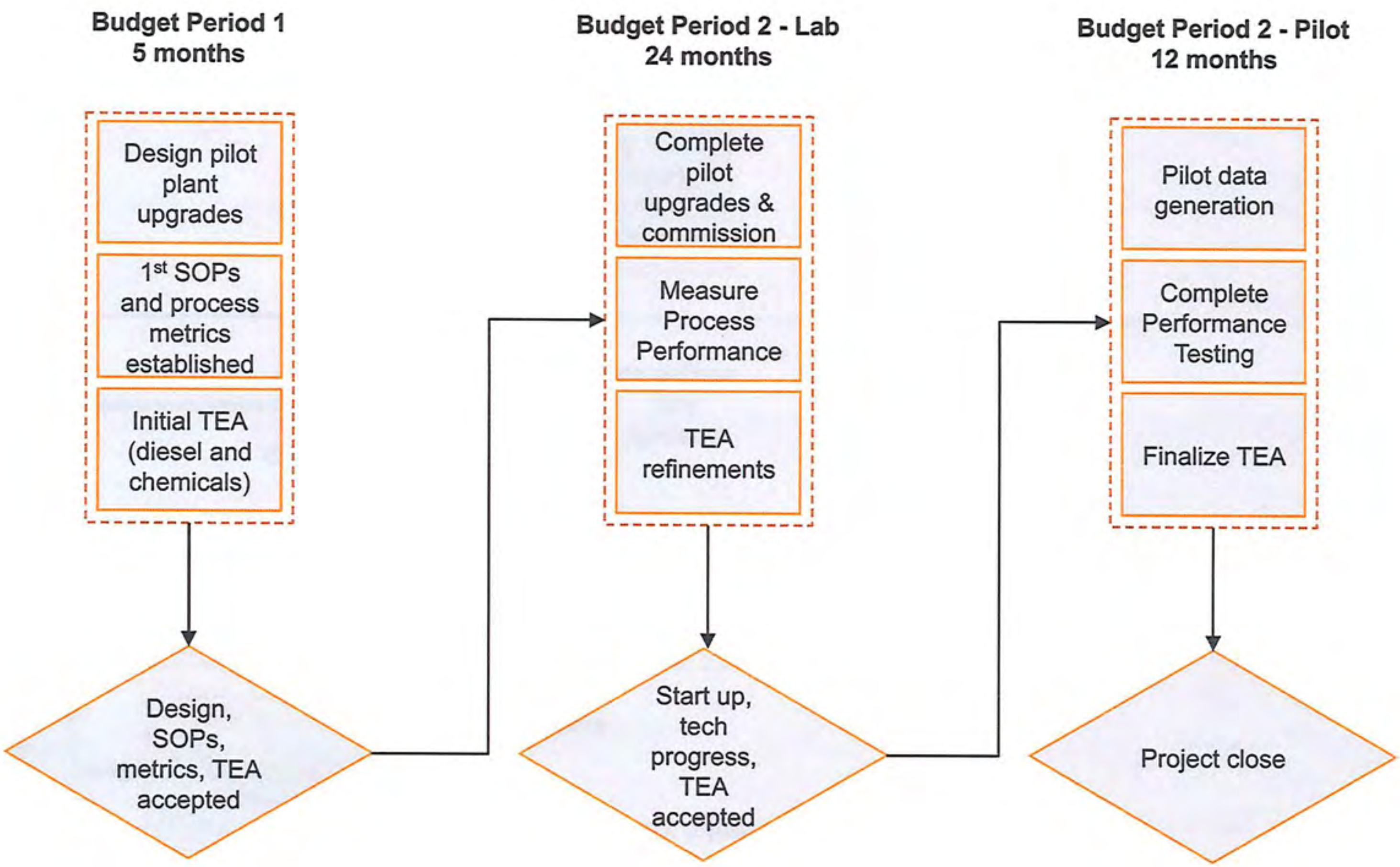
Pilot integration for sweet sorghum-based production

Liquid Fuel and Chemical Production from Sweet Sorghum



AMYRIS

Amyris-DOE IBR:
Stage gates and decision points



AMYRIS

Quad Chart Overview

Schedule

Activity	Planned	Actual
Budget Period 1	01/01/10-05/31/10	12/28/09-04/21/10
Budget Period 2	06/01/10 - 06/30/12	04/22/10-06/30/13 (est)
Mechanical Turnover	09/10/10	09/10/10
Start-up	10/15/10	10/15/10
Commissioning (Fermentation)	11/08/10	01/15/11
Commissioning (DSP)		04/30/11

- Project is 95% complete

Budget

- Total project funding: $35.5MM
  - DOE share: $25MM
- Funding Received – April, 2013: $23,438,366 ARRA

