Virent is Replacing Crude Oil.

CAAFI SOAP- Jet Webinar

March 21, 2014

Agenda

- Introduction
- Feedstock
- Conversion Technology
- Jet Fuel Quality/Testing
- Questions

Presenters

- **Randy Cortright, PhD**
  - Chief Technology Officer and Founder

- **Brice Dally**
  - Senior Process Development Engineer

- **Kevin Kenney**
  - Director Biomass Feedstock National User Facility

- **David Thompson, PhD**
  - Biochemical Engineer, Renewable Resources Distinguished Staff Engineer

- **Cynthia Ginestra, PhD**
  - Aviation Fuels Research Engineer

Introduction

Virent at a Glance

The global leader in catalytic biorefinery research, development, and commercialization

Employees

75+ Employees

Partners & Investors

Cargill

The Coca-Cola Company

HONDA
The Power of Dreams

Technology

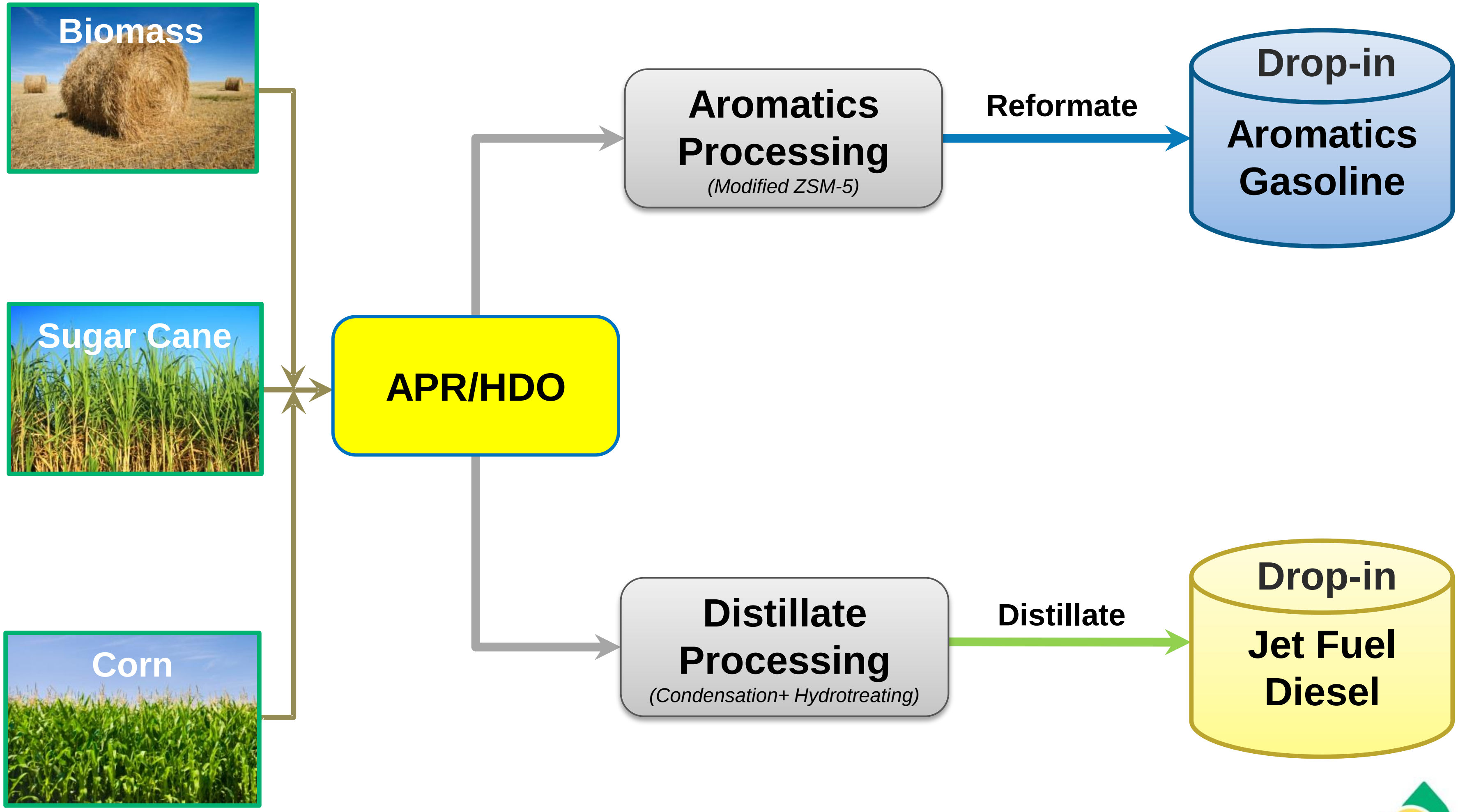
Converting plant-based feedstocks
to fuels and chemicals

Infrastructure

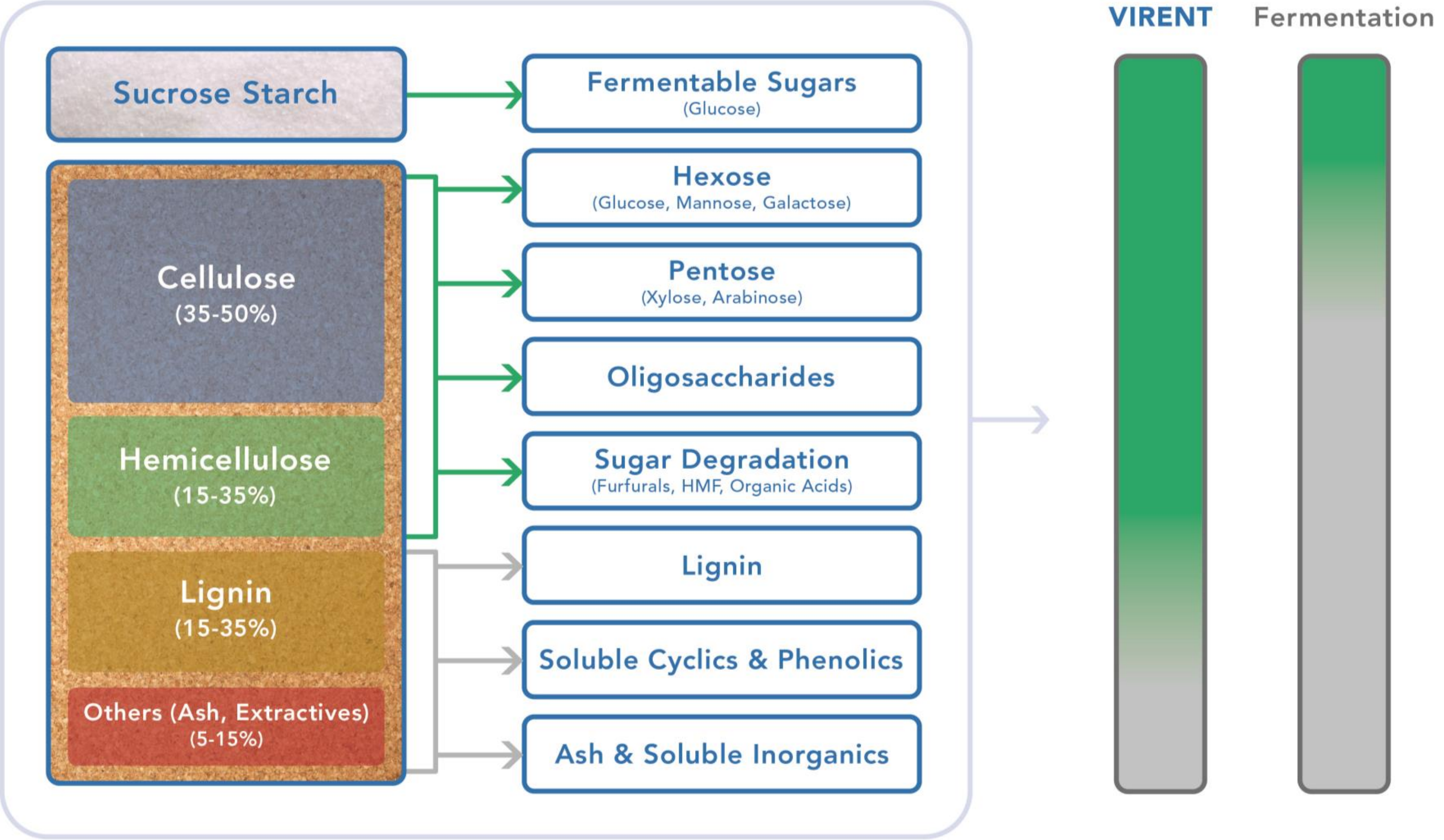
25x Development Pilot Plants
2x Process Plants

