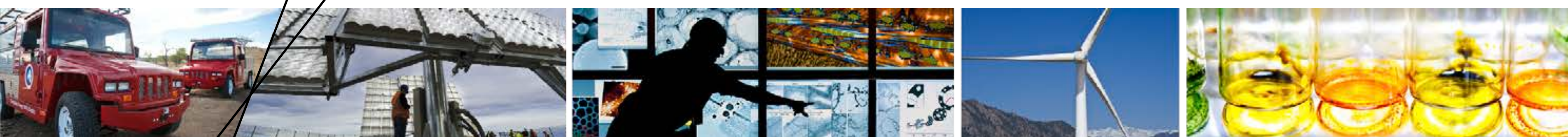
JOINT INER & IRENA

Cooperative Research and Innovation Liquid Biofuels for the transport sector



Research and Development Initiatives on Biofuels for Transport

Helena Chum
National Renewable Energy Laboratory, Golden, Colorado, USA

November 13, 2015

Outline

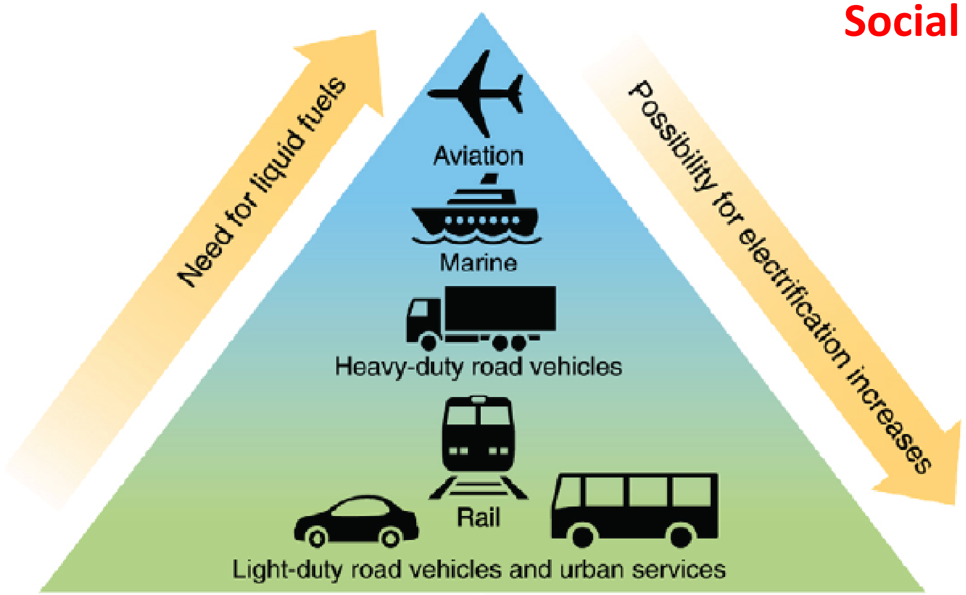
- **Transport Fuels and Systems**
- **Renewable Fuels - 20,000 ft view**
- **Global RD&D examples**
  - Sugar crops and lignocellulosic crops can make a variety of fuels and products
  - Aviation biofuels development – biofuels with identical properties of petroleum-derived fuels
  - Biomass Flexibility - Refineries and Systems
- **Sustainability Considerations**

Transport Fuels and Systems

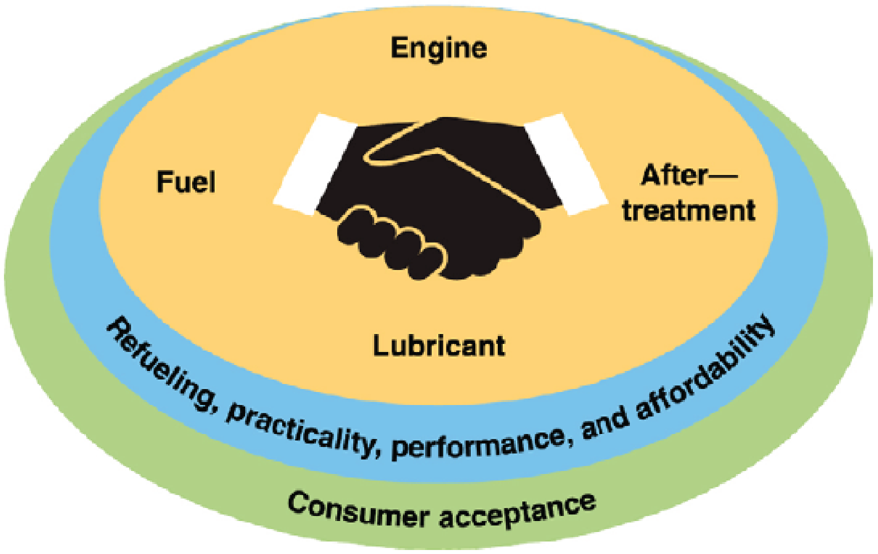
Strict Global Requirements for Aviation Fuels Requires Multiple Partnerships for RDD&D

SYSTEM SUSTAINABILITY
Economic
Environment
Social

Hierarchy of fuels



Everything has to fit together—
different stakeholders have to work together!



Off Road Less strict local applications can use local fuels appropriate for the engines and conditions

Innovation versus Invention

- Innovation is the improvement of a product or process (often in combination) which creates meaningful social/economic impact.

  "The successful translation of new ideas into tangible societal impact." — USC Stevens Institute for Innovation

- Innovation often involves:
  - Significant advances along an entire value chain.
  - Market demand and public acceptance.
  - Correct timing – confluence of historical factors/trends.
  - Cross-cutting, interdisciplinary inputs.
  - Longer term and significant impacts on economics and culture

- Invention is merely the starting point for innovation.