Project Development

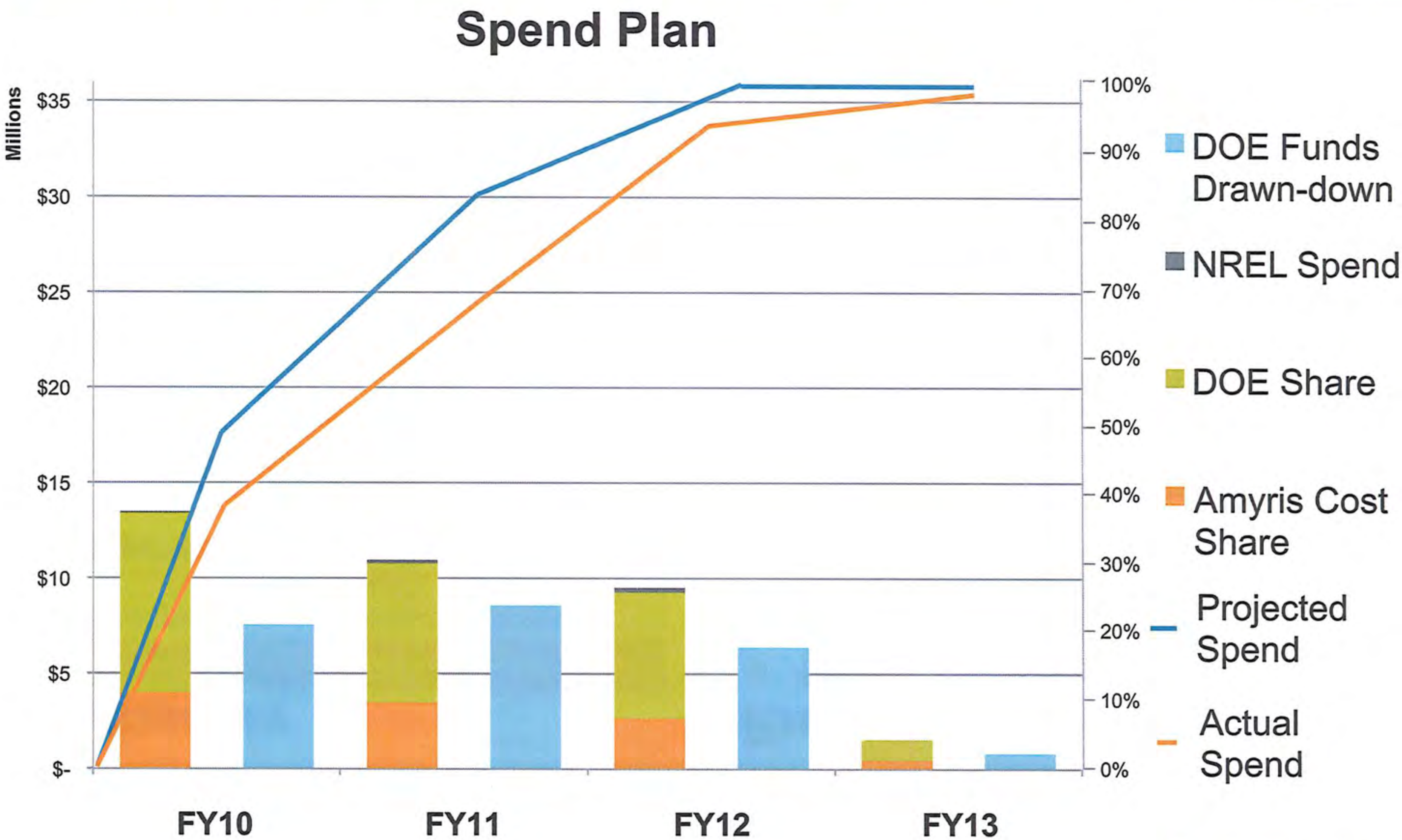
- Project utilized two no-cost extensions to complete evaluations of cellulosic feed stocks (mitigating supply delay)
- Project is on track, ending 6/2013
- Alternative chemistry demonstrated with plasticizer

Project Participants

- Dome Construction (GC)
- Ceres (sweet sorghum growth and processing)
- NREL (pretreatment)
- ICM (anaerobic digestion)
- Praxair (biogas cleanup and SMR)

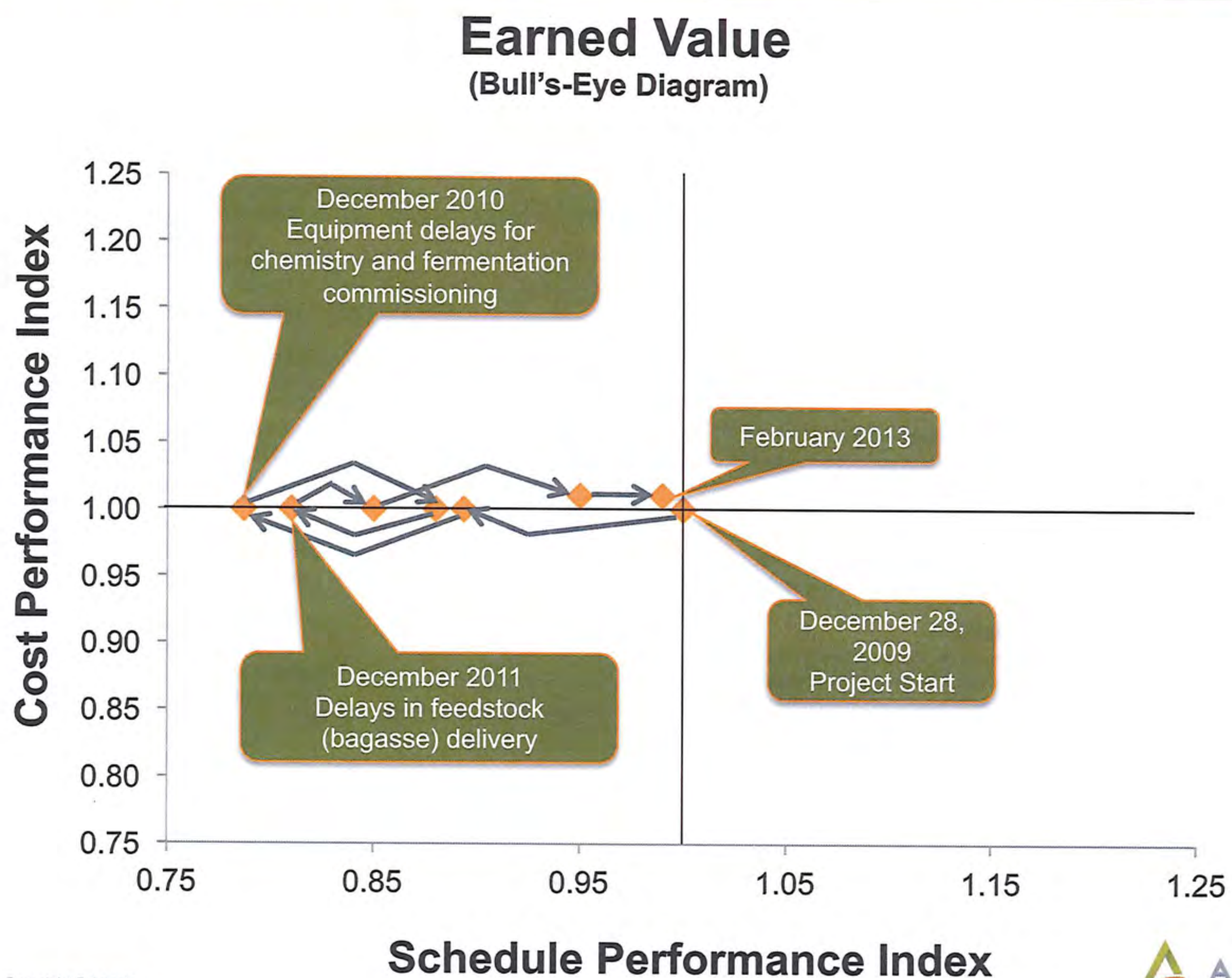
AMYRIS

Cost and Schedule Performance



AMYRIS.

