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New Directions in Fuels Technology

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Panel on New Directions in Engines & Fuels
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Strategy, Integration & Spec. Businesses

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Transportation Fuels Bottom Line

- All fuels have real economic and social costs and benefits; scale matters
- Liquid fuels compatible with current powertrains & energy infrastructure are near term answer
- Energy efficient vehicles are needed regardless of fuel
- Real commitment to improving energy security precludes taking any energy option off the table
- Long term, electricity offers primary energy diversification to transportation beyond oil & liquid biofuels
- Technology & innovation will drive the fuels of the future

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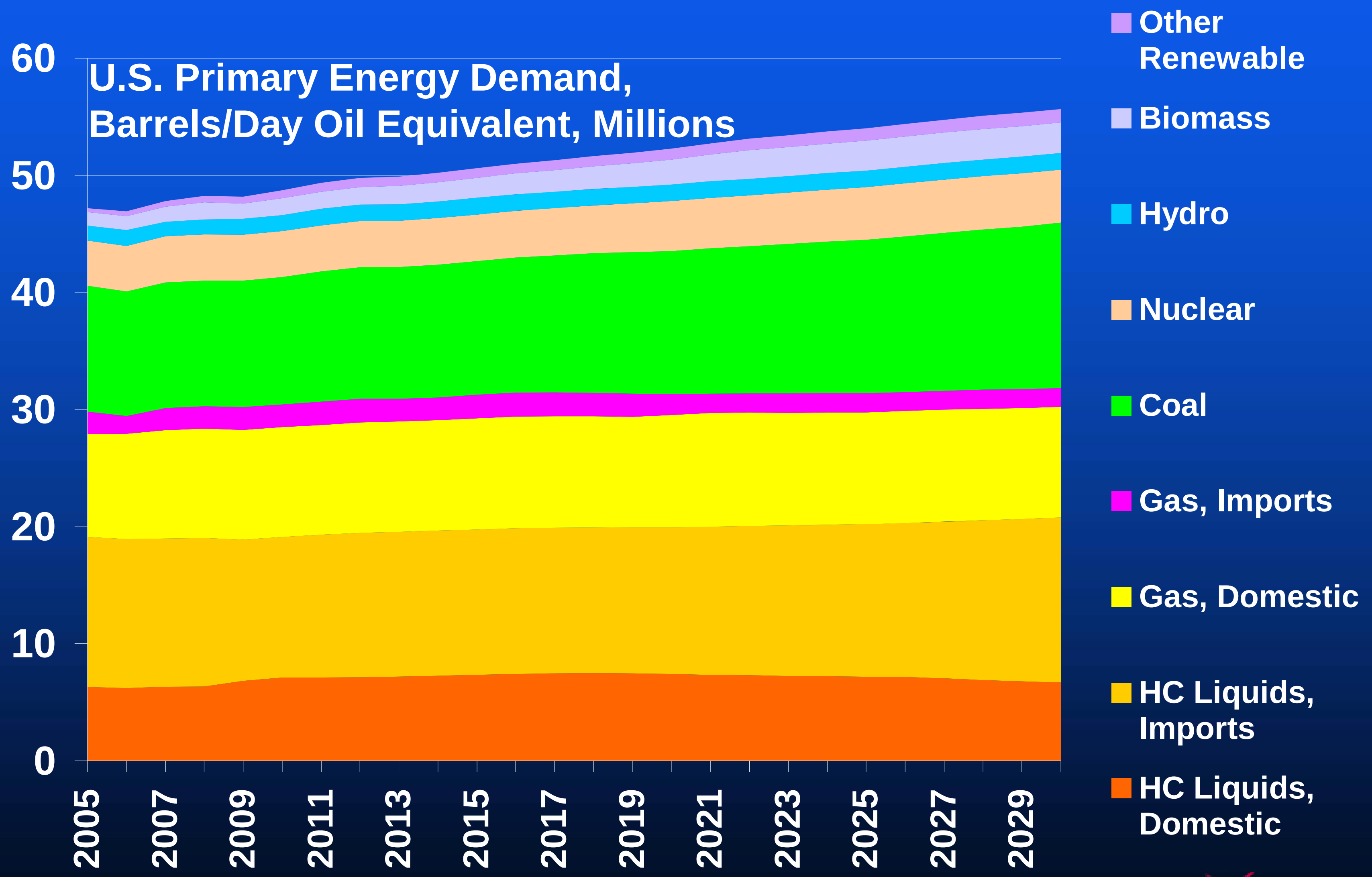
All Fuels Have Pros & Cons
They Become Evident at Large Scale

Selected Criteria	Petroleum-Derived Fuels	Bio-Derived Liquid Fuels	Electricity (Coal)	Hydrogen (Natural Gas)
Energy Security	Red	Yellow	Green	Yellow
Weather Vulnerability	Yellow	Red	Green	Yellow
In Use Fleet Compatibility	Green	Yellow	Red	Red
Infrastructure Readiness	Green	Yellow	Yellow	Red
CO_2 Intensity	Yellow	Yellow	Red	Yellow
Land Use Effects	Green	Yellow	Yellow	Green