The BioForming® Concept

Biobased feedstocks to direct replacement products



BioForming® Feedstock Advantage



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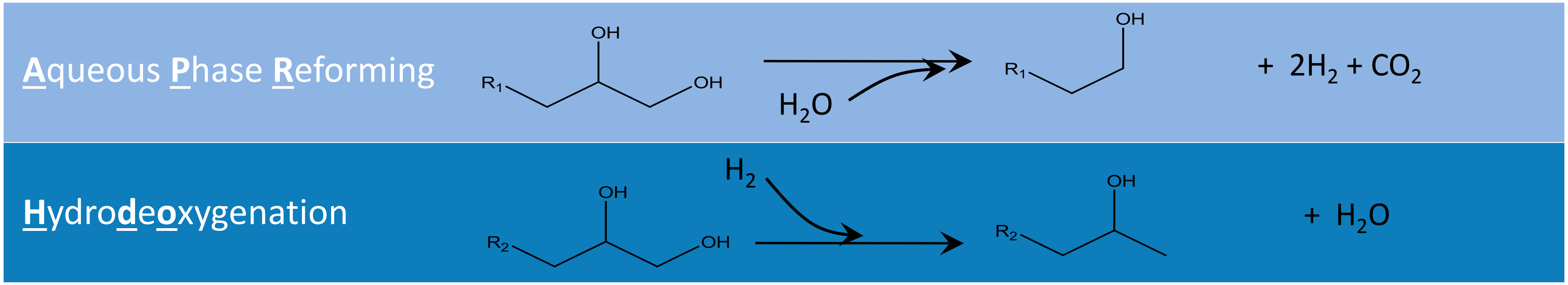
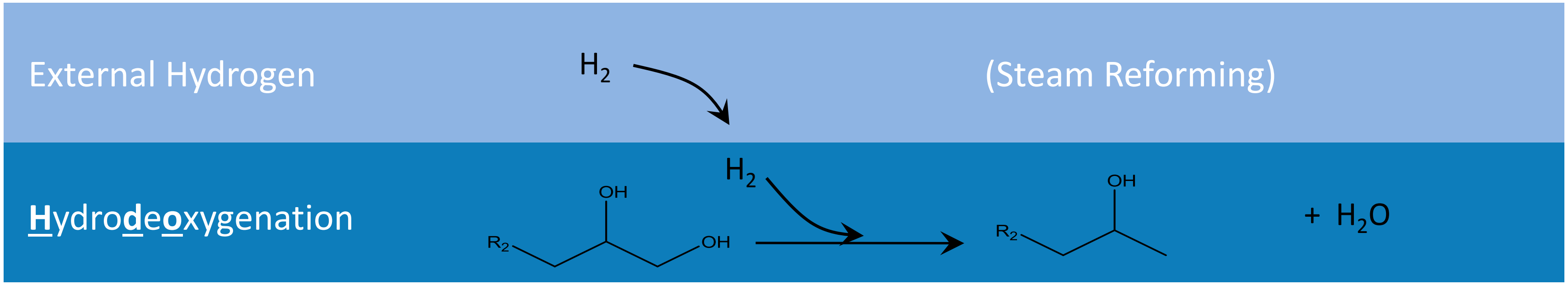
APR/HDO Reaction Pathways

Option 1 : APR (In-Situ H2 Production)


Aqueous Phase Reforming

Hydrodeoxygenation

Option 2 : HDO (Ex-Situ H2 Production)

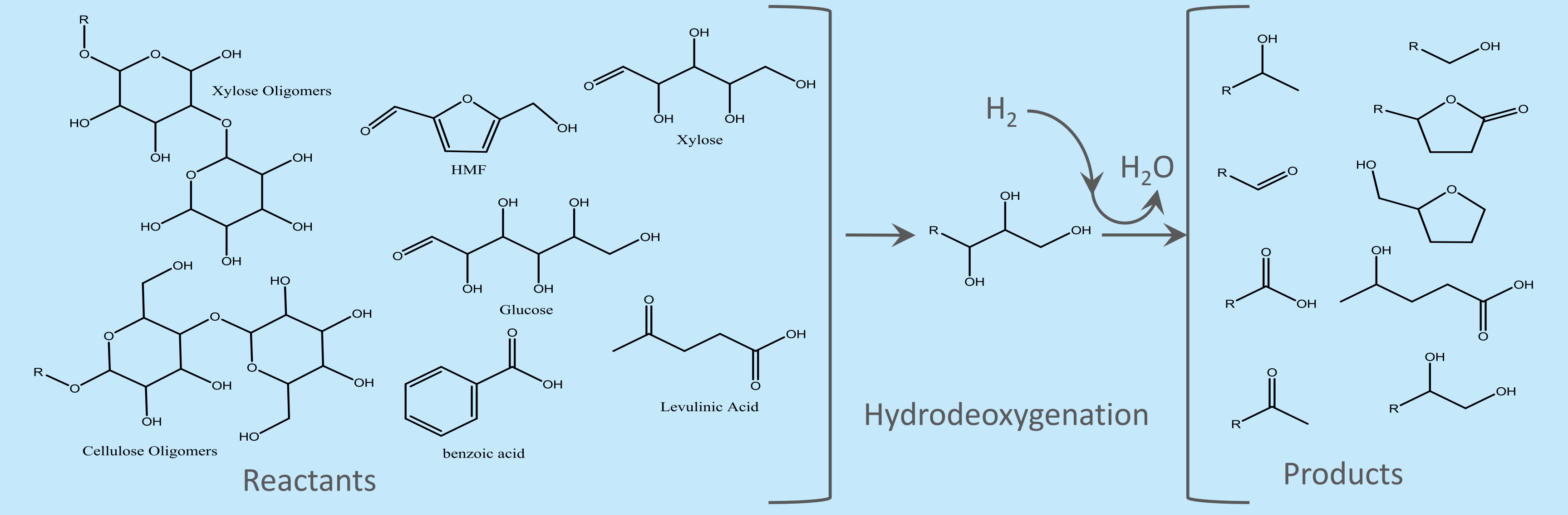

External Hydrogen

(Steam Reforming)

Hydrodeoxygenation

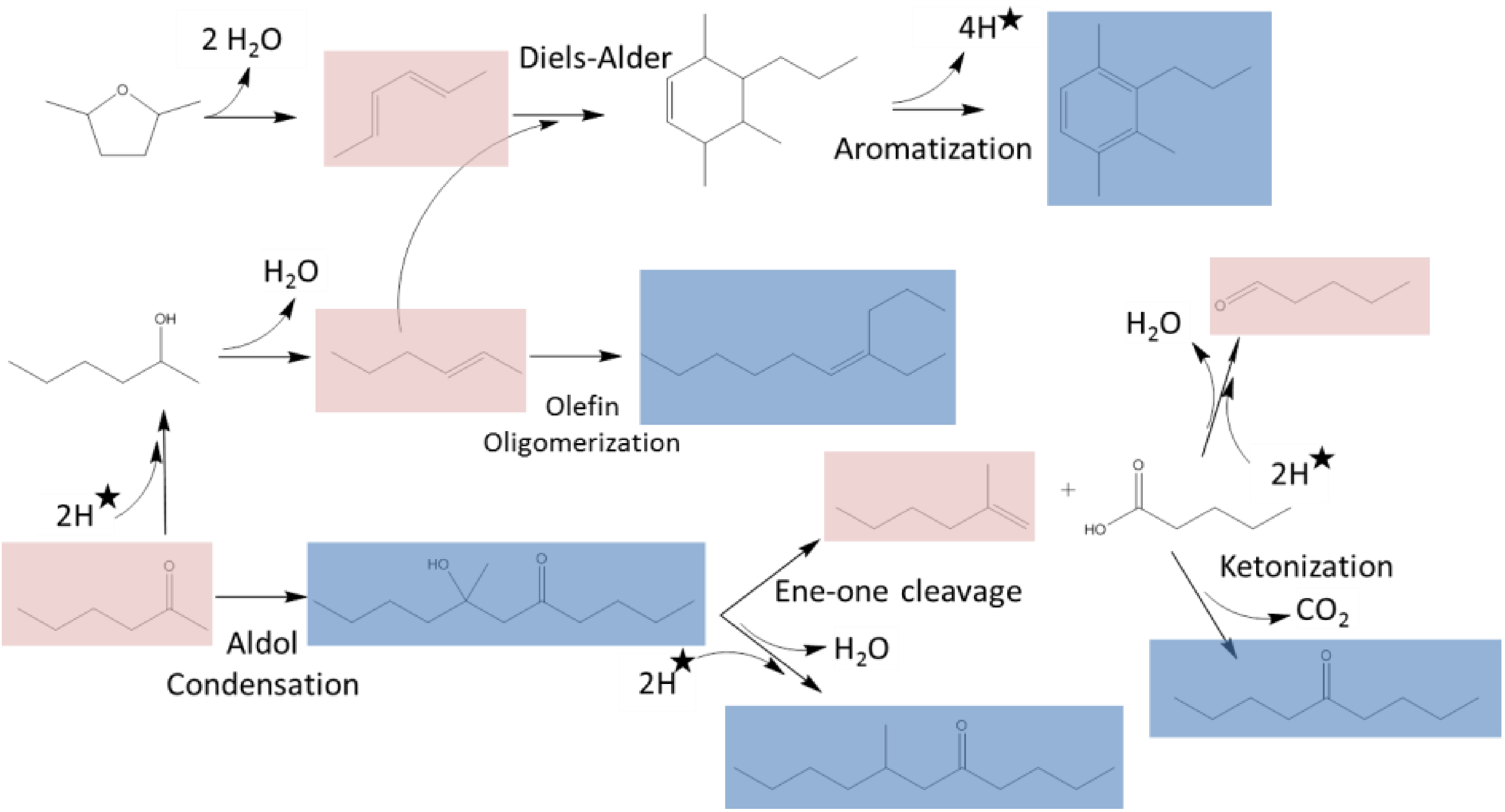
- Decision for APR vs. HDO based on relative cost of carbohydrate feedstock vs. NG
- HDO is currently preferred- cheap NG, improved yield- no loss of carbon to CO2