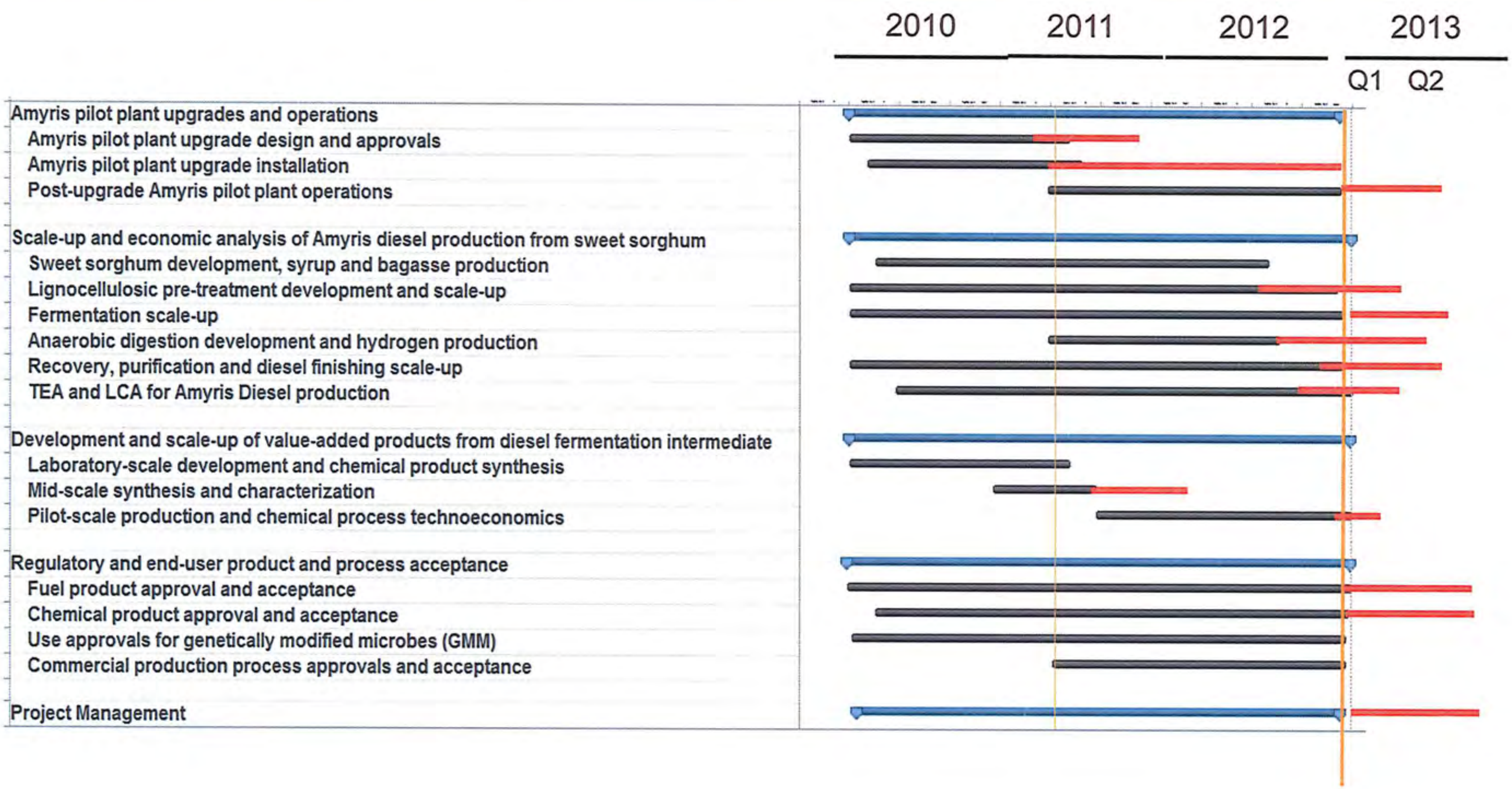
Cost and Schedule Performance



AMYRIS

1B Company Structure and Project Management – Performance Against Baseline

Progress against PMP – level 2 tasks



No formal baseline changes – tracking performance and variance (sub-tasks in red above) relative to original PMP schedule

AMYRIS

1 – Project Management

- WBS followed, Amyris supplies Project Manager
- "Virtual" Integration, leveraging expertise of many partners:
  - Ceres: Sweet Sorghum cultivation
  - NREL: Cellulosic Pretreatment
  - Amyris: Fermentation to Hydrocarbons and post-processing
  - ICM: Anaerobic Digestion
  - Praxair: Steam-Methane Reforming
- Materials sent from partner to partner according to schedule
- Capital expenditures an expansion of previously existing pilot facilities
  - Doubling of fermentation capacity
  - Additional upstream and downstream process equipment

AMYRIS

1 – Project Management (cont.)

- Experimentation performed with simulated feedstreams as well as feedstreams from actual biomass sources
- Go/no-Go decision points focused around construction and environmental impact reports
- Project divided into five subareas:
  - Task A: Pilot Plant upgrades and operations
  - Task B: Scale-up and economic analysis of Amyris diesel production from sweet sorghum
  - Task C: Development and scale-up of a value-added product (plasticizer) from farnesene
  - Task D: Regulatory and end-user product and process acceptance
  - Task E: Project Management