Red: Concern | Yellow: Potential Concern | Green: Minimal Concern

Moving Toward Energy Security Precludes Taking Energy Options Off the Table



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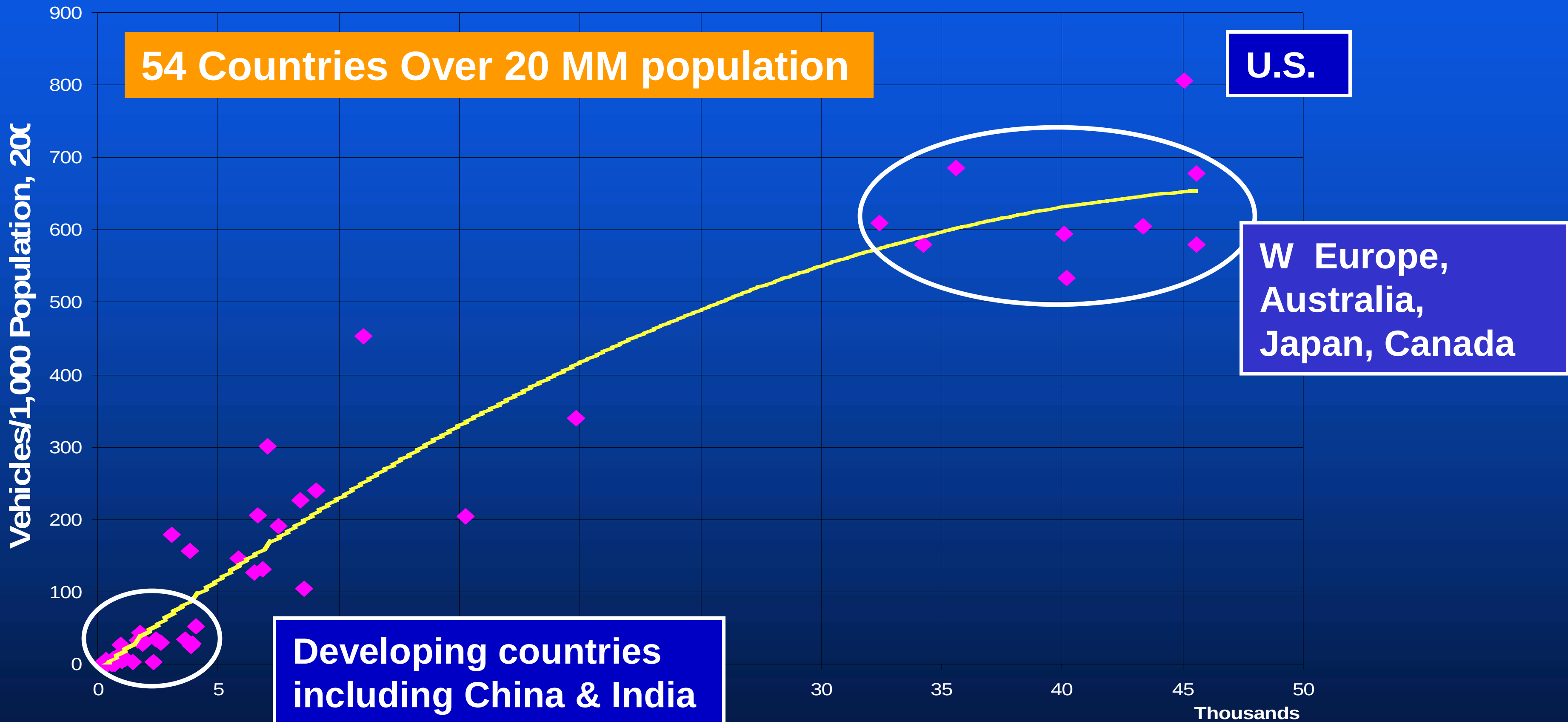
Source: AEO 2008 Revised Early Release Reference Case, March 2008

Economic Development Enables Personal Vehicle Ownership

Vehicles In Operation per 1,000 population, 2007



GDP Per Capita, '000s UD, 2007

Sources: United Nations statistics & WardsAuto.com

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Technology Focus Areas Within COP

Coal/CTL & Gasification

- Coal
- E-Gas
- Syn Gas
- CTL

Challenged Resources

- Shale
- Hydrates
- Arctic
- LNG
- Challenged gas (tight, stranded, sour)

Core Upstream

- Reliability & Integrity
- Exploration Improvements
- Production Opt
- Integrated Surveillance & Performance
- Improved Recovery

Core Downstream

- Advanced Hydrocarbon Fuels
- Refinery Processing
- Catalyst Evaluation
- Sulfur Removal Technology
- Process H_2
- Enhanced Reliability

Biofuels

- 1st Gen
- 2nd Gen

Alternative Energy

- Batteries
- Geothermal
- Solar
- Wind
- Ocean
- Fuel Cells
- Novel H_2
- Nuclear