APR/HDO Reaction Pathways



- Many types of feeds can be used
- Examples : Corn syrup, Sucrose, Sugar Alcohols, Biomass Hydrolyzate
- Diverse mixture of components produced
- Examples : Alcohols, Ketones, Cyclic Ethers, Diols
- Intermediates can be tuned to achieve different final product goals

Condensation Reaction Pathways



DOE CHASE Bio-Oil Award

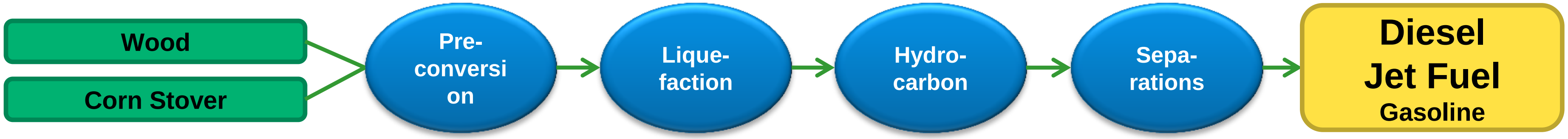
CHASE = Carbon, Hydrogen, and Separation Efficiencies

Project Title: Fractional Multistage Hydrothermal Liquefaction of Biomass and Catalytic Conversion into Hydrocarbons (DE-EE0006286)

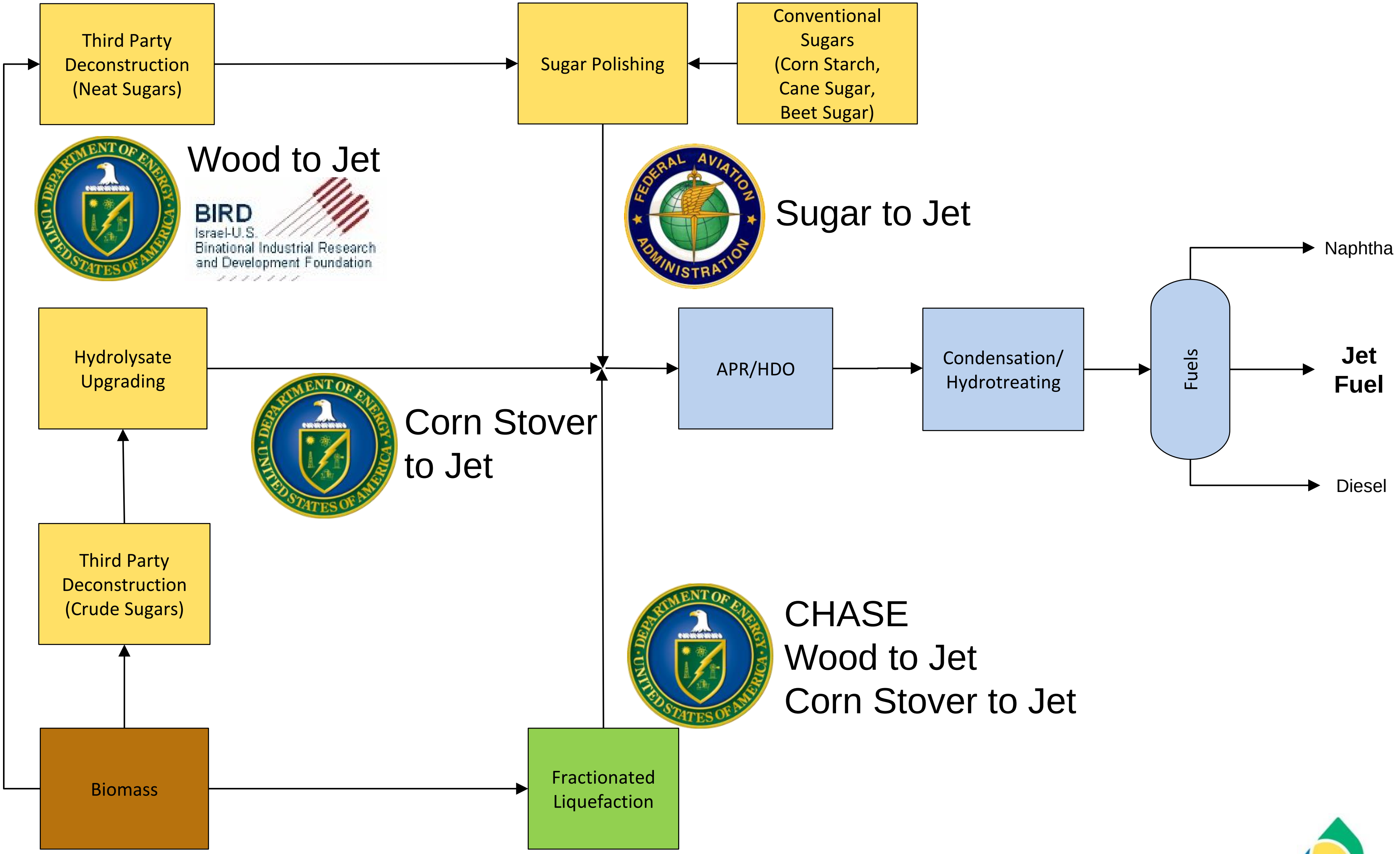
Objectives: Virent intends to develop an improved multistage process for the hydrothermal liquefaction (HTL) of biomass to serve as a new front-end, deconstruction process ideally suited to feed Virent's well-proven catalytic technology, which is already being scaled up. This process will produce water soluble, partially de-oxygenated intermediates that are ideally suited for catalytic finishing to fungible distillate hydrocarbons. Virent will utilize two high impact feedstocks; debarked loblolly pine and corn stover.

Innovation: Novel multistage hydrothermal fractionation and separation process, which improves overall carbon conversion and can be combined with Virent's catalytic BioForming technology platform to produce distillate fuels.

"Project Nighthawk"
(Q4 2013 – Q4 2016)



Virent’s Biomass to Jet Platform



Third Party Deconstruction (Neat Sugars)

Sugar Polishing

Conventional Sugars (Corn Starch, Cane Sugar, Beet Sugar)

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Wood to Jet

BIRD
Israel-U.S.
Binational Industrial Research
and Development Foundation

FEDERAL AVIATION ADMINISTRATION

Sugar to Jet

Hydrolysate Upgrading

APR/HDO

Condensation/ Hydrotreating

Fuels

Naphtha

Jet Fuel

Diesel

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Corn Stover to Jet

Third Party Deconstruction (Crude Sugars)

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

CHASE
Wood to Jet
Corn Stover to Jet

Biomass

Fractionated Liquefaction

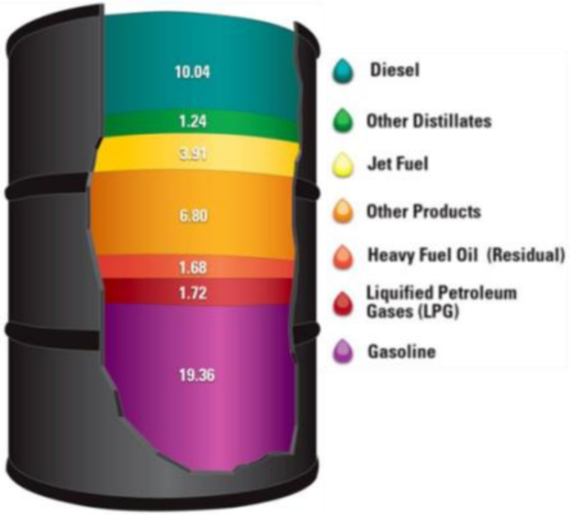
Feedstock

Idaho National Laboratory

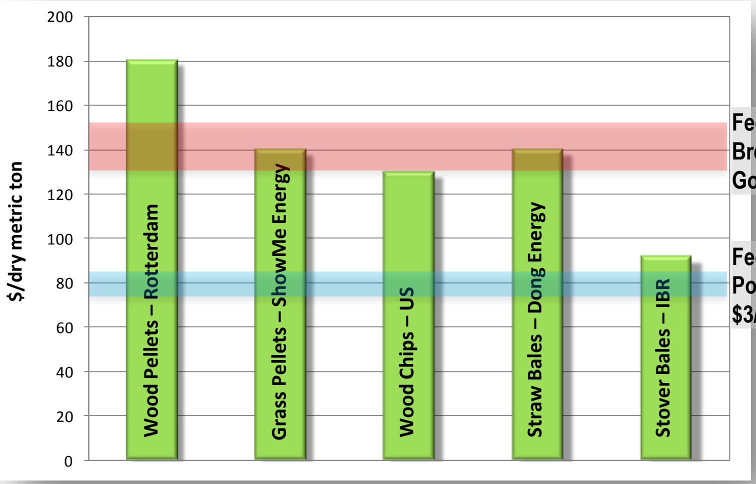
National Challenge

- Replacing the whole barrel
  - US spends $1billion/day on oil imports
  - Reducing dependence on oil requires replacing the whole barrel
  - Climate change mitigation by replacing fossil fuels
- Feedstock costs represent up to one-third current biofuel production costs