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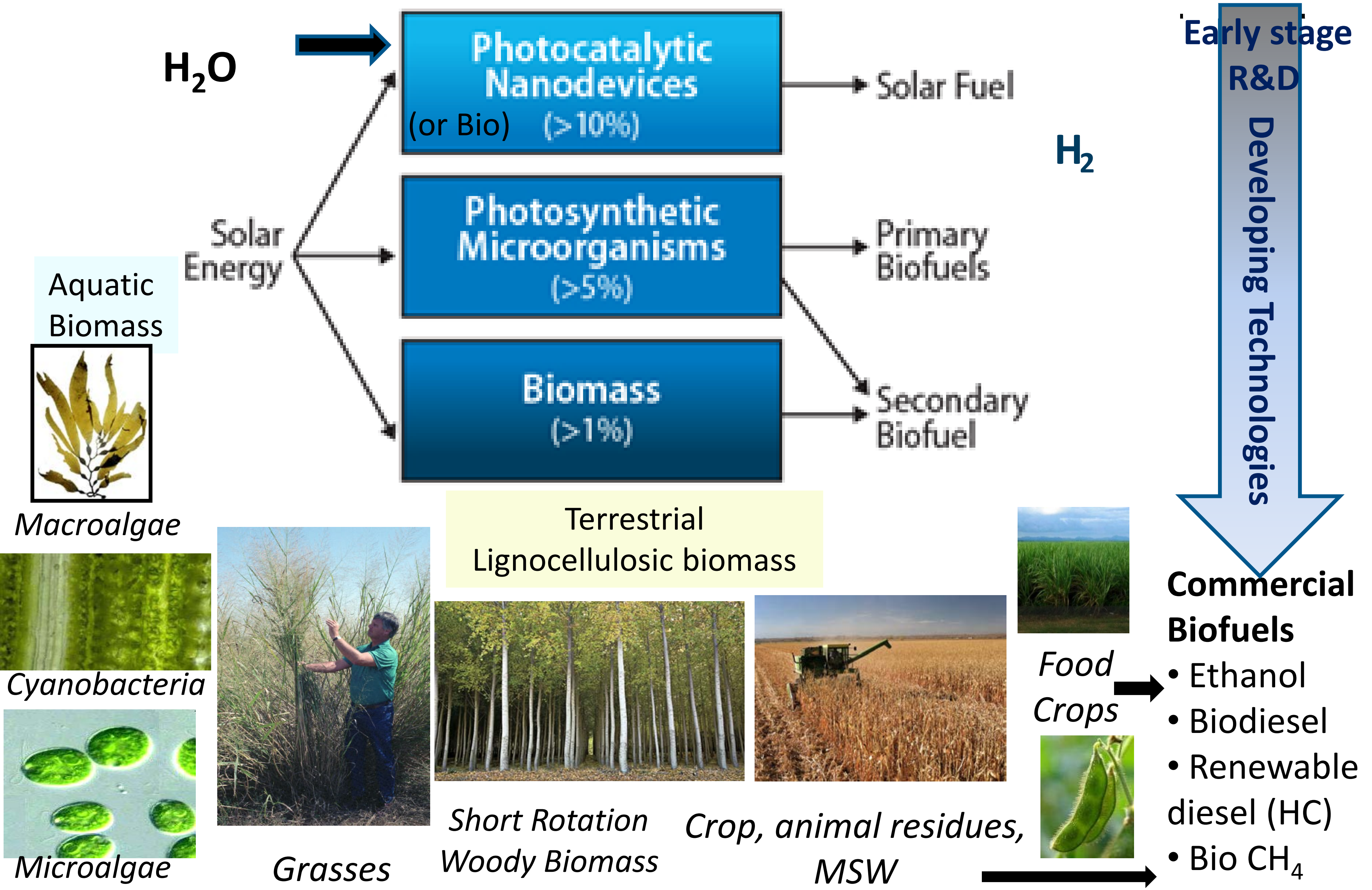
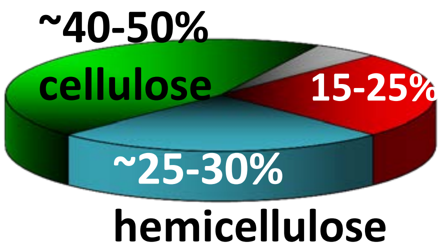
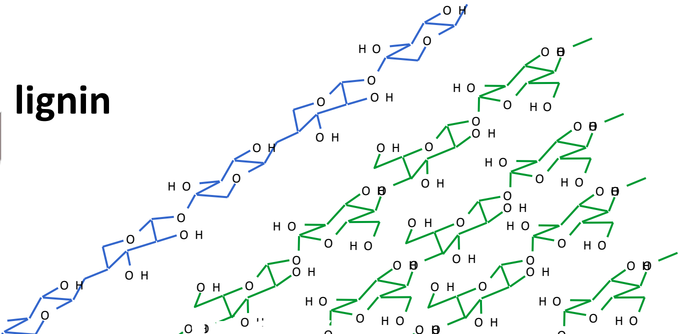
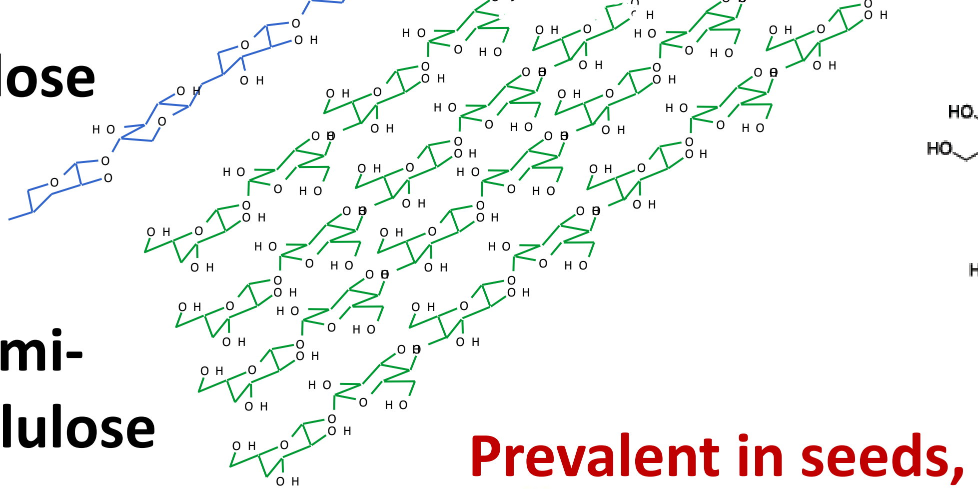
Renewable Liquid or Gaseous Fuels



What is in Biomass?

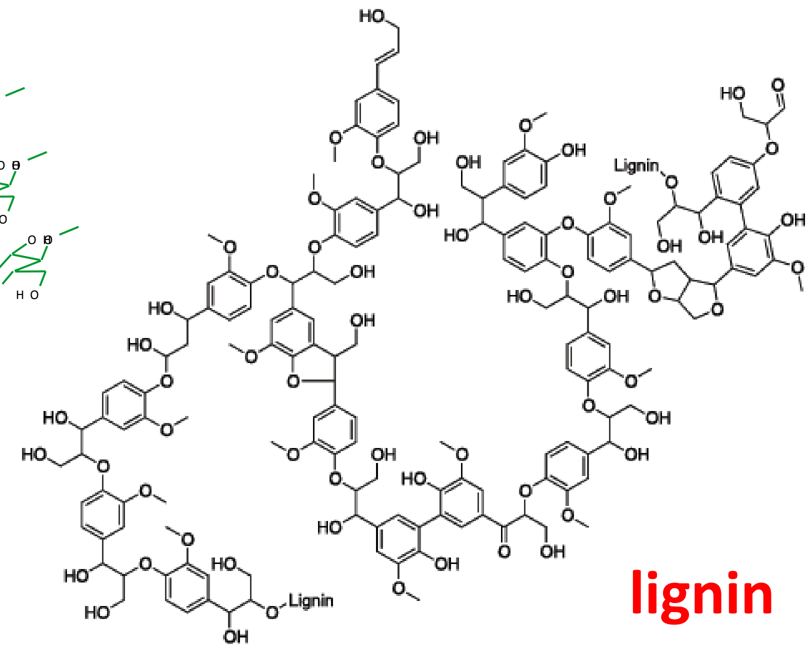
Prevalent in woody, herbaceous feedstocks:



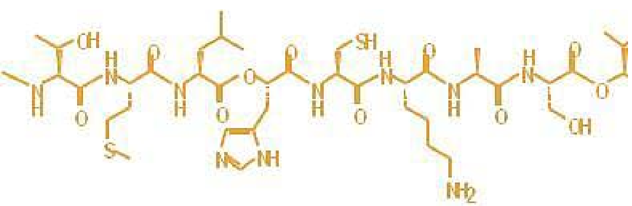
cellulose

Hemi-cellulose

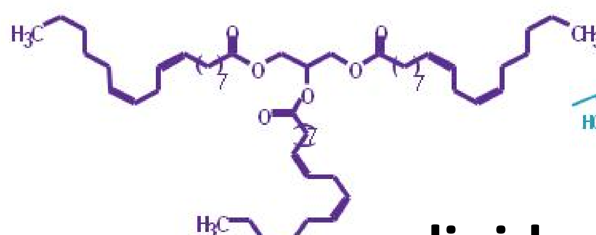


lignin

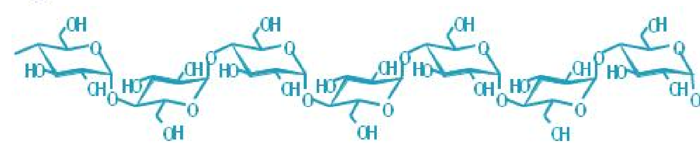
Prevalent in seeds, grains (foodstuffs)



protein

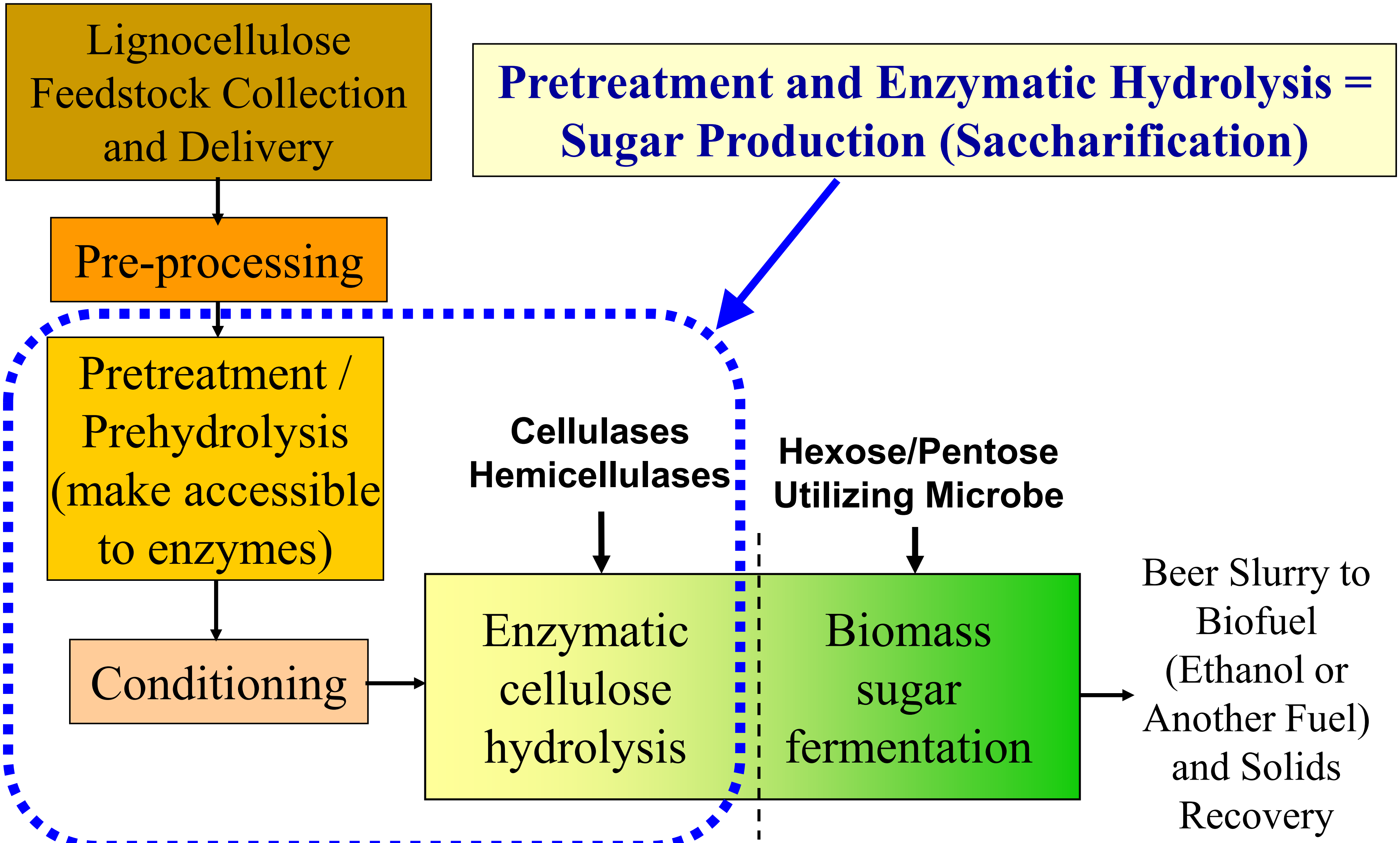


lipids



starch

Economic Sugar Production Remains Biggest Challenge



Major Commercial-scale Cellulosic Ethanol Projects

POET-DSM's Project LIBERTY

- Grand opening on September 3, 2014, in Emmetsburg, Iowa.
- Once operating at full, commercial-scale, the plant will produce 25 million gallons of cellulosic ethanol per year – enough to avoid approximately 210,000 tons of CO_2 emissions annually.
- Developed with the support of approximately $100 million in investments and research from DOE.

Abengoa Bioenergy Biomass of Kansas

- Grand opening on October 17, 2014, in Hugoton, Kansas.
- The plant will produce cellulosic ethanol from non-edible corn stalks, stems, and leaves harvested within a 50-mile radius of the plant.

http://energyoutlook.naseo.org/Data/Sites/6/media/presentations/Male.pdf

15 | Bioenergy Technologies Office

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Supply Chain Development to supply year round specified biomass

Conversion Technology Scale-up to First-of-a-kind Commercial Facility

Fuel and other products off-take agreements

Whole System has to be sustainable

Large scale plants in Crescentino, Italy
Further scaleup of that technology in Brazil, Alagoas – Gran Bio
Others Raizen in Brazil, DuPont in the United States, and others

Demonstration Portfolio – Selected Projects

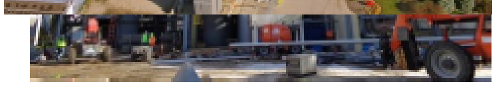
American Process, Inc., Alpena, MI

- Feedstock: waste hydrolyzate stream from hardboard manufacturing process (mixed northern hardwood and aspen).
- Capacity: 894,200 gallons/year of cellulosic ethanol (from C6 sugars) and 696,000 gallons/year of aqueous potassium acetate (De-Icer) (from C5 sugars).
- Accomplishments to date:
  - First batch of pure cellulosic ethanol produced in early FY14
- DOE share: $22,481,523; Cost share: $8,459,327

Pulp and Paper waste conversion to ethanol and deicer

Haldor Topsoe, Inc., Des Plaines, IL

- Thermochemical process for the conversion of wood waste and woody biomass to gasoline.
- Expected to produce approximately 345,000 gal/year.
- Accomplishments to Date:
  - Testing shows acceptable ranges for gasoline blendstock
  - Emission level was "substantially similar" to conventional gasoline
- DOE share: $25,000,000; Cost share: $9,388,778
- Collaborative agreements with Gas Technology Institute, Andritz-Carbona, UPM-Kymmene, and Phillips 66.