Heavy Oil

Environmental Technology

CO_2 Water Environment – License to Operate

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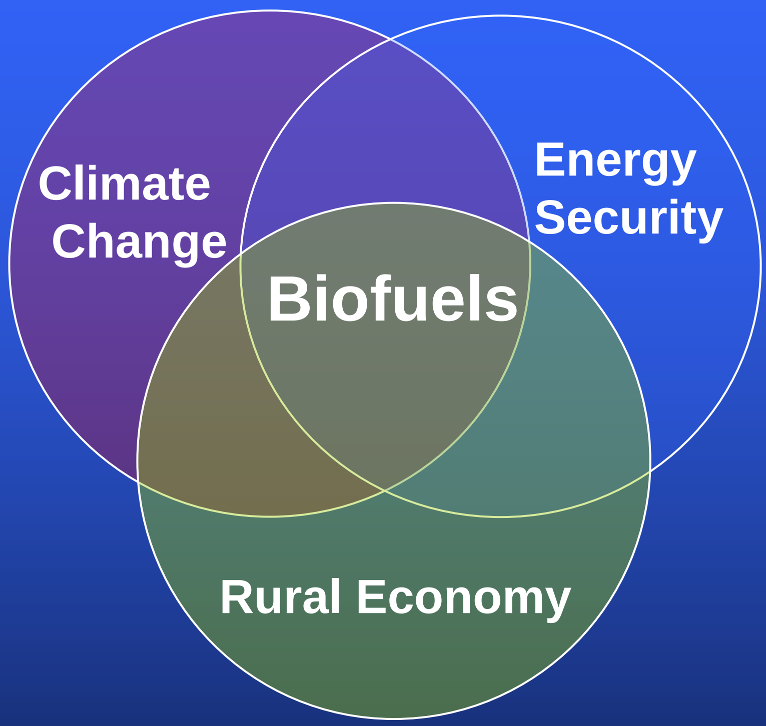
Why Biofuels?



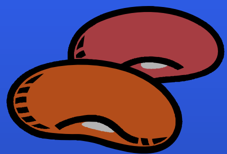
Incentives
- Federal
- State
- Local

Mandates
- Federal
- State
- Local

Biofuels are a critical <u>part</u> of the energy future, but are not the <u>only</u> solution

Quantity Challenges of Biomass

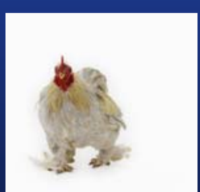
19 Bushels Corn



42 Bushels of Soybeans

2 Cows

14 Pigs



900 Chickens

900 lb of biomass

= **1 Barrel of Fuel**

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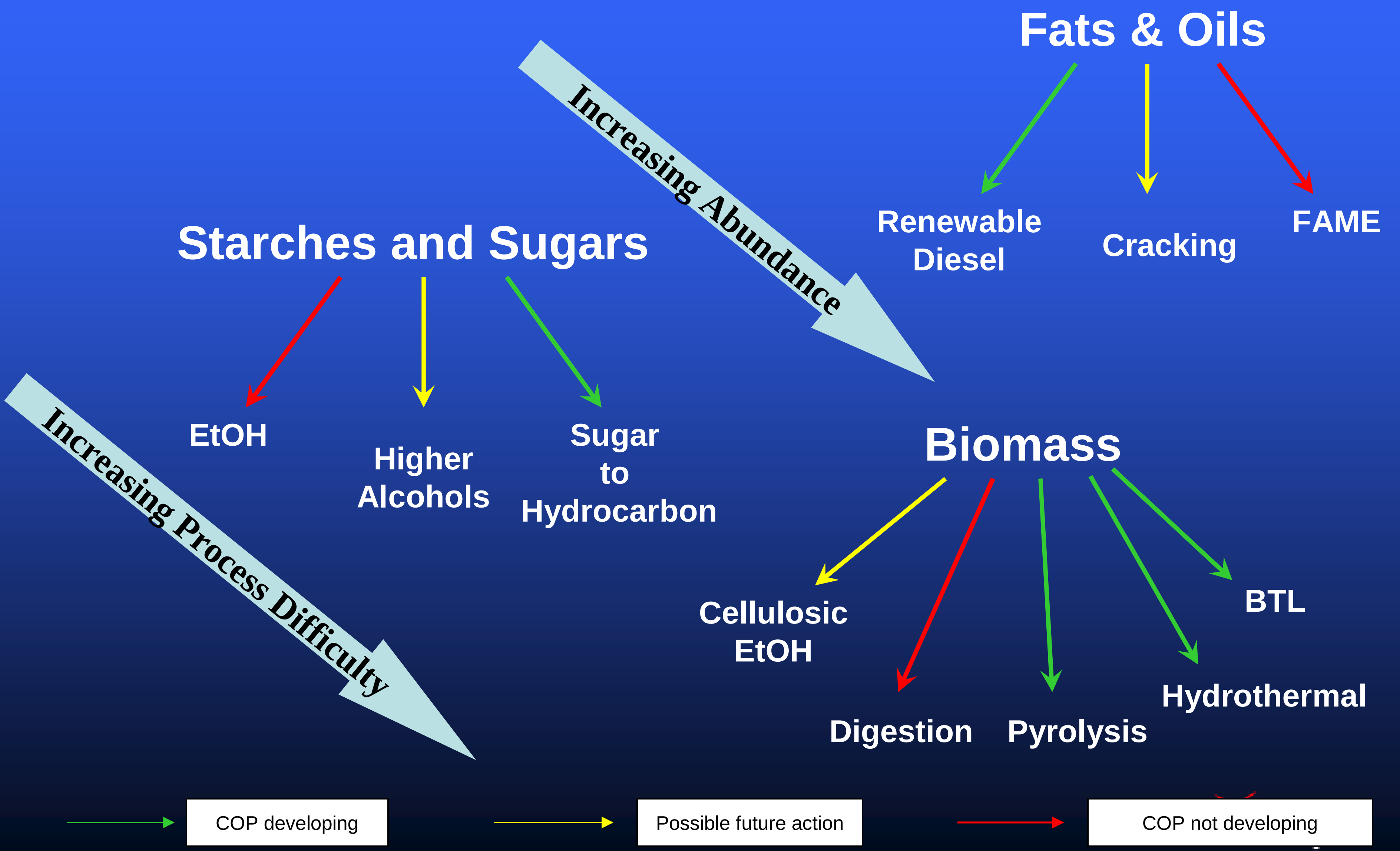
Biofuel Pathways