Products Made from a Barrel of Crude Oil (Gallons)
(2009)



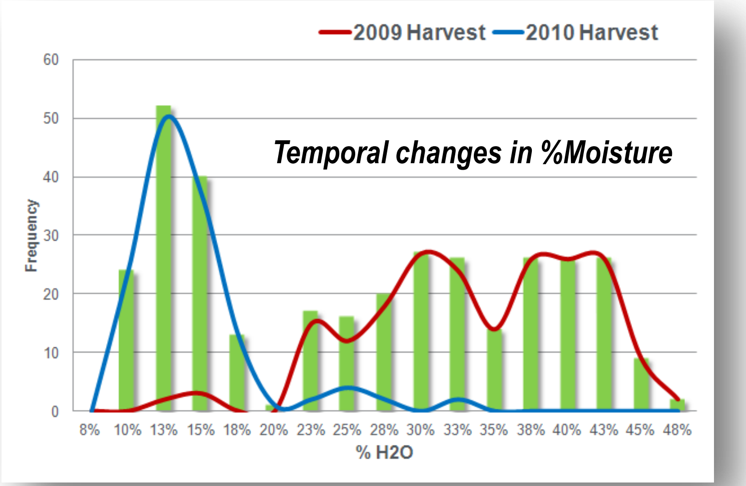
Feedstock Cost Challenge



Feedstock Business Break point to Achieve Going Concern

Feedstock Break Point to Achieve $3/gal Target

Feedstock Quality Challenge



Hydrocarbon Pathways

FEEDSTOCKS

Terrestrial
- Ag Residues
- Pulpwood
- Forest Residues
- Dedicated Energy Crops

Algal
- Monocultures
- Polycultures

Municipal Solid Waste
- Construction & Demolition Waste
- Yard Waste
- Food Waste
- Paper/ Cardboard

CHARACTERIZATION

- Composition
- Energy Content
- Moisture
- Ash/Elemental Species
- Particle Size
- Contaminants
- Performance Screening

PREPROCESSING

- Drying
- Size Reduction
- Separations
- Ash Reduction
- Blending

CONVERSION PATHWAYS

- Bio. Fermentation of Sugars
- Catalytic Upgrading of Sugars
- Fast Pyrolysis
- In-Situ Catalytic Fast Pyrolysis
- Ex-Situ Catalytic Fast Pyrolysis
- Syngas Upgrading
- Algal Lipid Upgrading
- Whole Algae Hydro. Liquefaction

CONVERSION INTERMEDIATES

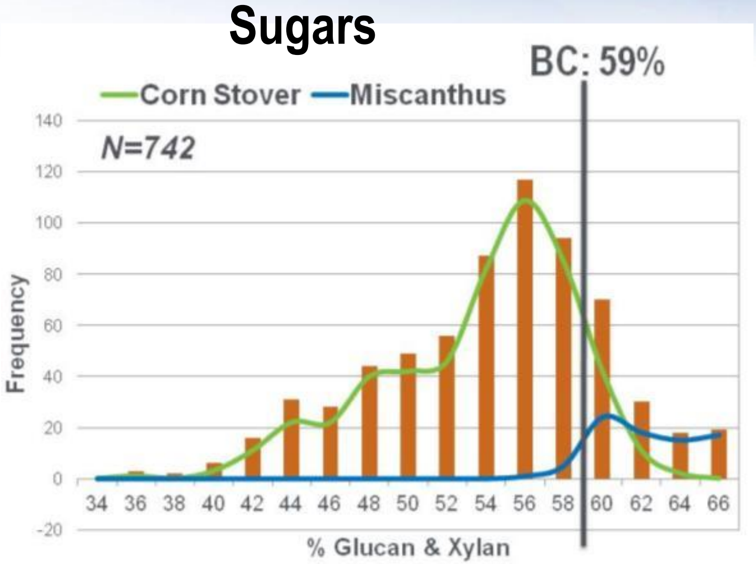
- Syngas
- Bio-Oil

PRODUCTS

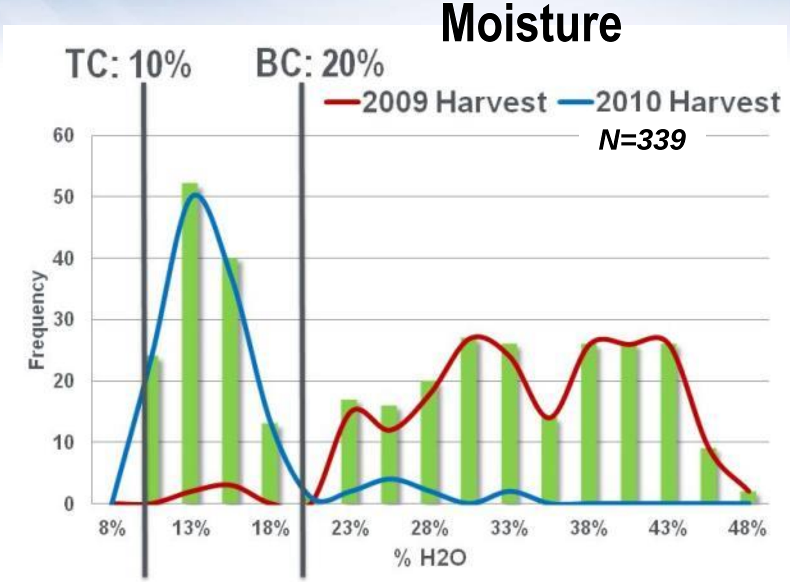
- Hydrocarbon Biofuels (gas, diesel, jet)
- Co-products

Feedstock Quality Challenge

Sugars

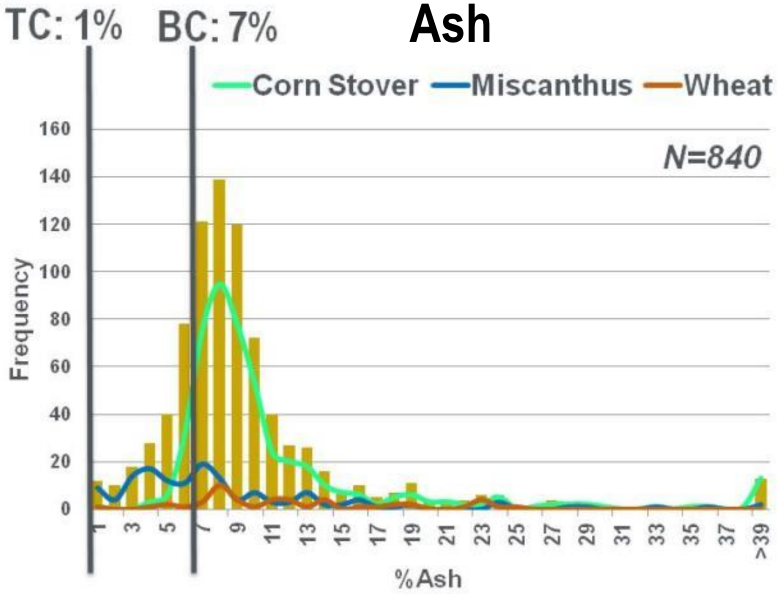


Moisture



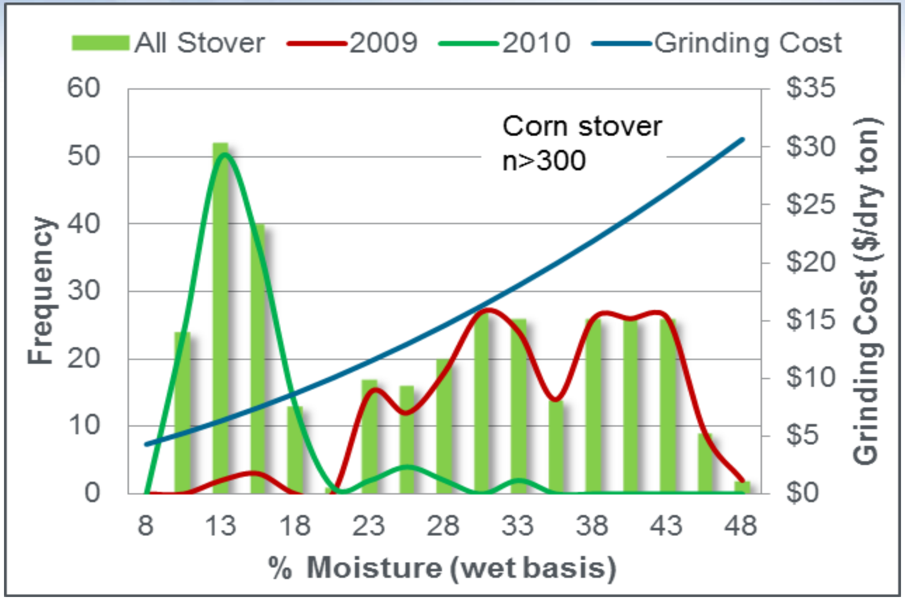
- Conversion specs shown (vertical lines) represent DOE biochem (BC) and thermochem (TC) pathway quality specs
- Distributions represent variability in biomass properties relative to spec
- Distributions likely greater if broader range of resources are considered
- Illustrates challenge associated with diversity