Gasification/ Catalytic

INEOS, Vero Beach, FL

- Expected to produce 8 million gallons per year of cellulosic ethanol and 6 MW of power from wood and vegetative waste.
- DOE Share = $50M; Cost share = $82M.
- Created 400 construction jobs; 65 permanent jobs are expected for operation.
- Major construction began in October 2010, commissioning was completed in June 2013, and the facility initiated commercial production of cellulosic ethanol in July 2013.
- First commercial production of cellulosic ethanol in the U.S.

Gasification/ Biological conversion Syngas to ethanol

http://energyoutlook.naseo.org/Data/Sites/6/media/presentations/Male.pdf

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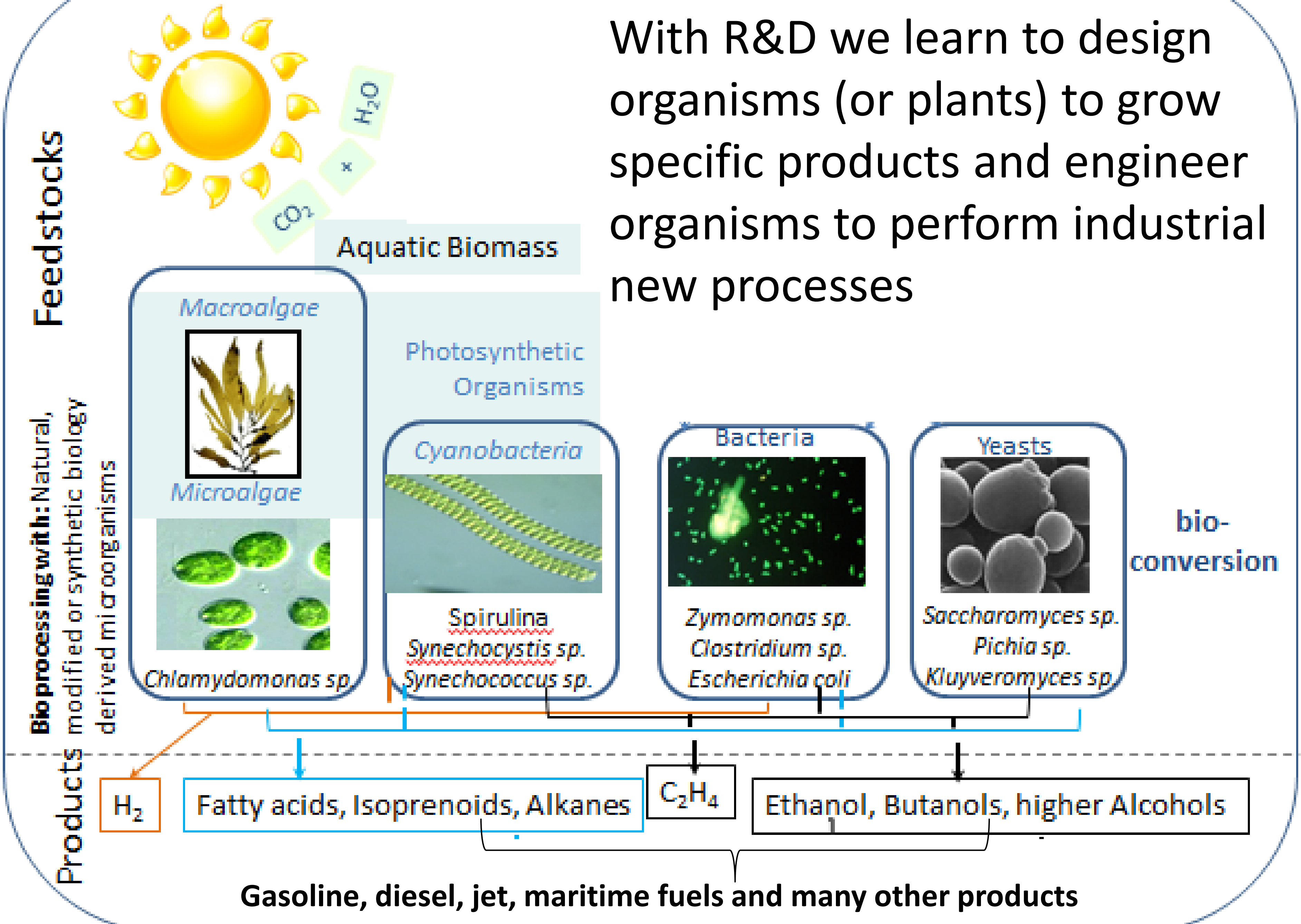
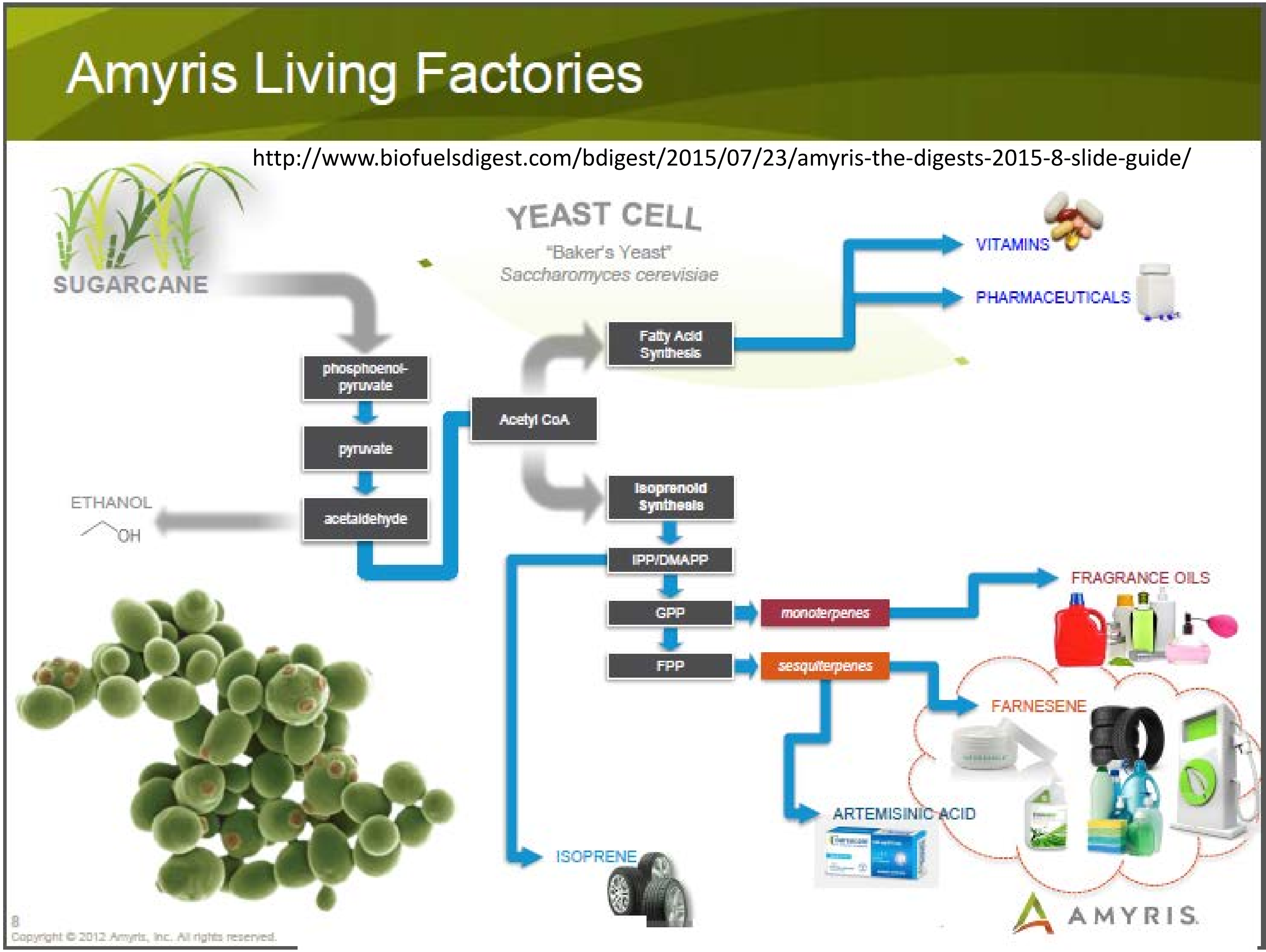
With R&D we learn to design organisms (or plants) to grow specific products and engineer organisms to perform industrial new processes