COP Funded Research Areas

- Renewable Diesel
  - Commercialized refinery co-processing of oils/fats with distillates in 2007
- Biocrude Development Program
  - Developing technology to produce transportation fuels from biomass
  - ADM-COP joint program to commercialize technology by 2013
- COP Biofuels Algae program
  - Conducting research necessary for development of a long term position on algae as a renewable fuel feedstock
  - Leveraging internal expertise on oil extraction & oil conversion with externally sponsored algae research
  - Member of Colorado Center for Biorefining & Biofuels (C2B2) consortium
- Biomass Gasification R&D
  - Member of NREL-ISU-COP collaboration
  - Conducting multiple programs at Iowa State University through 2014
  - Plan to demonstrate integrated BTL pilot plant (0.5 TPD)
- CRC (Coordinating Research Council) Participation
  - AVFL Committee: Gasoline HCCI, diesel HCCI, E20, & biofuels research
  - FACE: Develop and characterize fuels for advanced combustion engines

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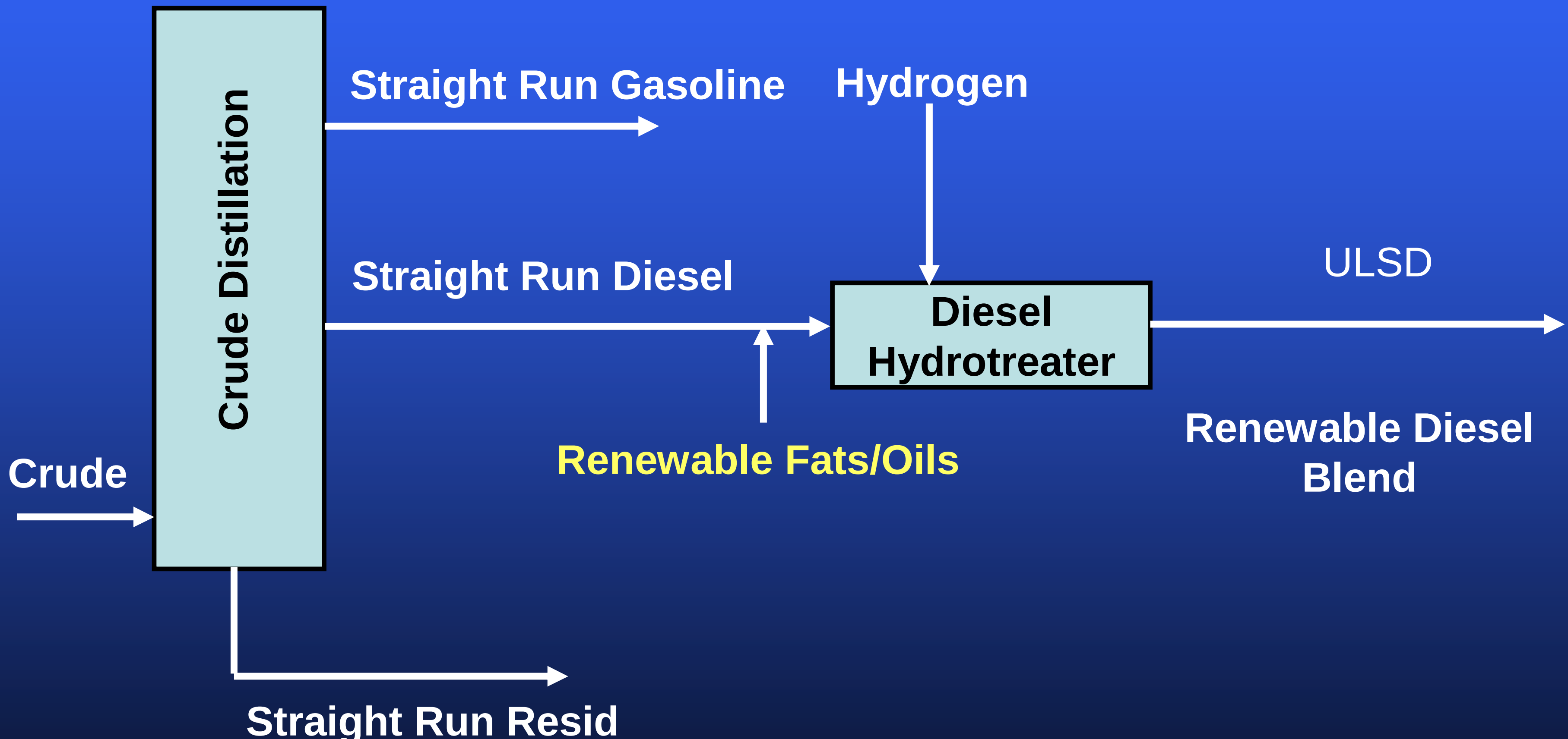
Renewable Diesel Process



Note: Over 100 million gallons of fats and oils have been processed into renewable diesel worldwide by COP & others.