AMYRIS

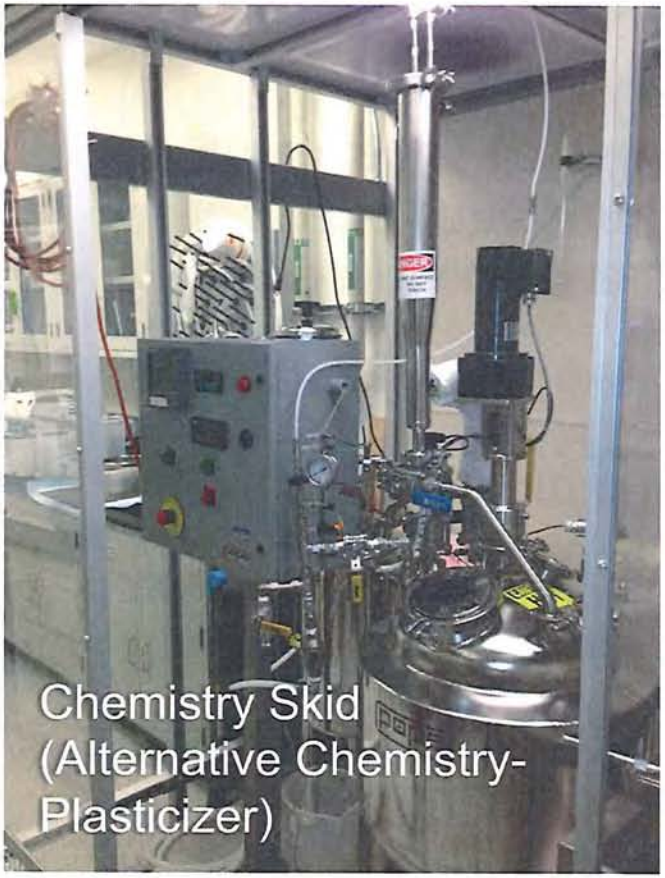
Task A : Pilot Plant Upgrades and Operations

- Facility expansion completed July 2010
- Additional 300L (2) fermentors installed and commissioned Dec 2010
- Chemistry reactor and flash distillation skids installed Aug 2011
- Added direct steam HTST system (replacing indirect HTST sterilizer) Sept 2012
- Pilot scale operational integration using defined and cane syrup (2010), sorghum syrup (late 2010) and lignocellulosic sugar (2012)
- Zero LTA's during construction and operation

Direct steam sterilizer

AMYRIS.

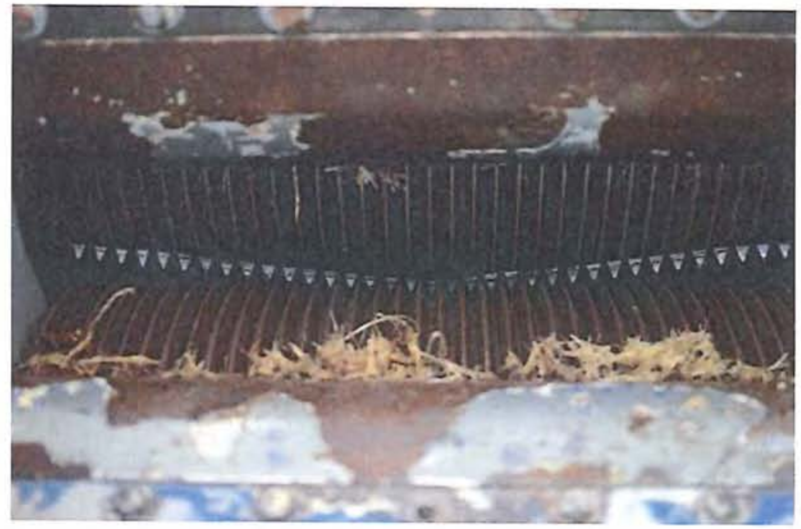
Task A : Pilot Plant Upgrades and Operations



Equipment installed and commissioned August 2011

AMYRIS

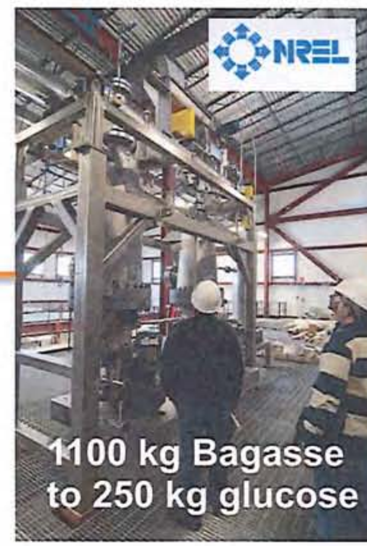
Task B: Field operations & crush (Ceres Inc.)



AMY ceres

Task B: Sorghum Feedstock Throughput

Concentrated 65% Brix Syrup



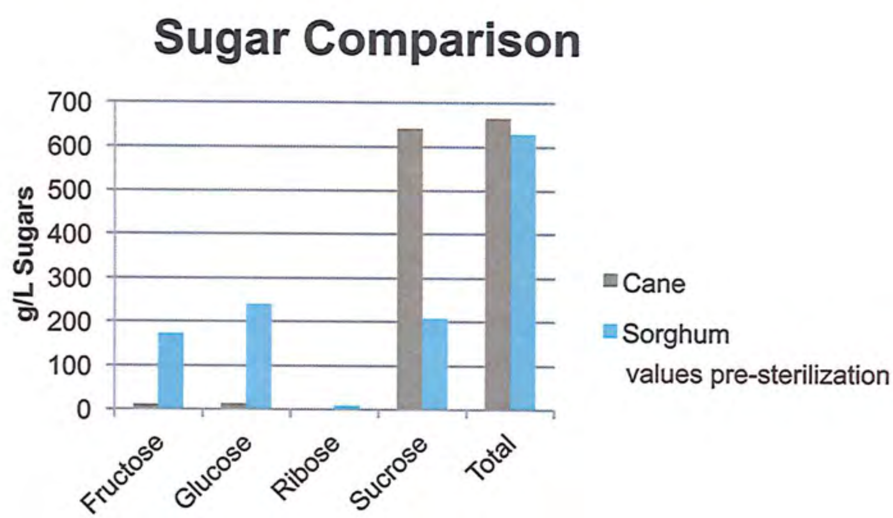
Evaporated to
250 g/L glucose

AMYRIS

Task B: Sorghum syrup looks a little different, but ferments the same

Sorghum Syrup (Ceres 2010 Tennessee Lots), raw materials basic properties

Property	Cane Syrup	Sorghum Syrup
Density (g/ml)	1.310-1.345	1.298
Solids (vol%)	0.2	4.0
Brix (%)	69	62
Other		Elevated Invert Sugar