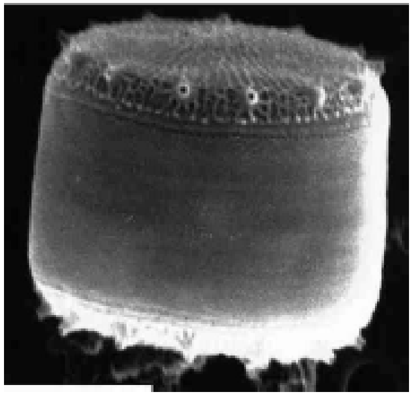
Global RD&D and commercialization – Using synthetic biology and unlocking value

U.S. DOE/ Office of Sciences; Bioenergy Technologies Office. Brazilian BNDES, multiple global companies



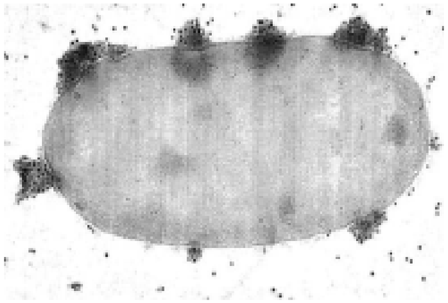
Nature's solutions to energy challenges

Thalassiosira pseudonana



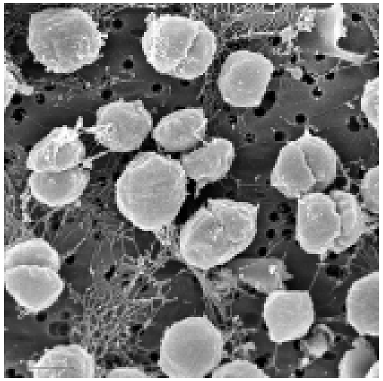
Ocean carbon pumping

Microbulbifer 2-40



Biomass conversion

Methanococcus jannaschii

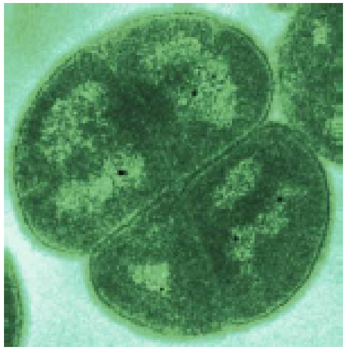


Methane production

Rhodopseudomonas palustris

Hydrogen production / Carbon sequestration

Deinococcus radiodurans



Radiation resistance - bioremediation

Found useful for consolidated bioprocessing (France)Deinove

U.S. DEPARTMENT OF ENERGY

Office of Science

See presentation on Genomes to life at https://ec.europa.eu/research/biotechnology/eu-us-task-force/pdf/thomassen_19_july_9-45_en.pdf