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Relative CO_2 Life Cycle Emissions

	Petroleum Diesel	Biodiesel B100	Renewable Diesel R100
COP **(substitution, soy)**	100%	59%	44%
UOP (mass allocation, soy)	100%	43%	26%
NExBTL® (substitution, rapeseed)	100%	60%	31%
GREET Model **(energy allocation, soy)**	100%	32%	26%

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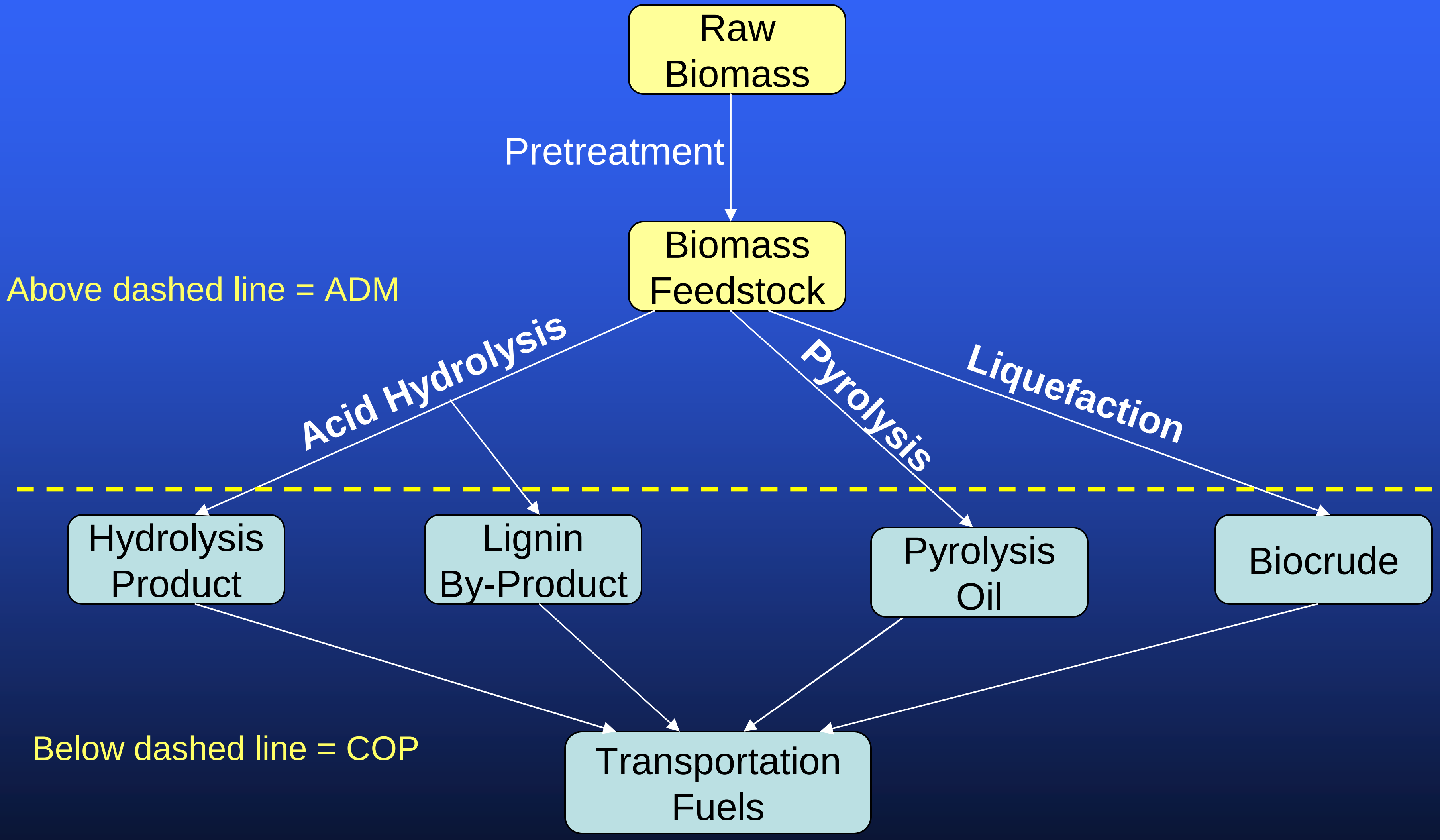
ADM-COP Biomass Conversion Pathways