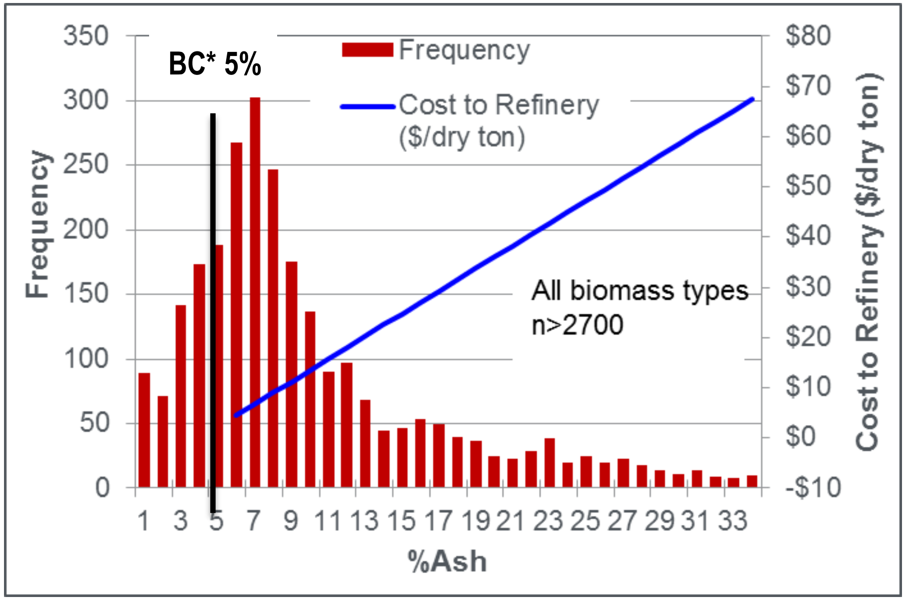
Ash



Impact of Variability

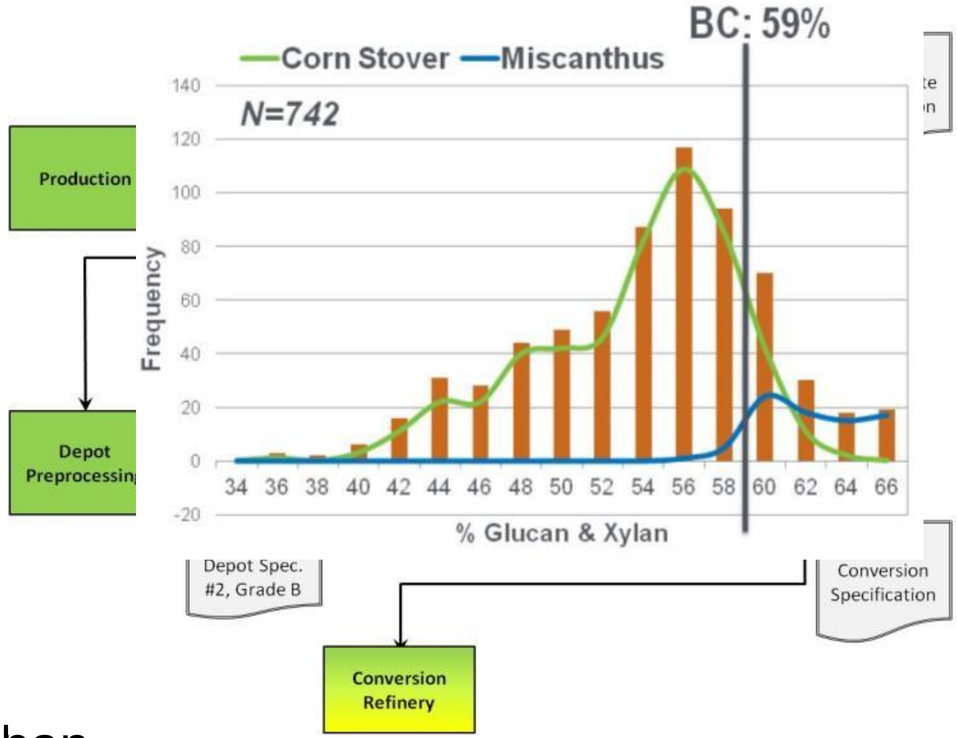
- Challenge: Understanding impacts of variability
  - Supply chain logistics
  - Biomass preprocessing
  - Conversion performance
- Our Approach
  - Logistics modeling & sensitivity analysis
  - Preprocessing R&D
  - Conversion performance screening





Sources of Variability

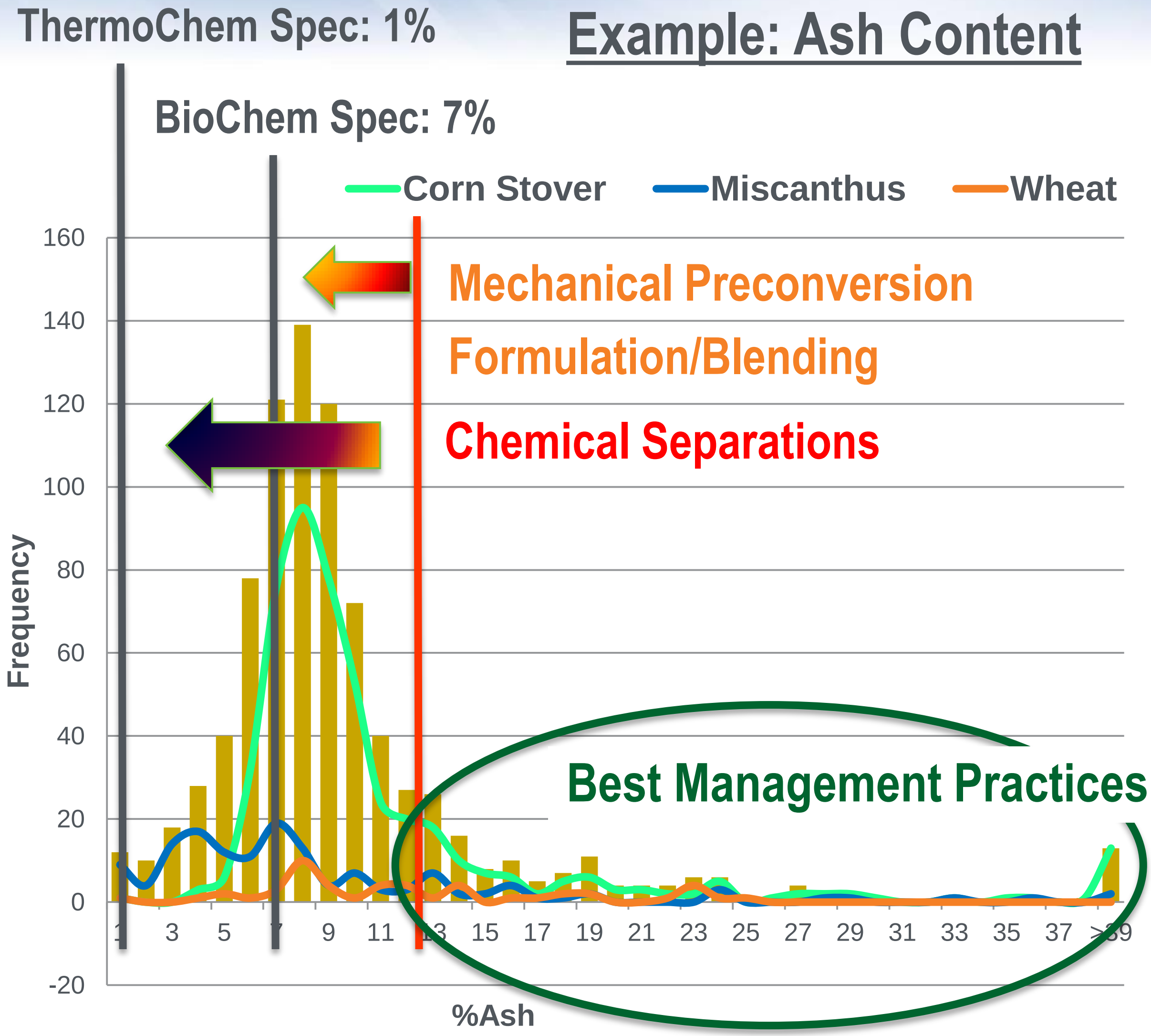
- Challenge: Understanding sources of variability
  - Genetic
    - Feedstock type, variety
  - Environmental
    - Soil type
    - Weather
    - Agronomic practices
  - Annual
  - Supply Chain Practices
- Our Approach
  - Biomass Feedstock Library: database consisting of more than 60,000 samples (and growing)
  - INL biomass field research



Solutions to Variability

- Challenge: Developing cost effective solutions to variability
- Our Approach: a graded approach
  - Best Management Practices
  - Preprocessing Technology R&D