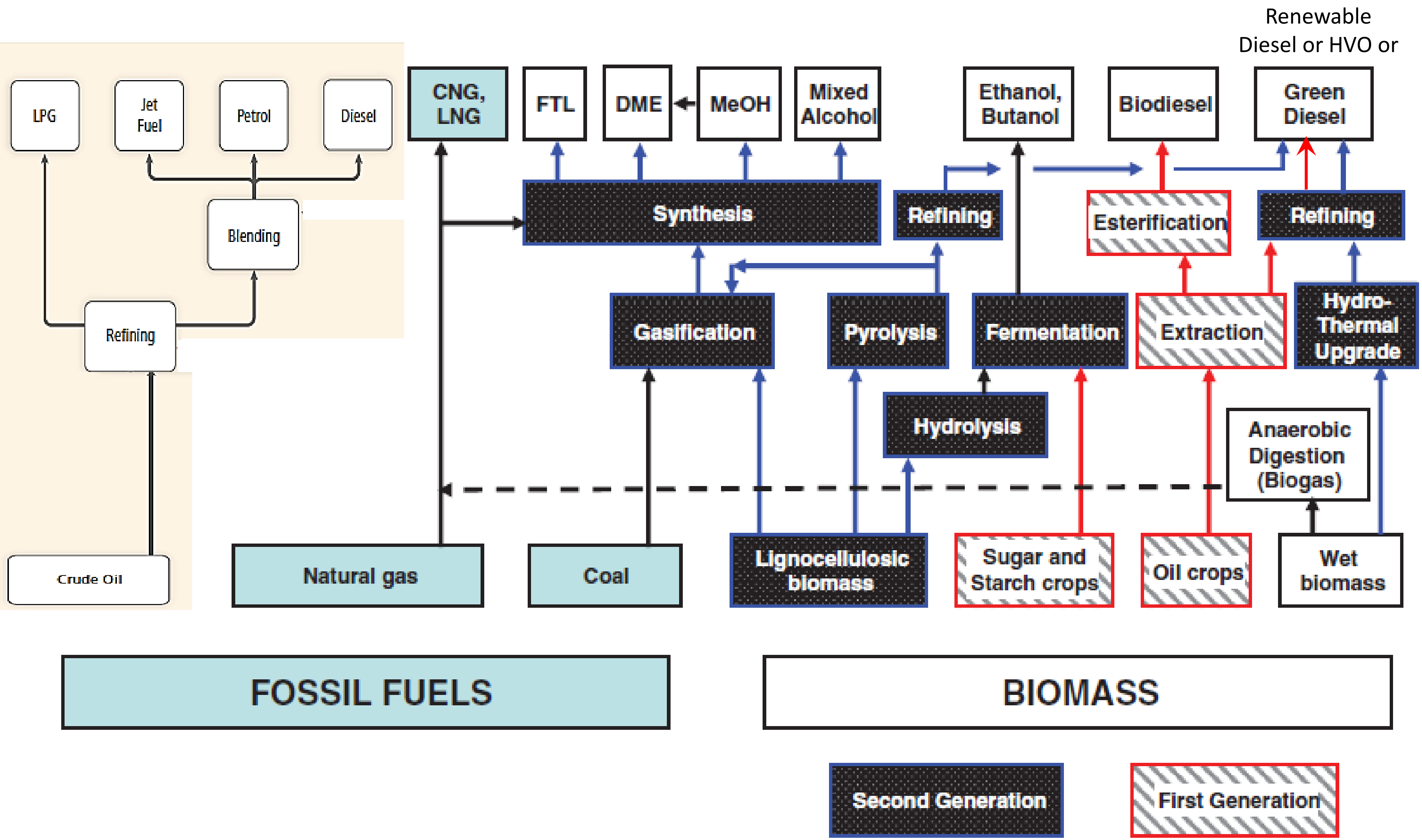
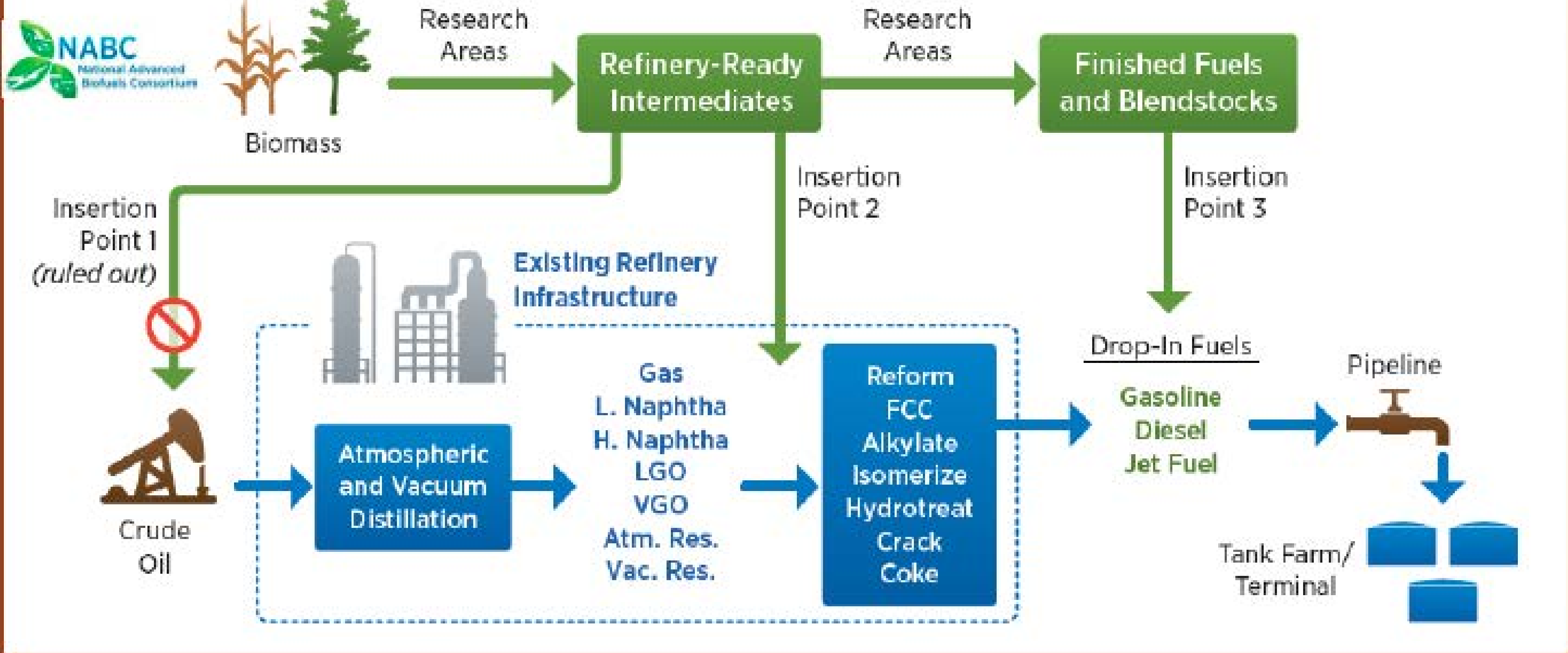


Figure 11.14 | Production paths to liquid fuels from biomass and, for comparison, from fossil fuels.

Global Energy Assessment, 2011

Refinery insertion points

T. Foust at http://energy.gov/eere/bioenergy/downloads/integrating-nabc-bio-oil-intermediates-petroleum-refinery



- Renewables may be added to petroleum refineries at different locations.
- The easiest is as a blendstock (insertion point 3),
- Greater capital savings may occur if the renewables use refinery unit operations for processing (Insertion 2)

America's RD&D development

Refinery Coprocessing

RFO Coprocessing leverages on existing refinery infrastructure

- Lowers total CAPEX & OPEX
- Facilitates implementation

Coprocessing Yields

NREL PETROBRAS ENSYN

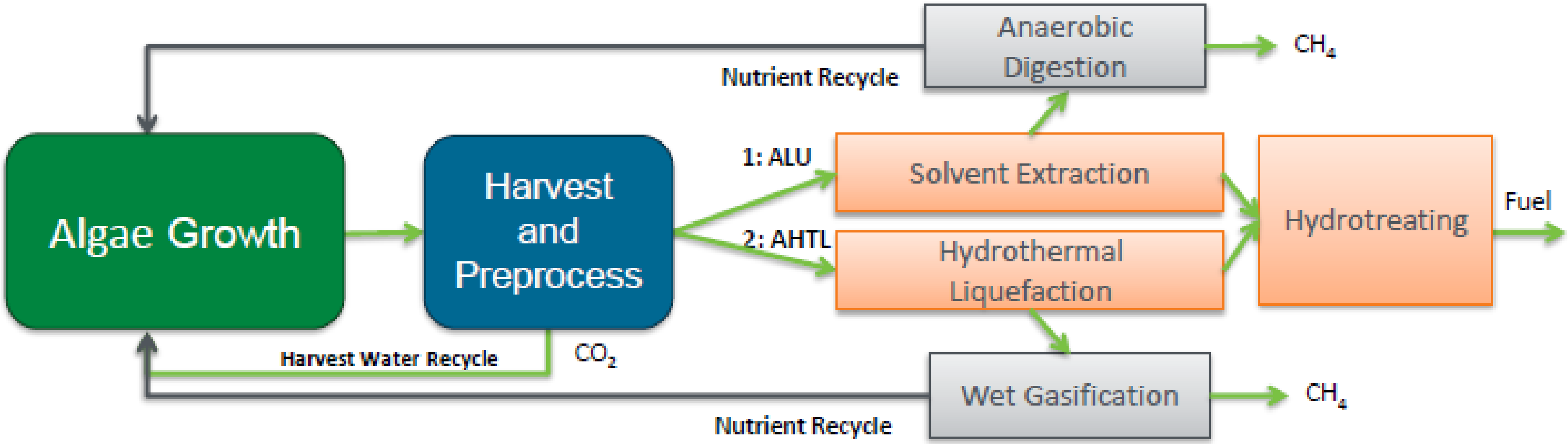
Weight %	100% VGO	95% VGO + 5% RFO	90% VGO + 10% RFO
Dry Gas	3.5	2.8	2.8
LPG (C3-C4)	13.8	13.8	12.5
Gasoline (C5-220°C)	39.9	40.6	38.8
Diesel (220-344°C)	20.3	19.6	19.2
Bottoms (+ 344°C)	16.1	14.4	14.4
Coke	6.4	6.0	6.5
CO	0.0	1.0	1.7
CO_2	0.0	0.4	0.6
Water	0.0	1.4	3.5

ENSYN

Chum et al. 2015. Helena Chum (NREL), Andrea Pinho (Petrobras), Barry Freel (Ensyn Corporation "DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review, 2.4.2.303 Brazil Bilateral: Petrobras-NREL CRADA." March 15, 2015. http://www.energy.gov/sites/prod/files/2015/04/f21/thermochemical_conversion_chum_24230 pdf