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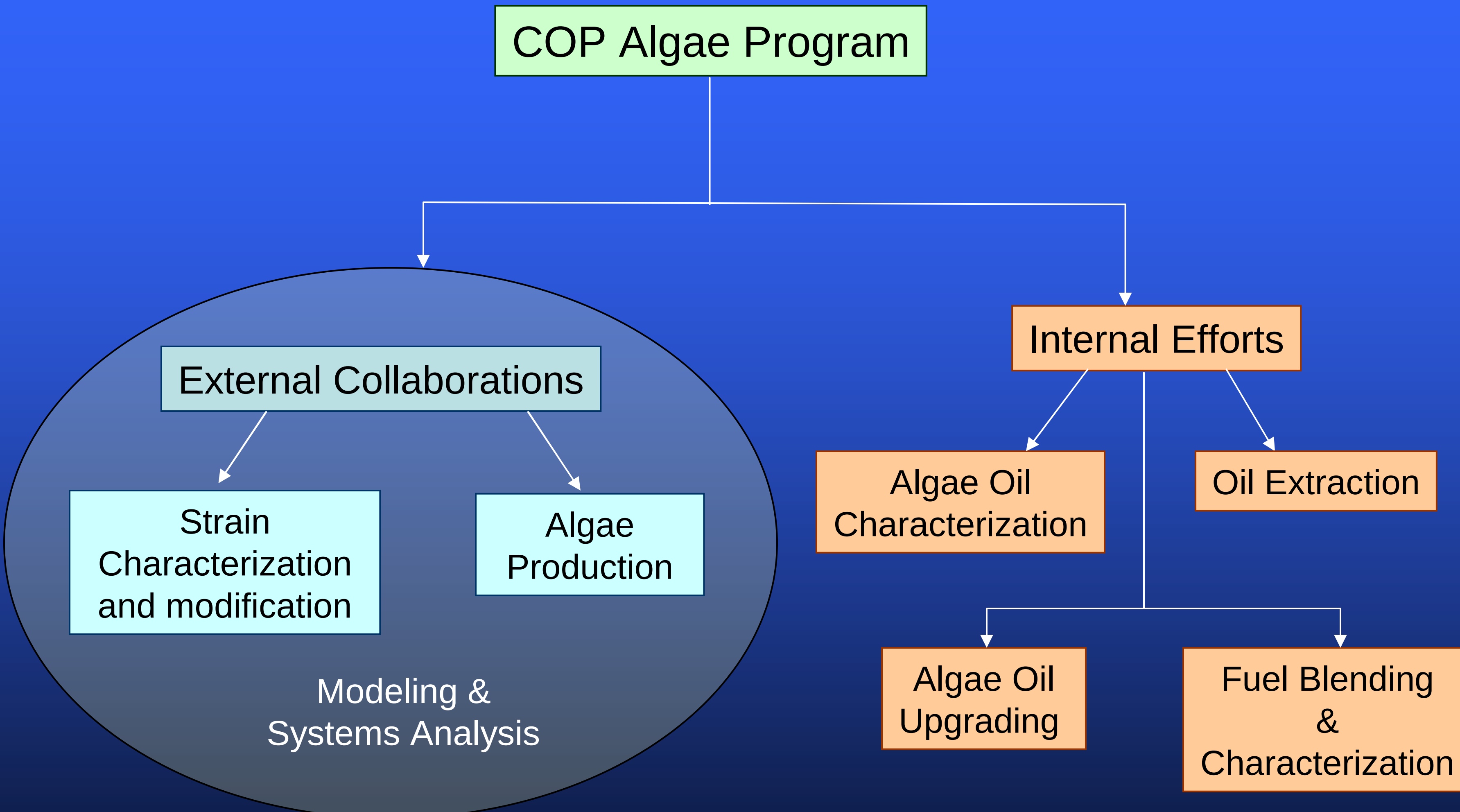
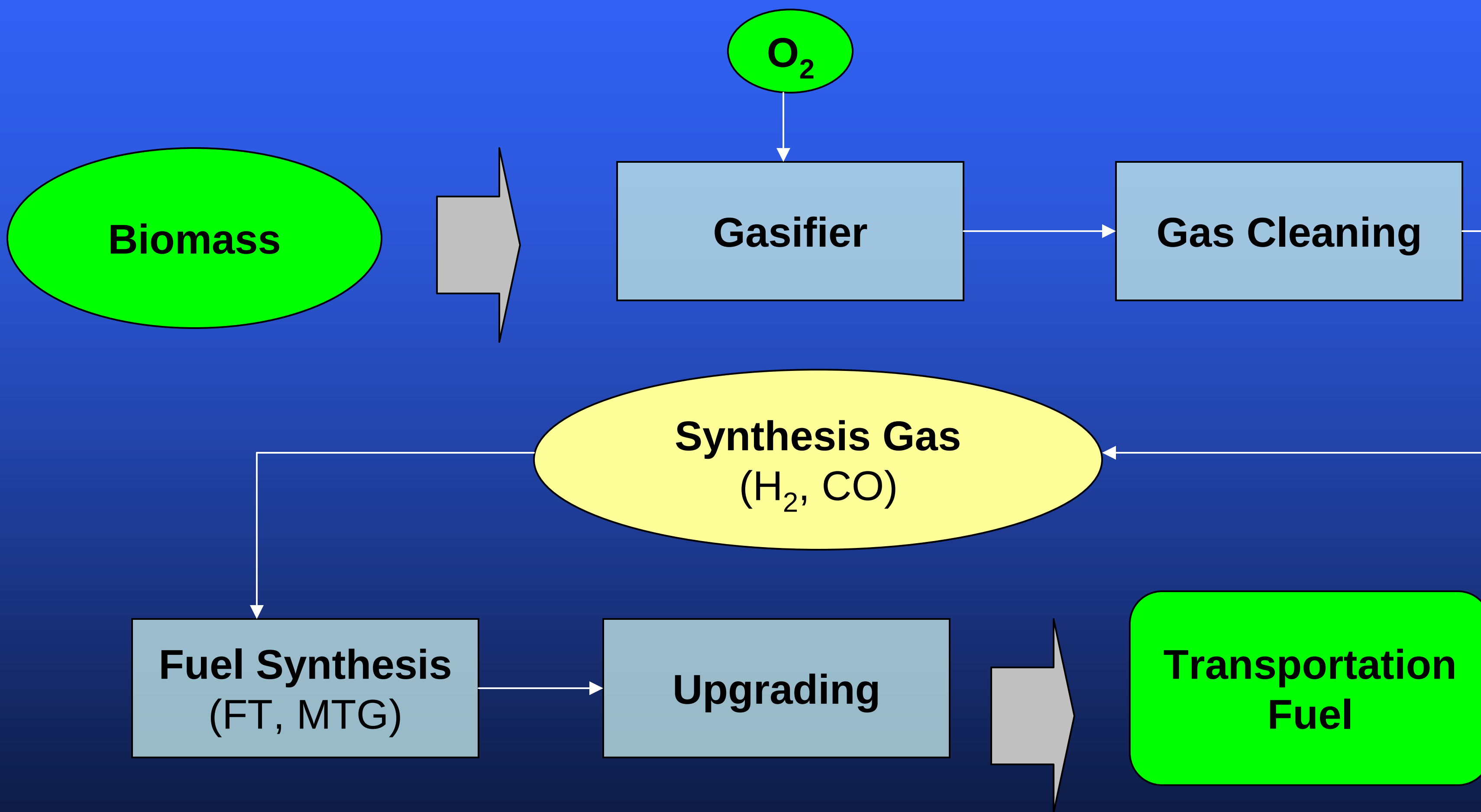