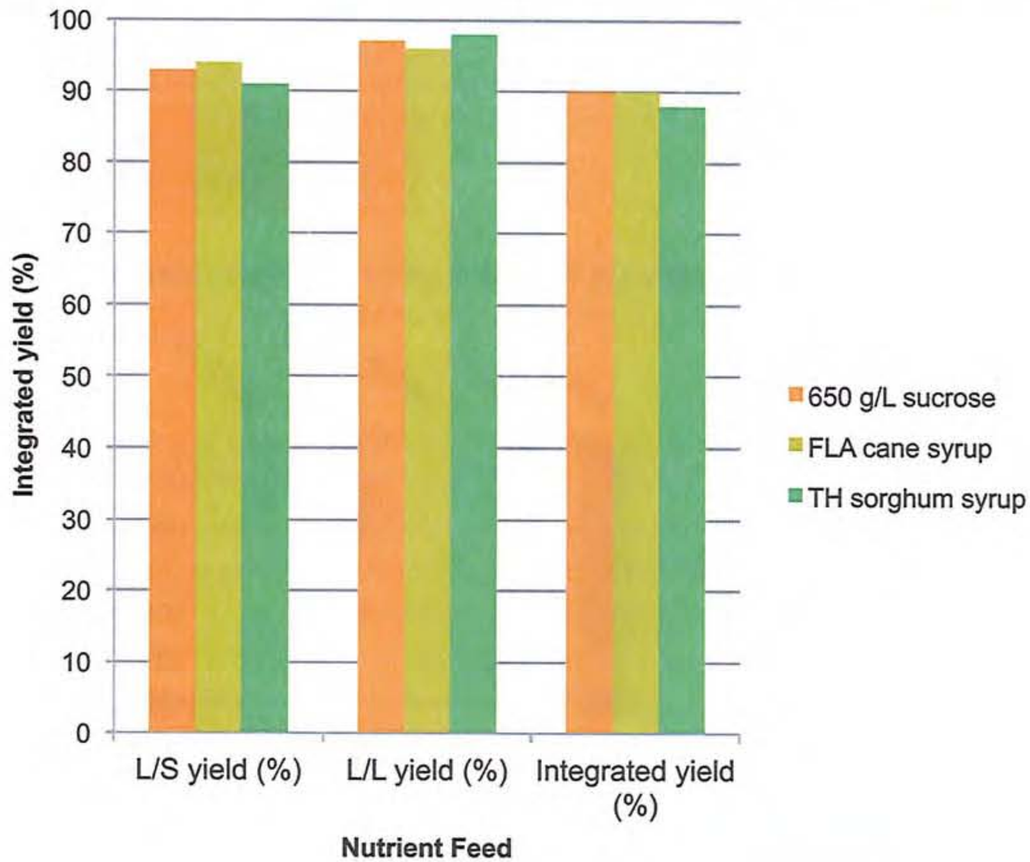
Sorghum has a more inverted sugar characteristic compared to cane syrup

Nutrient feed	Rel. yield (%)
650 g/L sucrose	100
FLA cane syrup	96
TN sorghum syrup	97

AMYRIS

Task B: Farnesene from sorghum, separation = sugarcane

- 300L fed-batch fermentation using filter sterilized TN sorghum syrup
- Fermentor harvest broth processed thorough to crude farnesene to determine down-stream processing performance
  - L/S centrifugation
  - L/L centrifugation
- Fermentation yields



- Down-stream processing yields similar for all feedstocks

AMYRIS

Task B: Crude Fuel Separation

Nutrient feed	Crude farnesene purity (% w/w)
Defined Medium	96.5
Cane syrup	95.2
Sorghum syrup (TFF)	97.3
Sorghum syrup (Non-TFF)	94.3