Two Baseline Pathways for Conversion of Algae to Fuels:

1. Algal Lipid Upgrading (ALU)
2. Algae Hydrothermal Liquefaction (AHTL)



http://energyoutlook.naseo.org/Data/Sites/6/media/presentations/Male.pdf

*Jonathan Male at https://www.biorenew.iastate.edu/mbo/**energymfg**workshop/*

Closest to Commercial for Aviation Biofuels

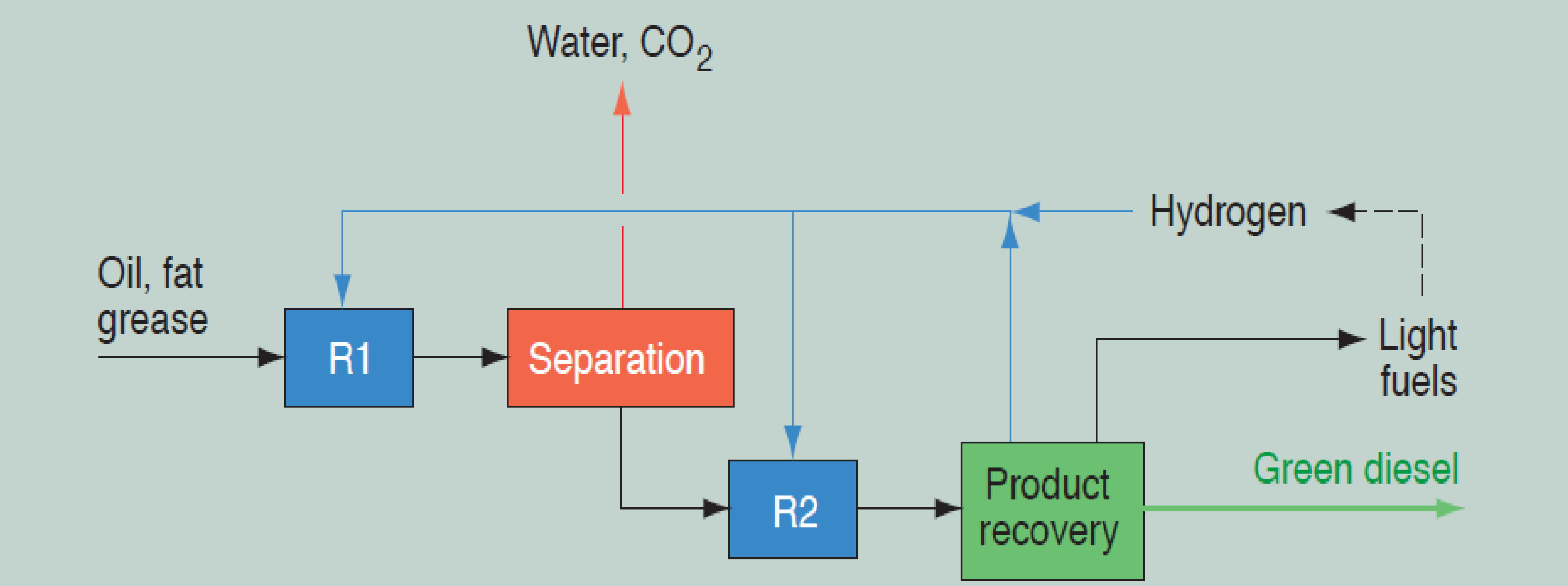
Limited Feedstock Supply

Neste
UOP/ENI
And others

HEFA-Hydroprocessed Esters and Fatty Acids -2011

Up to 50% blend

- Plant and Animal Oils/Tallow



Honeywell UOP, Controlling Production of Transportation Fuels from Renewable Feedstocks. Patent: WO 2009/151692 A2, 2009.

Defense Production Act (DPA) Initiative

In July 2011, the Secretaries of Agriculture, Energy, and Navy signed a Memorandum of Understanding to commit $510M ($170M from each agency) to produce hydrocarbon jet and diesel biofuels in the near term. This initiative sought to achieve:

- Multiple, commercial-scale integrated biorefineries
- Cost-competitive biofuel with conventional petroleum (w/o subsidies).
- Domestically produced fuels from non-food feedstocks.
- Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP8).
- Help meet the Navy's demand for 1.26 billion gallons of fuel per year.
- Contribute to Navy's goal of launching "Great Green Fleet" in 2016.
- Demonstration of the production and use of more than 100 million gallons per year will dramatically reduce risk for drop-in biofuels production and adoption.

DOE has a $45M appropriation for DPA in FY14

The four projects selected under DPA are:

Company	Location	Feedstock	Conversion Pathway	Capacity (MMgpy)
Emerald Biofuels	Port Arthur, TX	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	94.0
Natures BioReserve	South Sioux City, NE	Fats, Oils, and Greases	Hydroprocessed Esters and Fatty Acids (HEFA)	65.8
Fulcrum BioEnergy	McCarran, NV	Municipal Solid Waste	Gasification – Fischer Tröpsch (FT)	17.0
Red Rock Biofuels	Lakeview, OR	Woody Biomass	Gasification – Fischer Tröpsch (FT)	16.0

http://energyoutlook.naseo.org/Data/Sites/6/media/presentations/Male.pdf

*Jonathan Male at https://www.biorenew.iastate.edu/mbo/**energymfg**workshop/*

Sustainability Activities

Identifying and addressing the challenges for sustainable bioenergy production through field trials, applied research, capacity building, modeling, and analysis.

Feedstock production and logistics

- Assess and reduce impact on land, water, climate, air quality, biodiversity, and resource use
- Increase landscape productivity

Conversion

- Minimize water consumption, GHG footprint, air pollution, and waste
- Maximize efficiency