Example: Ash Content



Examples of Ash Reduction to Meet Specifications

- Mechanical separations
  - Screening to separate rocks and soil from biomass
  - Classification by density or color to separate plant tissue fractions
  - Fractional milling to separate size fractions with higher ash
  - Triboelectrostatic separation of finely ground biomass to reduce silica
- Chemical separations
  - Simple washing to remove soil
  - Leaching with water/acid to remove alkali metals/alkaline earth metals
  - Limited structural disruption with hot water or acid to remove cell-bound nitrogen and sulfur
  - Dissolution of silica with alkali
- Formulation strategies
  - Blending the same feedstock from different sources/harvest methods
  - Blending different feedstocks of varying qualities

INL Ash Reduction in Support of Nighthawk

- Nighthawk approach to biomass conversion
  - Fractionate biomass into its individual polymers using various chemistries
  - Utilize fraction-specific reaction conditions and catalysts to convert each fraction to hydrocarbon fuels and chemical intermediates
- Utilize the CPS remove ash and effect structural modifications
  - Goal: Make corn stover look like clean stemwood in a feedstock depot
  - Simple washing or mechanical screening to remove soil
  - Dissolution of silica and lignin with alkali followed by lignin recovery
  - Additional structural disruption with dilute acid to remove cell-bound nitrogen and sulfur together with alkali metals & alkaline earth metals
- Advantages over direct hydrothermal fraction
  - Fouling agents removed before reaching conversion facility
  - Less non-convertible material delivered to conversion facility
  - Less severe fractionation conditions required at conversion facility

INL Chemical Preconversion System (CPS)

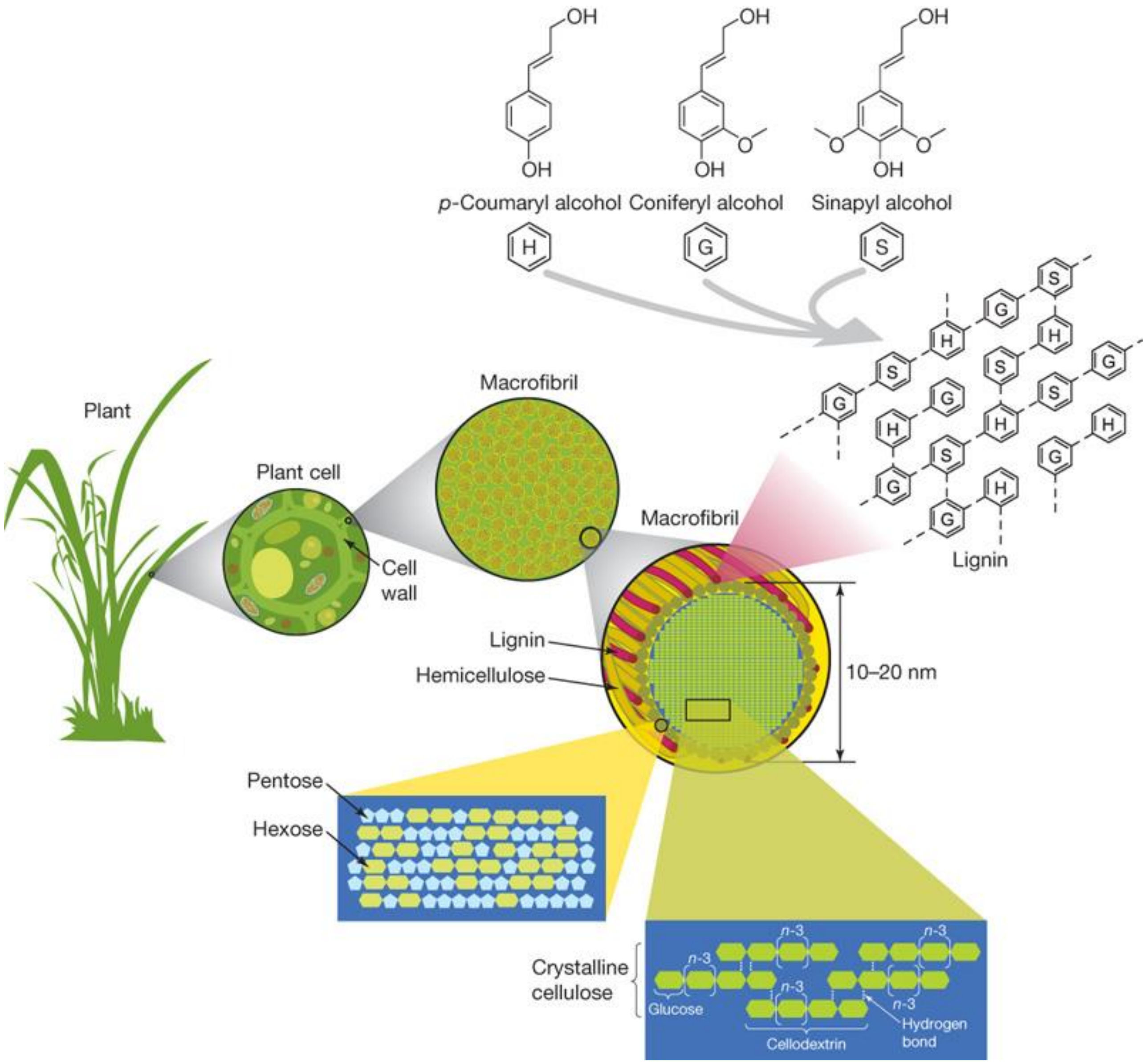
- Designed to effect limited structural modifications
  - Structural ash removal
  - Reduced grinding & pelleting energy usage
- Unique in its applicability to
  - large particle sizes
  - low bulk densities
  - high or low pressure operation
  - high or low temperature operation
  - widely varying chemistries

10/02/2013

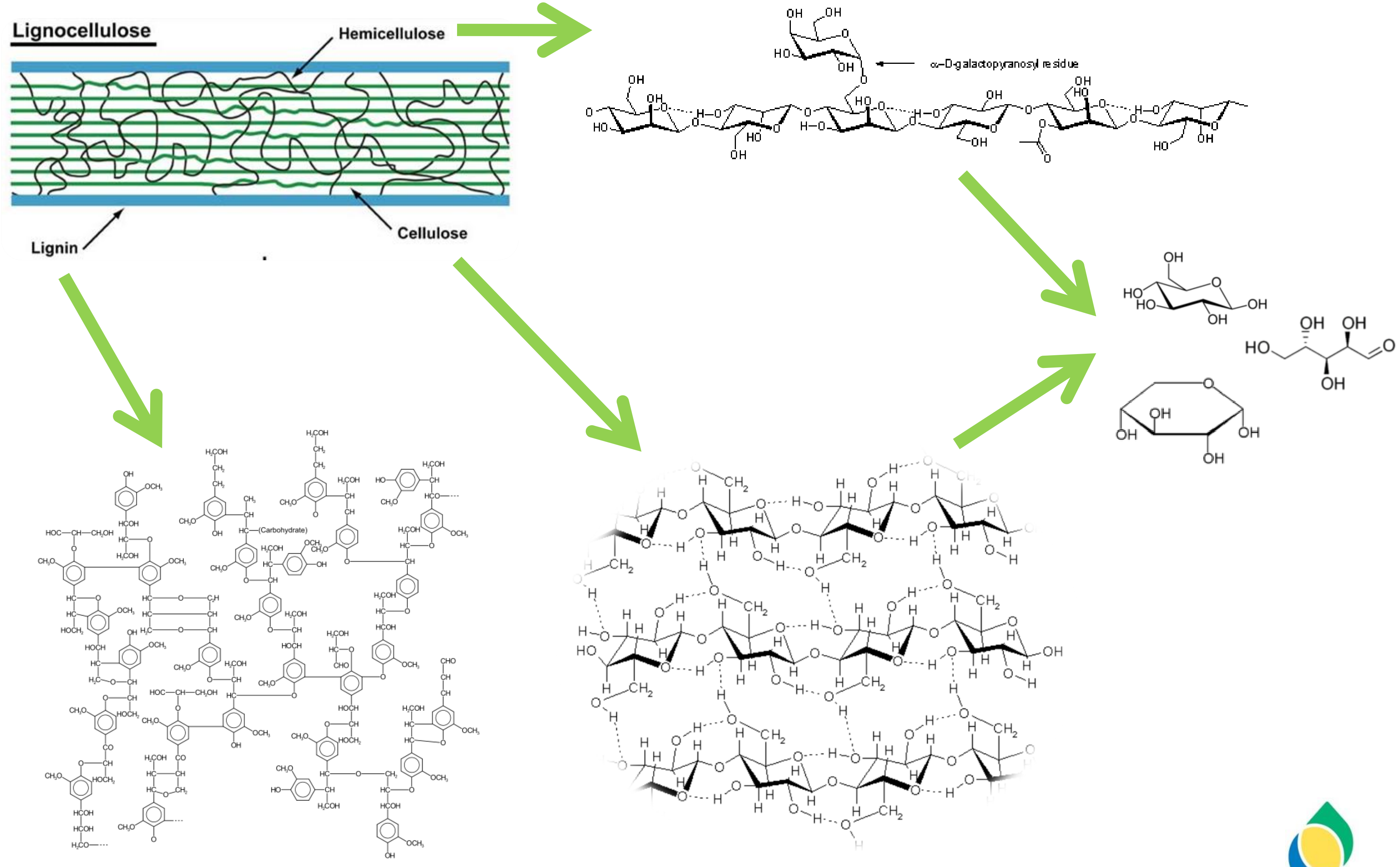
Parameter	Range
Particle size (in)	< 2.0
Temperature range (°C)	40-200
Pressure range (psig)	0-200
pH range	0.5-13.5