Sorghum
Syrup Non-TFF cFene

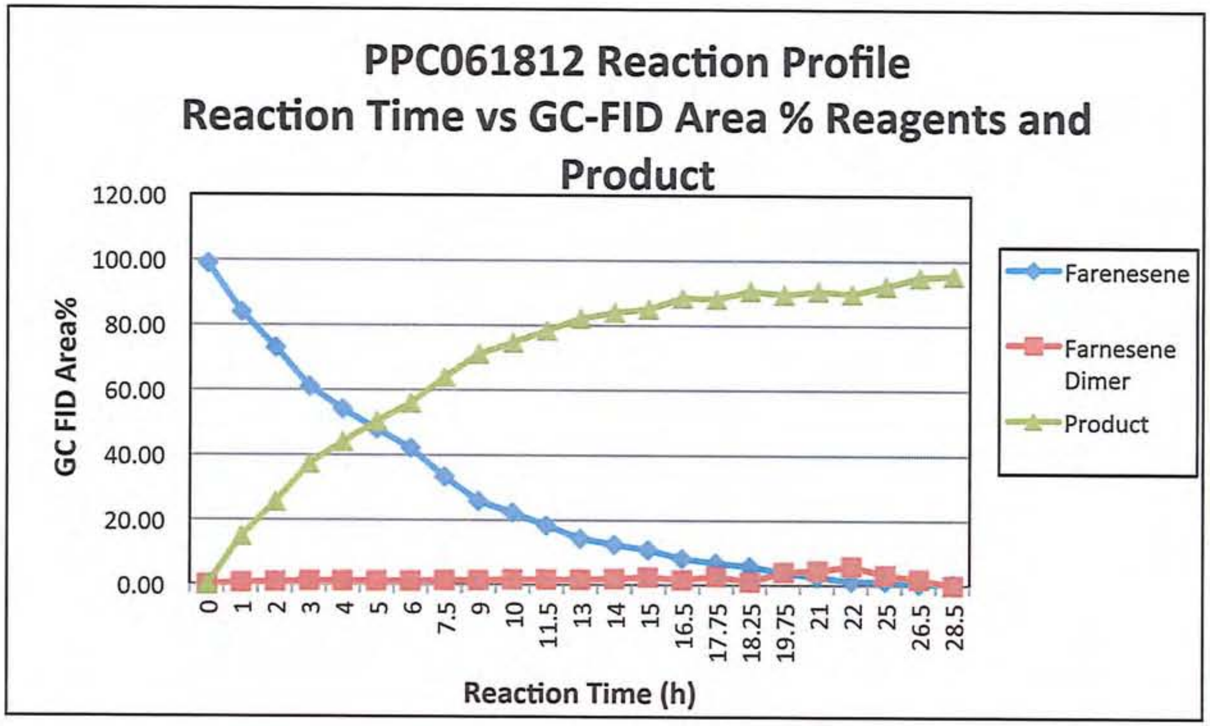
Cane Syrup cFene

AMYRIS

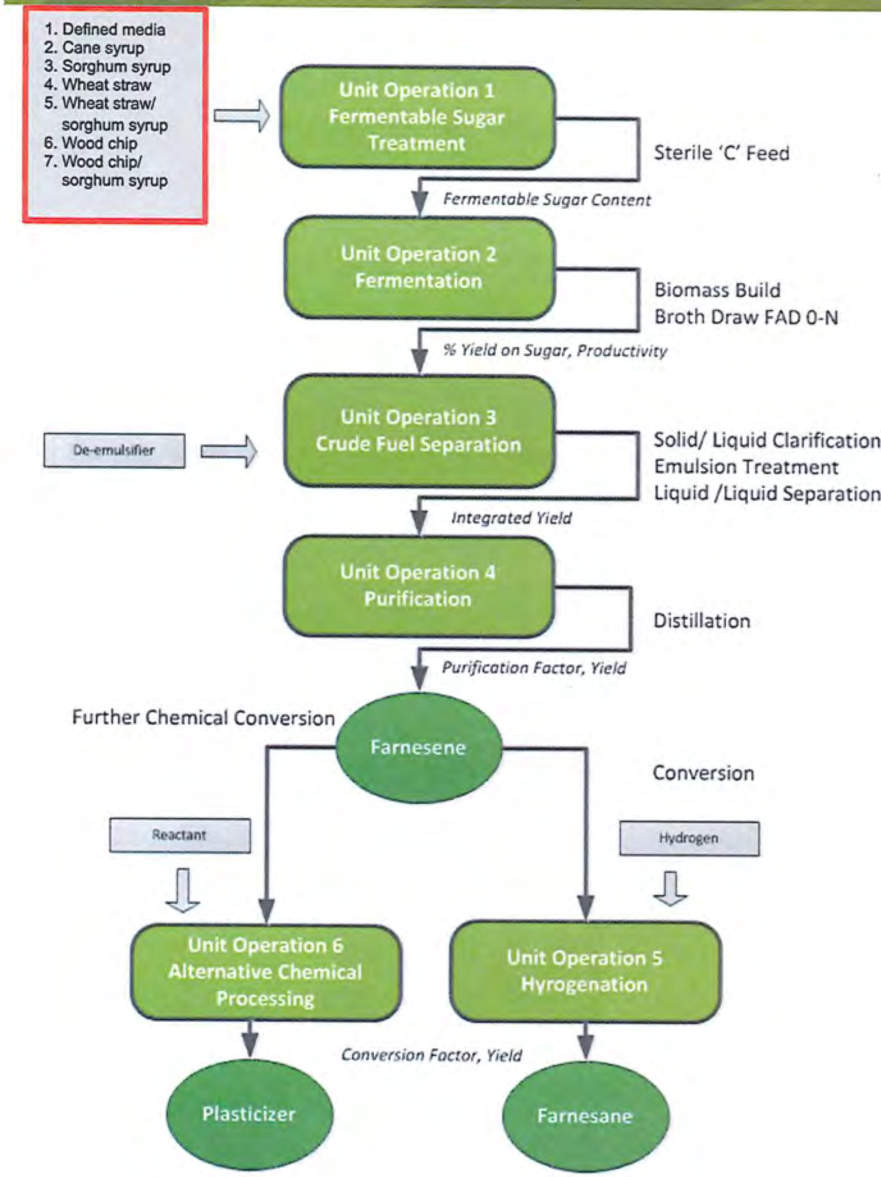
Task C: Alternative Chemistry (Plasticizer) Production

Lot Number Product from Diels -Alder	PPC061812
Theoretical Yield Diels-Alder Product	20.68 kg
Diels-Alder Product Mass (Area % Plasticizer precursor)	19.68 kg
% Yield Diels-Alder Product	95.16%
%Conversion Farnesene (% fene kg/kg product)/ Fene Starting Material kg	95.18%
Diels-Alder Product Area %	95.51% area
Diels-Alder Reaction Time	28.5 h

Plasticizer alternative chemistry performance testing from sorghum feedstock derived Farnesene



Expanding feedstock investigation to lignocellulosics



Key Measurements:

Raw Material Parameters
- Sugar content Brix
- Sugar Content by HPLC
- Solids volume %
- Sugar Content (trs) / Mass Feed
- Density

Fermentation
- Yield% wt product/ wt fermentable sugar consumed
- Productivity g product/ L.hr
- Sugar consumption rate g sucrose equivs/L.hr

Crude Fuel Separation
- S/L Separation Step Yield %
- L/L Separation Step Yield %
- Integrated Yield %

Purification
- % Recovery
- Purity wt %

Hydrogenation
- % Recovery
- Purity wt %

Overall Process
- Overall Recovery %

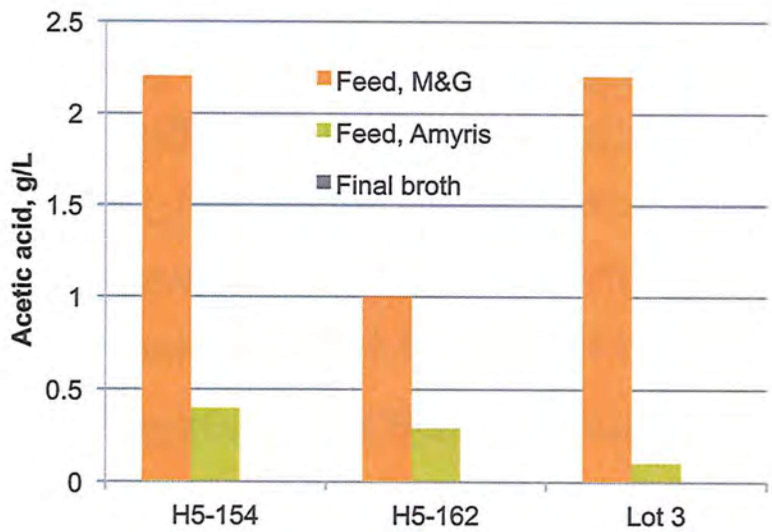
AMYRIS

IBR - bagasse production and farnesene conversion (NREL)