COP Algae Program
External Collaborations
Strain Characterization and modification
Algae Production
Modeling & Systems Analysis
Internal Efforts
Algae Oil Characterization
Oil Extraction
Algae Oil Upgrading
Fuel Blending & Characterization

Biomass Gasification (BTL)



Closing Thoughts

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How do we meet the challenges?

- Diversify supply
  - Oil, Gas, Coal will still provide most energy
  - Biofuels and Renewables are a vital part of the mix
- Improve Energy Efficiency
  - Transport, Residential and Industrial
  - Within our industry
- Develop new technologies
  - Improve conventional oil and gas
  - Recover unconventional from oil sands to shale to hydrates
  - Focus new technology to convert biomass to fuel
- Protect the environment
  - Lower the footprint of our operations
  - Address climate change issues


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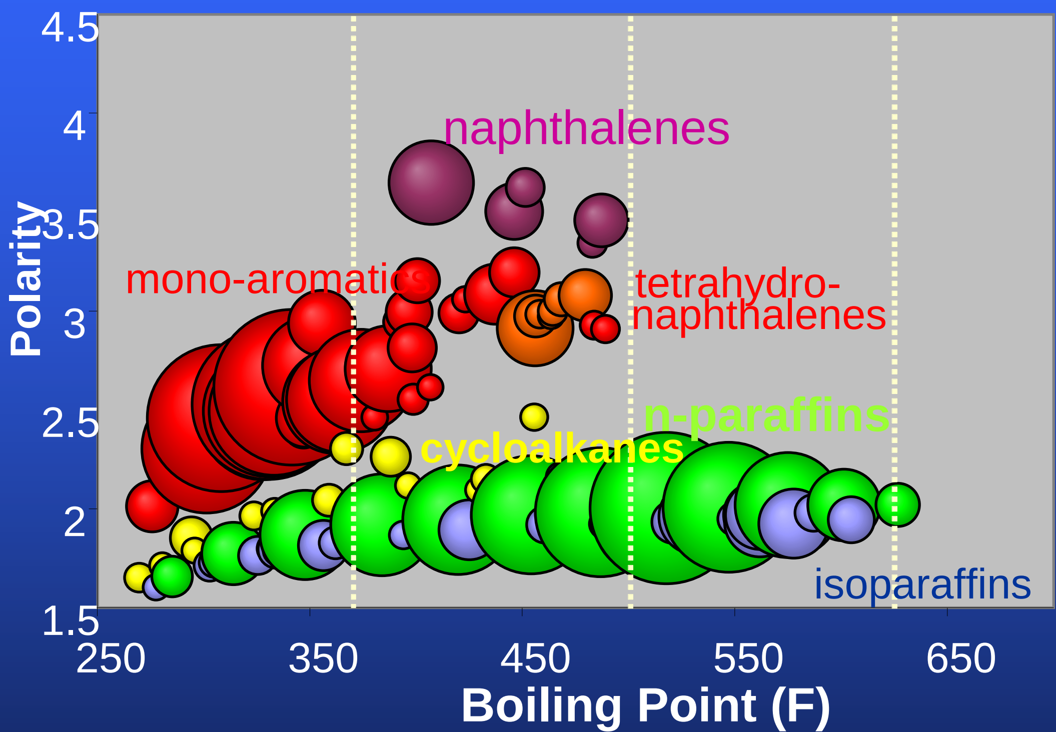
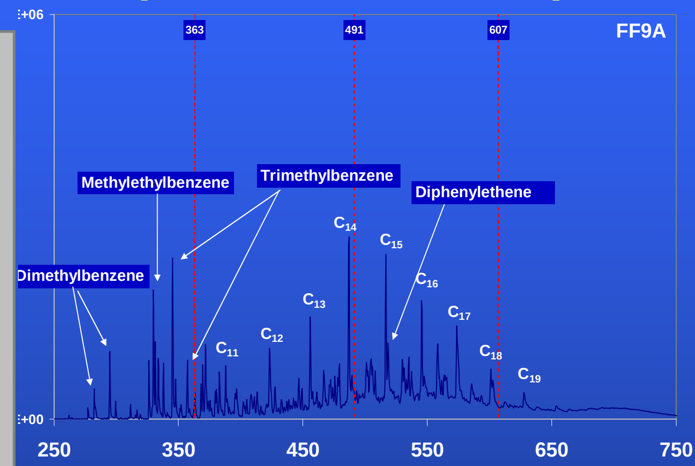
Backup Slides