Conversion Technology

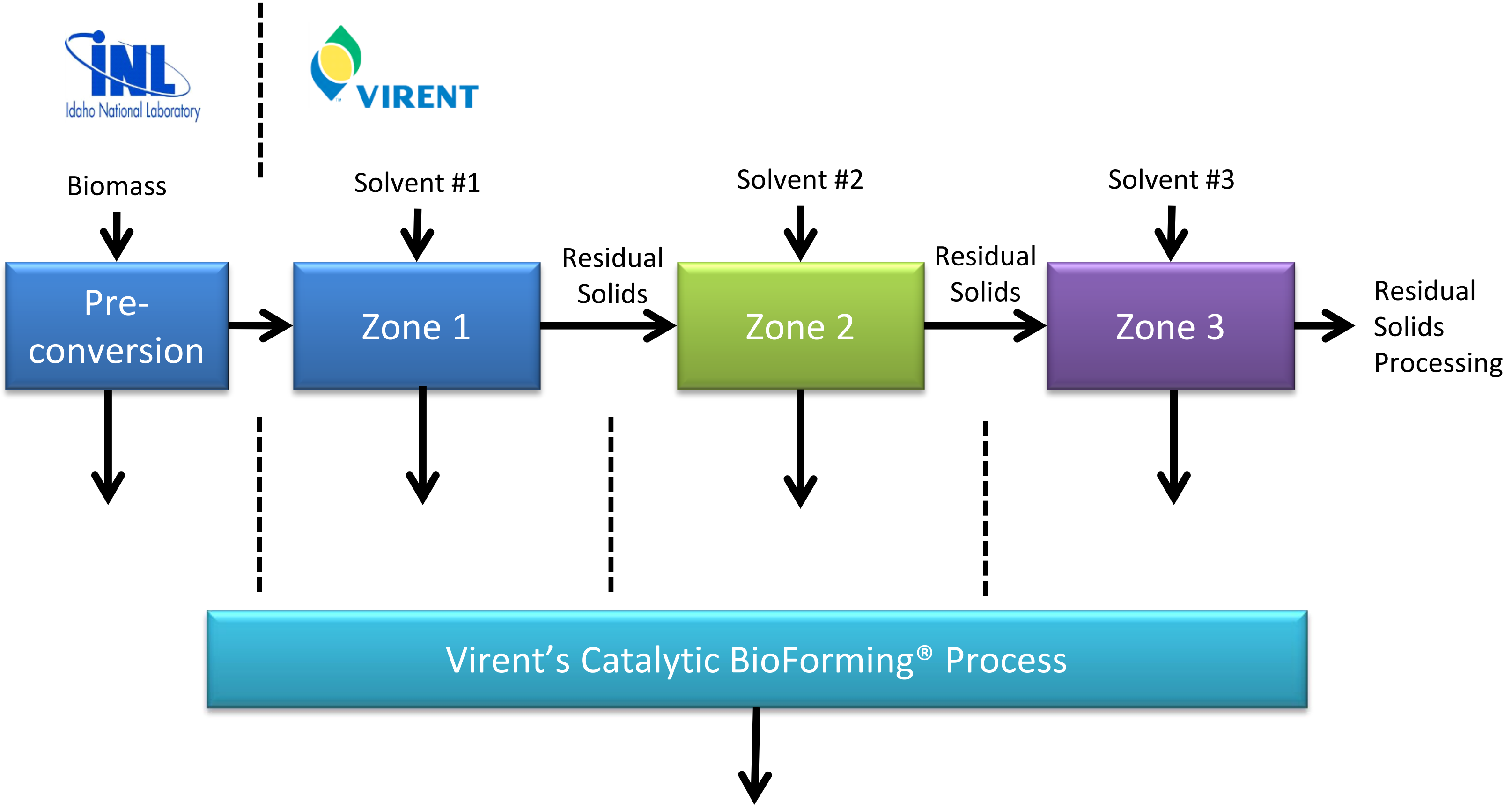
Lignocellulosic Biomass



Depolymerization of Lignocellulosic Biomass



CHASE Multistage HTL Concept



Biomass

Pre-conversion

Solvent #1

Zone 1

Residual Solids

Solvent #2

Zone 2

Residual Solids

Solvent #3

Zone 3

Residual Solids Processing

Virent's Catalytic BioForming® Process

Drop-in Hydrocarbon fuels (Distillates, Naphtha, Fuel oil)

CHASE Work Plan

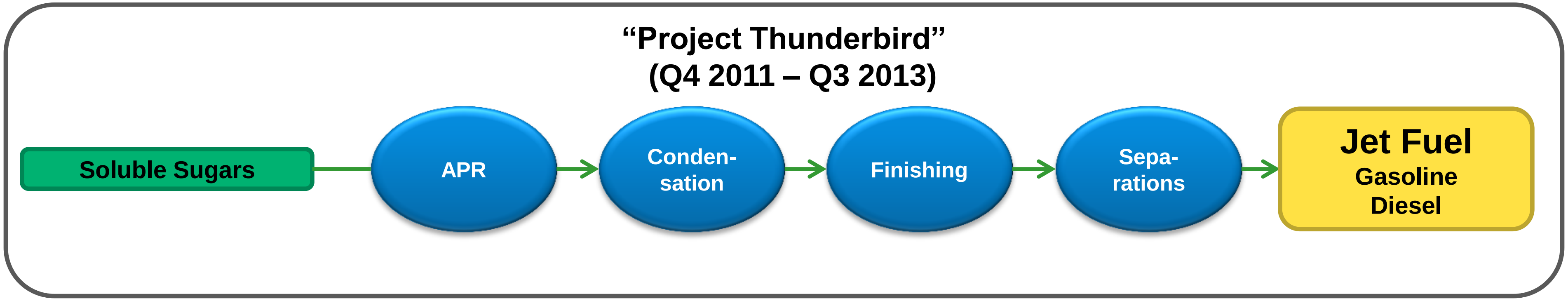
1. Sand bath: small scale, rapid testing
    - Temperature
    - Pressure
    - Solvent
    - Residence Time
2. Small-scale flow-through system
    - Kinetic Modeling
3. Prototype unit
    - 1-5 kg/hr throughput
4. Existing BioForming pilot plant to finished jet fuel

FAA Award

Objective: The funding provided by this proposal has supported Virent’s efforts to complete specification and fit-for-purpose testing on HDO-SK through at least CAAFI Fuel Readiness Level (FRL) 6.1 (100 gallons).

Funding: FAA/DOT/Volpe (Contract DTRT57-11-C-10060)