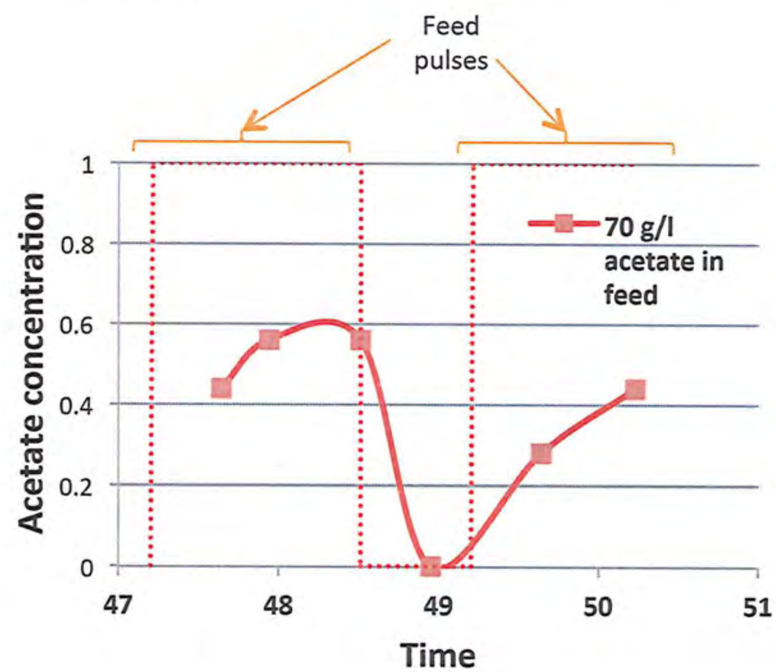
AMYRIS

Acetate is consumed - wheat straw example

- For all three wheat straw hydrolysate studies acetate was undetected in fermentation broth



- Hydrolysate results consistent with previous study of high acetate loading in defined media



AMYRIS

2 – Technical Accomplishments/ Progress/Results

Project Status and Progress through 2013

- Task A: Pilot Plant upgrades and operations
  - Pilot plant equipment installation completed
  - Pilot scale production of farnesene and farnesane (diesel) from sweet sorghum syrup demonstrated
  - Pilot scale production of farnesene and farnesane (diesel) from lignocellulosic sugars (woodchip, wheat straw, +/- sorghum syrup) near completion
- Task B: Scale-up and economic analysis of Amyris diesel production from sweet sorghum
  - Bench-scale production from sweet sorghum and bagasse hydrolysate (+/- acid treatment) completed
  - Pilot scale production of flexasene (plasticizer) from sweet sorghum syrup demonstrated
  - TEA completed for syrup-based feedstock and near completion for lignocellulosic-based feedstock

AMYRIS

2 – Technical Accomplishments/ Progress/Results

Project Status and Progress through 2013

- Task C: Development and scale-up of value-added products from farnesene
  - Crude farnesene derived from all feedstocks successfully distilled to meet specifications for chemical processing
  - Distilled farnesene derived from all feedstocks successfully hydrogenated to meet specifications for farnesane (bio-derived diesel)
  - Farnesene derived from all feedstocks chemically converted into plasticizer meeting specifications
- Task D: Regulatory and end-user product and process acceptance
  - Validation by major OEMs such as Cummins Engine Company, Caterpillar, Mercedes-Benz, MAN, Volvo, Scania, and Volkswagen
  - On-going validation by the U.S. Air Force and Navy

AMYRIS

3- Relevance

- The work in this project progresses towards:
  - The development of an inherently risk-mitigated energy crop, capable of growing throughout the Southeast U.S.
  - The production of renewable hydrocarbon diesel fuel to support the EISA goal of 36 BGPY by 2022
  - The commercialization of renewable diesel and other petroleum replacements from sweet sorghum at a price competitive with the existing incumbents
- Demonstrated production of chemicals from alternative feedstocks
- The envisioned n^{th} plant integrated bio-refinery is anticipated to produce cost competitive renewable diesel with net positive carbon utilization

AMYRIS

4 – Critical Success Factors

General

- Commercial success of the project will hinge on:
  - Growth of sweet sorghum at relevant yields and volumes
  - Establishment of sweet sorghum harvest and processing infrastructure
  - Further integration across pretreatment, fermentation, and downstream processes (solids removal)
  - Further improvement of fermentation strains for yield and productivity
  - Production of biogas from a C5 waste sugar stream
  - Cost-effective biogas reforming to 'green' hydrogen

AMYRIS

4 – Critical Success Factors

Regulatory and End-User Acceptance

- Completed registration of Amyris Diesel with US EPA at 35% blend as ultra-low sulfur diesel
- Pipeline Renewable Diesel Criteria & Compliance
  - Met Colonial Pipeline product specifications
- Department of Defense Fuel Validation
  - Validation to Naval MILSPEC F-76 Distillate performed by Navy NAVAIR Fuels Laboratory
  - Ongoing validation to new Naval MILSPEC DSH-76 Renewable Diesel
  - Ongoing Air Force ground diesel fuel validation
- Preliminary assessment of a low-blend jet fuel – completed preparation of a ASTM Research Report
- CA Multi-media Inter-agency Acceptance
- Toxicity Assessment Supporting EPA PMN Approval
- EPA LCA certification (ongoing)

AMYRIS

Regulatory and End-User Acceptance (cont'd)

- OEM Validation by Engine & Vehicle Dynamometer
  - Cummins Engine Company (US)
  - Caterpillar (US)
  - Mercedes-Benz Truck & Bus (Brazil)
  - VW AG (US)
- Advance Combustion Modeling & Validation
  - Cummins, *Validation, Reduction, and Evaluation of Chemical Mechanism for Engine Combustion Analysis*
  - Princeton University, *Quantification of Molecular Structure Impact on Combustion Properties for Synthetic Diesel Fuel*
- On-highway Validation
  - FedEx – Oakland Facility (HD Kenworth/Cummins)
  - Sierra Nevada Brewery (Peterbilt Hybrid)
  - Volkswagen of Americas (3.0L Passat and Jetta vehicles)
- EC REACh registration (farnesane to 100 TPA threshold)