Coordinating Research Council is Developing Test Fuels for advanced combustion in their FACE (Fuels for Advanced Combustion Engines) Work Group





%of total mass	n-paraffins	Iso-paraffins	Cyclo-alkanes	aromatics
0-300 °F	1.2	4.5	1.3	20.0
301-400 °F	3.1	7.3	1.7	11.8
401-500 °F	4.1	13.8	2.1	10.5
501-end °F	2.6	10.3	2.5	1.5
TOTALS	**11.0**	**35.9**	**7.6**	**43.8**

- **Fuel design & individual species information.**
- **Info on grouping and visualization of chemical families by boiling point or carbon number.**
- **Data reduced to tabular form for use in correlations to combustion data.**
- **Example: FACE Diesel No. 9 shown here.**

Oak Ridge National Laboratory

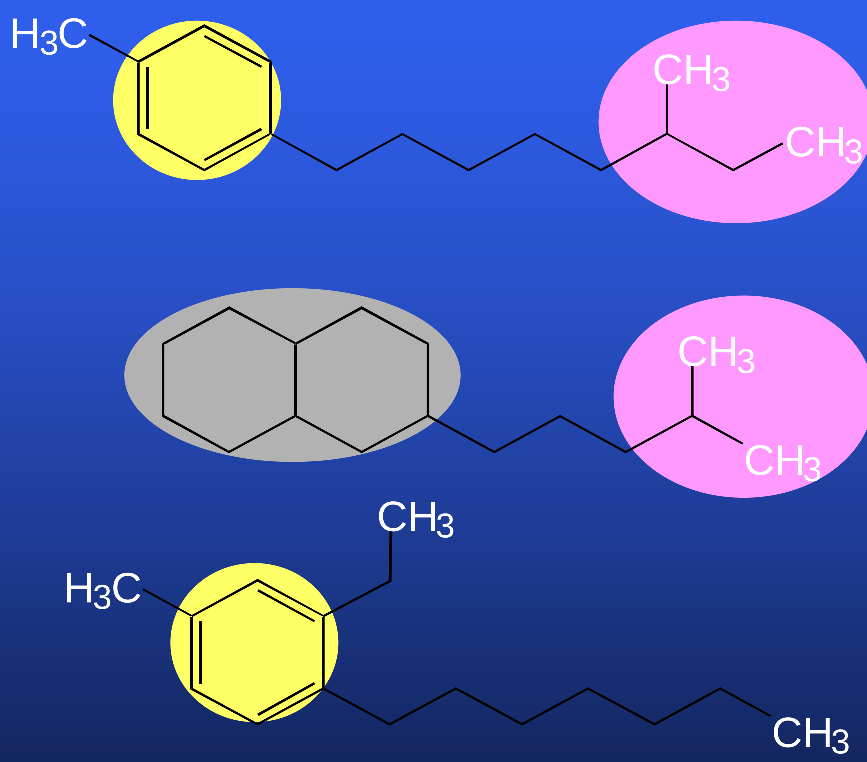
NCUT National Centre for Upgrading Technology

CRC AVFL (Advanced Vehicle/Fuel/Lubricants) Committee is testing gasoline & diesel HCCI fuels and developing new diesel surrogates

Carbon type	Content (mole%)	
	Calculated	Measured
Aromatic	25	23
Cycloparaffinic	21	25
Branched Paraffin	15	17
Paraffin Chain (C1+)	40	36
Olefin	0	0
C=O*	0	0
Total	100	100

Parameter	Calculated	Measured
Ar Cluster size (#carbons)	6	7
Cy Cluster size (#carbons)	10	11
Chain length	5.0	4.8

Example of branch chain characterization that can be used to replicate a fuel with a limited number of surrogate compounds



- **Useful in visualizing relative importance of carbon structures to the bulk makeup of the fuel; example here is for 16 carbon chain.**
- **May be useful in formulating kinetic surrogate fuels.**

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