ethanol
diesel
gasoline
jet fuel
biopower
bioproducts

End use

- Evaluate air quality impacts
- Avoid negative impacts on human health

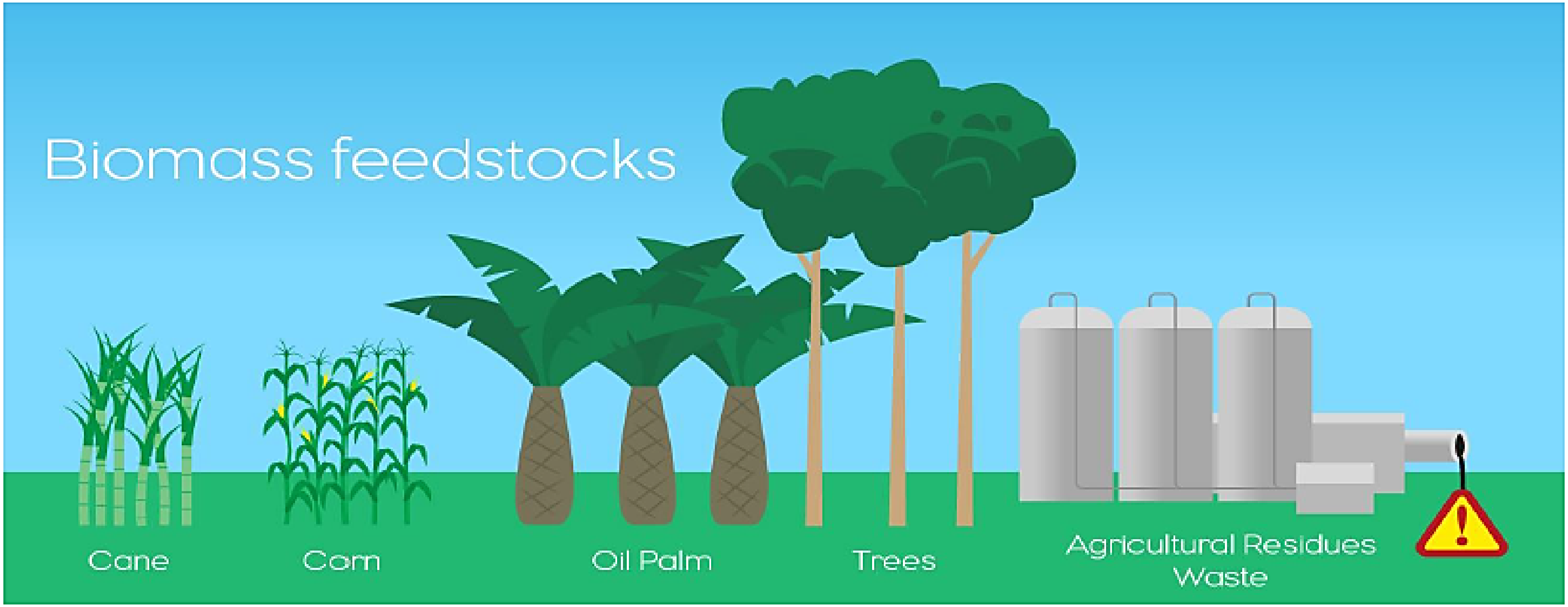
Cross-cutting

- Life-cycle analysis of water consumption and GHG emissions
- Supply chain environmental, economic, and social factors

http://energyoutlook.naseo.org/Data/Sites/6/media/presentations/Male.pdf

Agroforestry integration

http://bioenfapesp.org/scopebioenergy/



Integrated food/forest/energy systems, i.e. growing energy crops and food or fiber crops in synergy, can be accomplished with:

- spatial approaches (strategic placement on the landscape)
- temporal approaches (crop rotations and succession plantings)
- at a system level, with residue recovery, nutrient and energy recycling and waste reduction addressing sustainability challenges of our conventional food and energy systems.

Harmonizing forestry and agriculture policies is fundamental for the implementation of integrated approaches to sustainable production and supply of bioenergy.

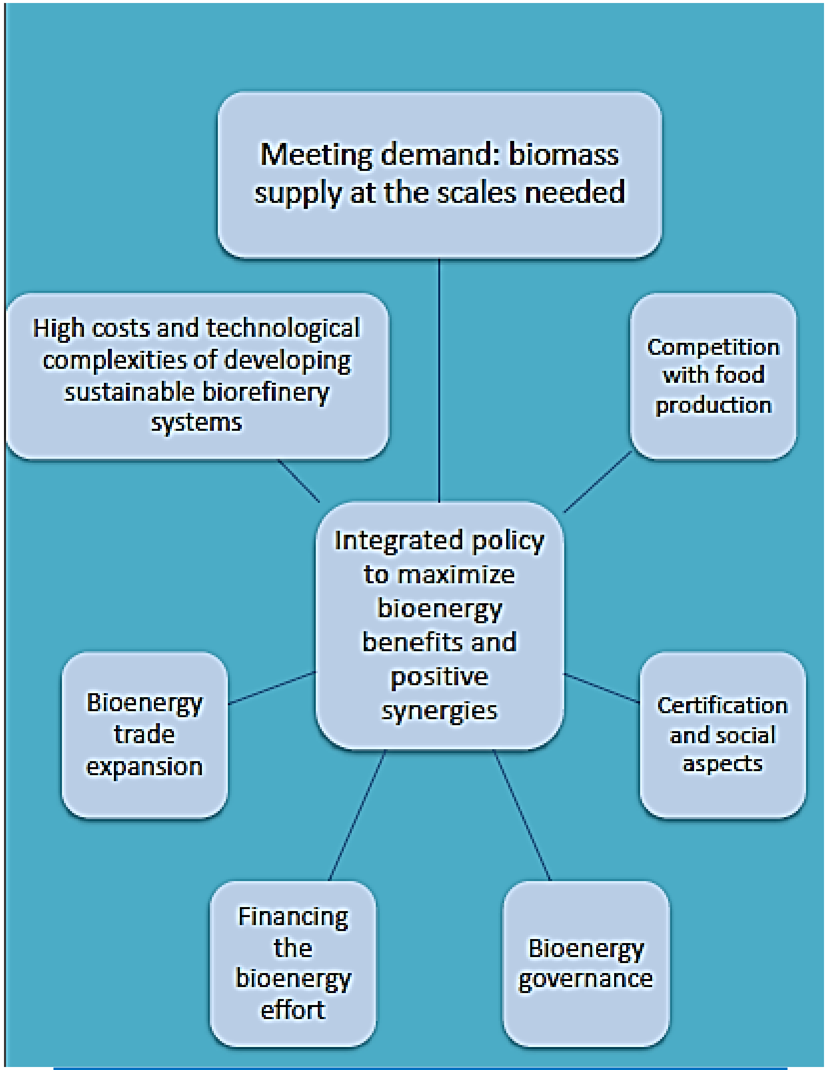
Richard and El-Lakany, Chapter 13

Summary

http://bioenfapesp.org/scopebioenergy/

- Development of bioenergy can replenish a community's food supply by improving management practices and land soil quality
- New technologies can provide communities with food security, fuel, economic and social development while effectively using water, nutrients and other resources
- The use of bioenergy, if done thoughtfully, can actually help lower air and water pollution
- Bioenergy initiatives monitored and implemented, hand in hand with good governance, can protect biodiversity, and provide ecosystems services
- Efficiency gains and sustainable practices of recent bioenergy systems can help contribute to a low-carbon economy by decreasing greenhouse gas emissions and assist carbon mitigation efforts
- With current knowledge and projected improvements 30% of the world's fuel supply could be biobased by 2050

To address issues Integrated policies and deployment are needed



SCOPE Bioenergy and Sustainability

Acknowledgments

- **IRENA and INER for the invitation**
- **U.S. Department of Energy, Bioenergy Technologies Office (Kristen Johnson and Alison Goss Eng)**
  - https://www.bioenergykdf.net/
- **State of Sao Paulo Research Foundation (FAPESP) Glaucia Souza and SCOPE colleagues**
  - Souza, G. M., Victoria, R., Joly, C., & Verdade, L. (Eds.). (2015). *Bioenergy & Sustainability: Bridging the gaps* (Vol. 72, p. 779). Paris: SCOPE. ISBN 978-2-9545557-0-6 http://bioenfapesp.org/scopebioenergy/
- **International Energy Agency Bioenergy Agreement, Kees Kwant, Netherlands, Jim Spaeth, U.S. and tasks 38, 39, 40, 43, 42**
- **Roundtable on Sustainable Biomaterials, Barbara Bramble, Rolf Hogan, Matt Rudolf, Arthur Barrit**
  - http:/rsb.org
- **Gerry Ostheimer (SE4ALL, Novozymes)**
- **Some presentation slides from Dr. Jonathan Male, BETO, USDOE**
- **Some presentation slides from Tom Foust, NREL (NABC)**