AMYRIS

5 – Future Work

- Completing performance data from lignocellulosic sugar
  - Fermentation and Recovery Process
  - Chemistry process to biodiesel
  - Chemistry process to alternative chemistry (plasticizer)
- Completing program documentation and final write-up
- EC REACh Registration >1,000 TPA Threshold
- EPA PMN Approval
  - Completion of ongoing toxicity assessment
  - Action due to delayed EPA guidance
- Completion of ICM/Praxair evaluation of lignocellulosic vinasse for bio-methanation and hydrogen production steps
- Further strain engineering under NABC to utilize C5 sugars

AMYRIS

Summary

- Pilot Plant expansion commissioned in 2011 and operations ongoing with zero LTAs
- Technical results
  - Farnesene-producing yeast fermentation performance with sorghum syrup equal to cane syrup performance
  - Proven ability to utilize diverse feedstock sources including lignocellulosic (C6) sugars + acetate
  - Integration with NABC to demonstrate C5 + C6 sugar use
- Progress in accessing diesel market
  - EPA Registration
  - OEM and Fleet Validation
- Project scheduled to complete in June 2013

AMYRIS

Summary

- Higher value products in the near term
- JV partners for first-gen and next-gen production of high volume commodity products
- Looking to build on current core production in the US
- Looking for partners to continue development of strains and processes for lignocellulose utilization

- Still focused on fuels as a key objective for volume, cost and IMPACT

AMYRIS

The NABC: Helping Amyris Commercialize Farnesene from Lignocellulosic Sugars

NABC
National Advanced Biofuels Consortium

Biofuels
for Advancing America

Developing cost-competitive, sustainable biofuels for today's transportation infrastructure.

Techno-Economic Analysis & Life Cycle Analysis

Feedstock Supply
Iowa State University
Catchlight Energy™ A Chevron | Weyerhaeuser Joint Venture

Pretreatment & Hydrolysis
NREL National Renewable Energy Laboratory
Washington State University

Clarification & Concentration
PALL
NREL National Renewable Energy Laboratory
Washington State University

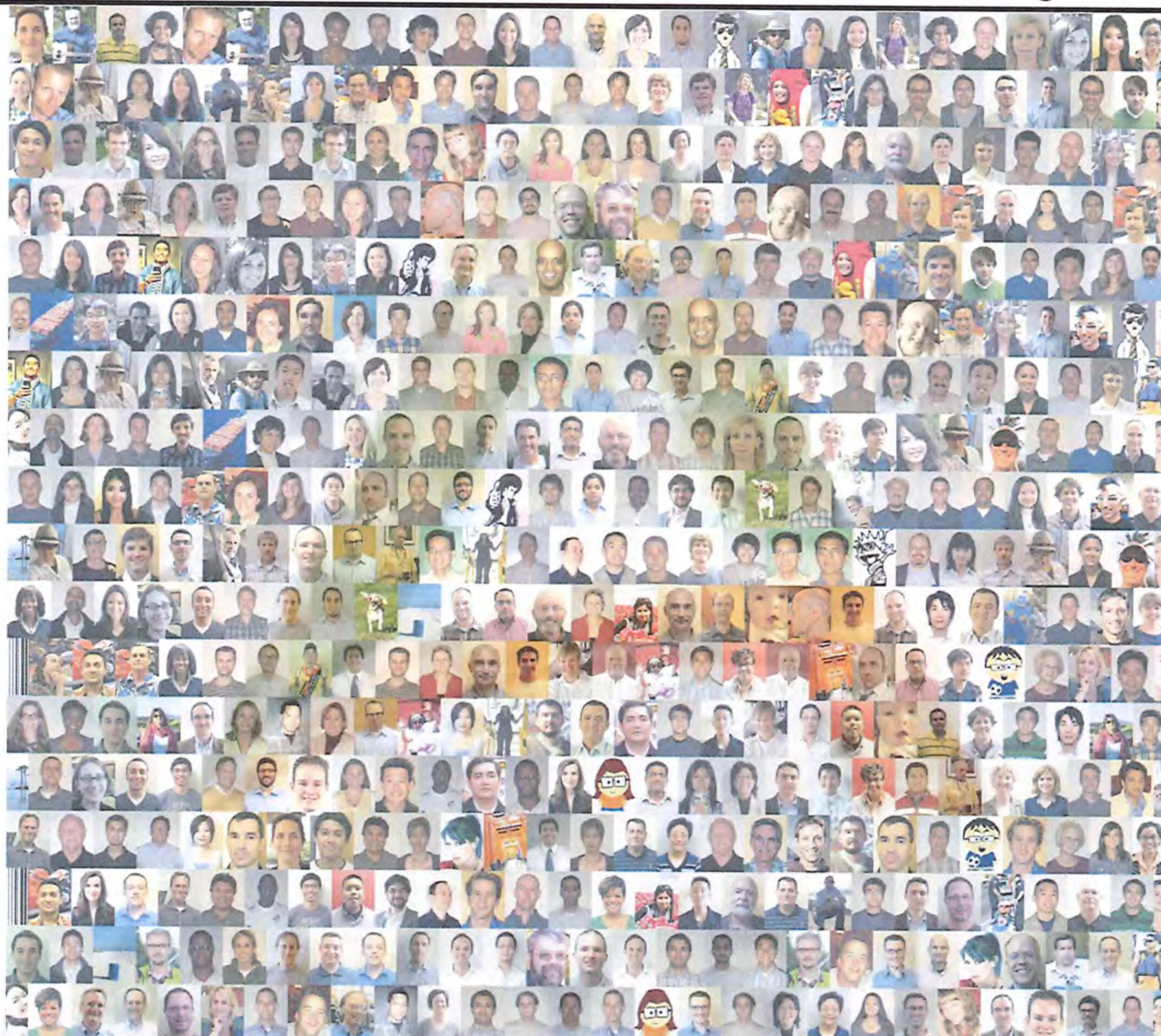
Fermentation of C5 & C6 Sugars
AMYRIS

Farnesene Recovery & purification
AMYRIS

Product Finishing & Blending
AMYRIS
TESORO

AMYRIS

Thanks to the US DoE, and thanks for listening



And of course this work not possible without all Amyrisians!