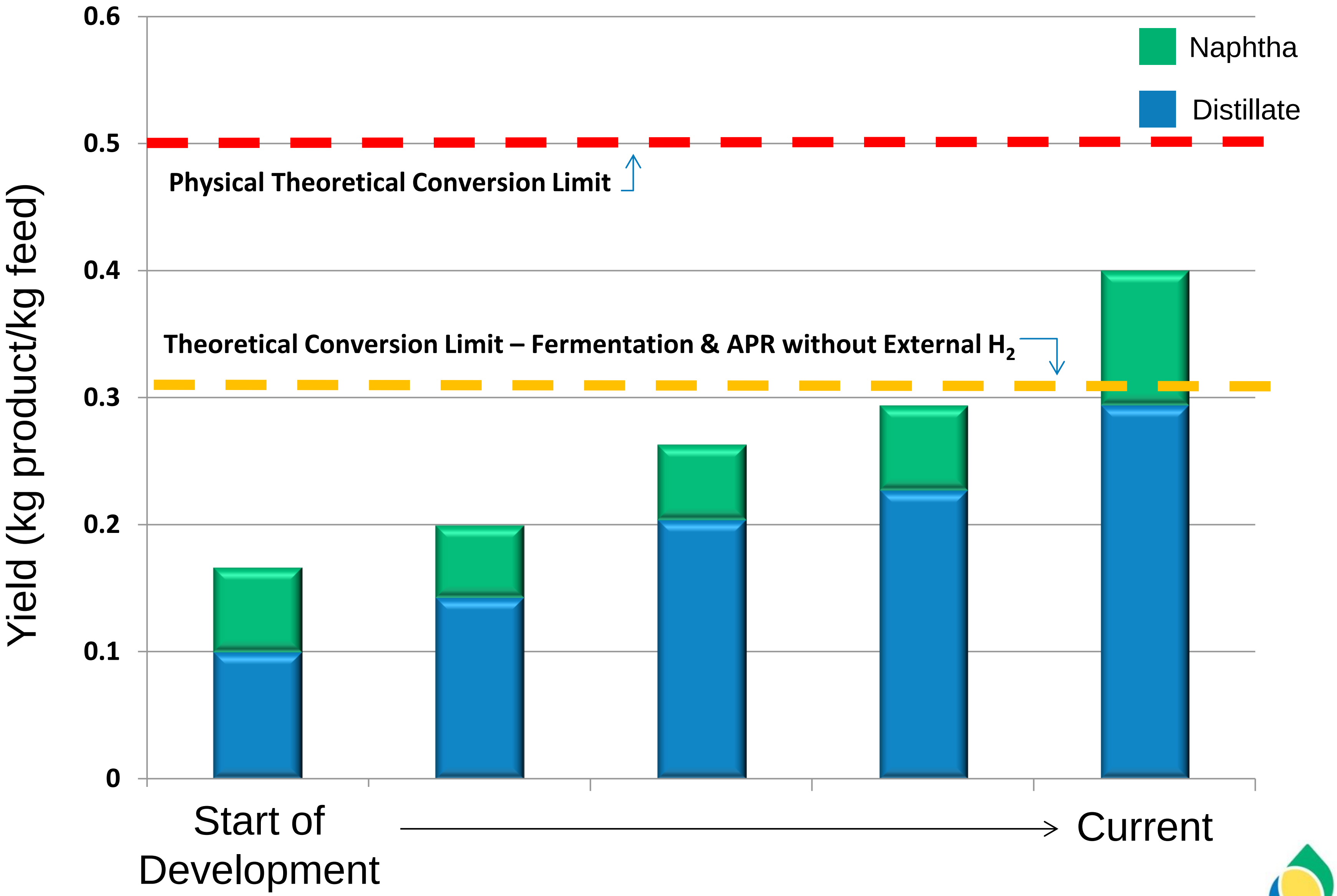
Duration: 2 years, Q4 2011- Q3 2013



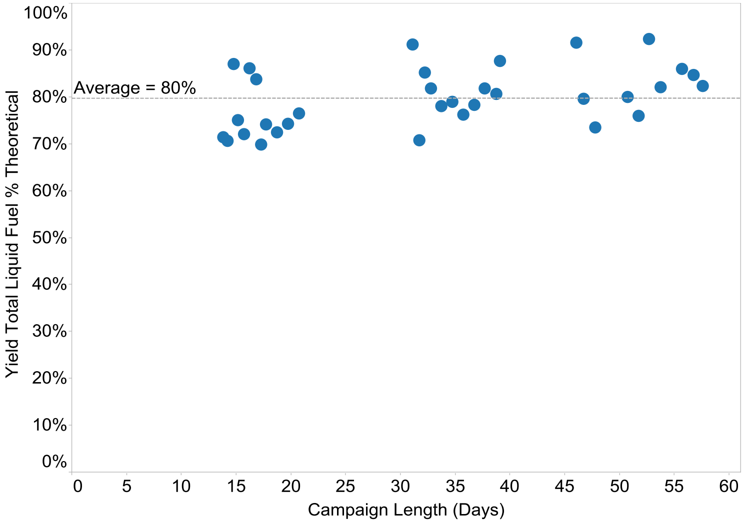
“Project Thunderbird”
(Q4 2011 – Q3 2013)

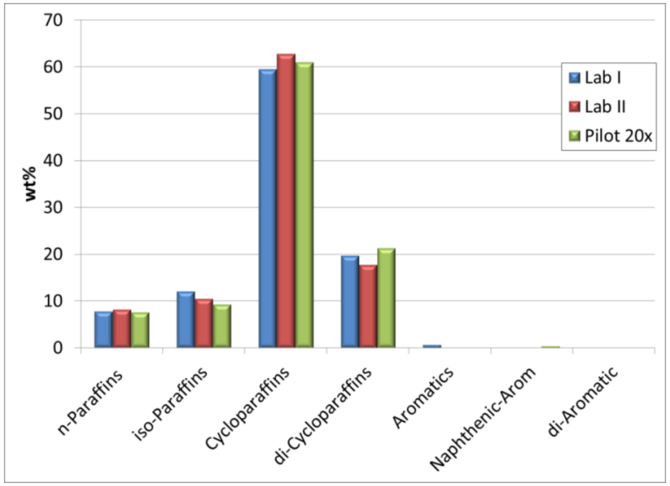
Soluble Sugars → **APR** → **Conden-sation** → **Finishing** → **Sepa-rations** → **Jet Fuel** **Gasoline** **Diesel**

Virent Demonstrated Yields



BioForming® Distillate Platform

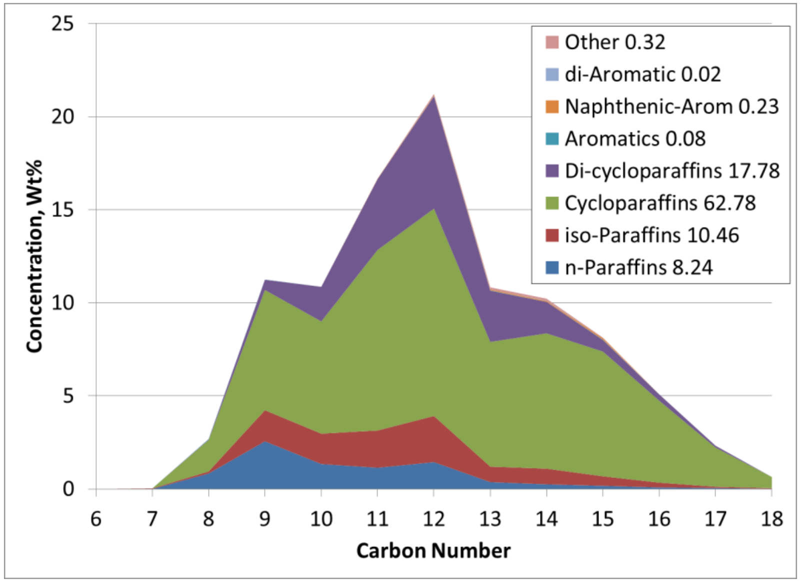


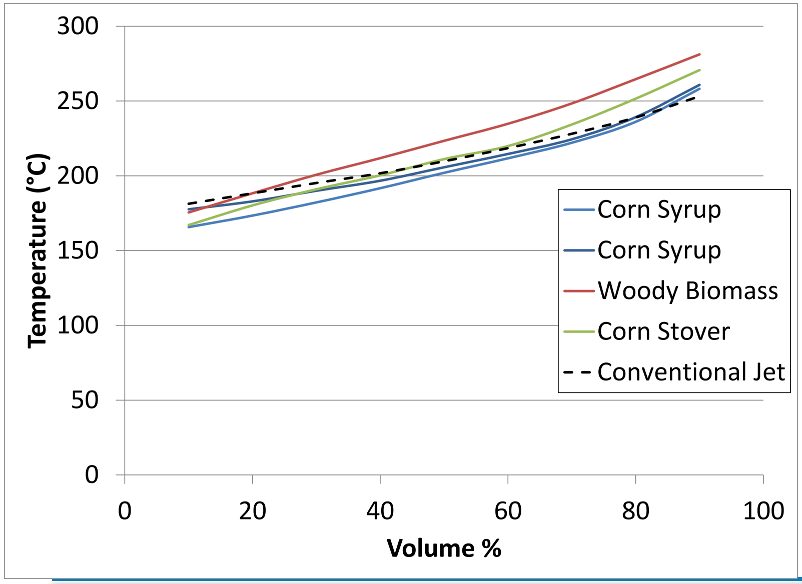


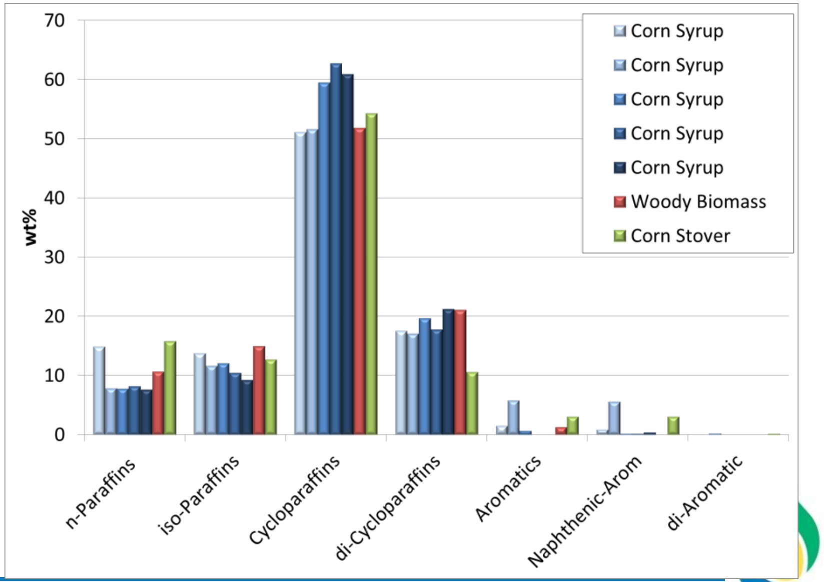
- Mini-Distillate Pilot Plant
  - 15 gal/day Liquid Fuel (20x lab)
  - 100 gal Jet Fuel produced
  - Scalable Yield and Product Quality Proven
  - ASTM Certification ongoing

Jet Composition

- Broad boiling point range
- Cycloparaffins from condensation + hydrotreating chemistry
- No composition differences from biomass derived fuels = feedstock agnostic
- Fuel testing important to gain industry support







Jet Fuel Quality and Testing

DEFINITIONS & CAUTIONARY NOTE

Reserves: Our use of the term “reserves” in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

Resources plays: our use of the term ‘resources plays’ refers to tight, shale and coal bed methane oil and gas acreage.

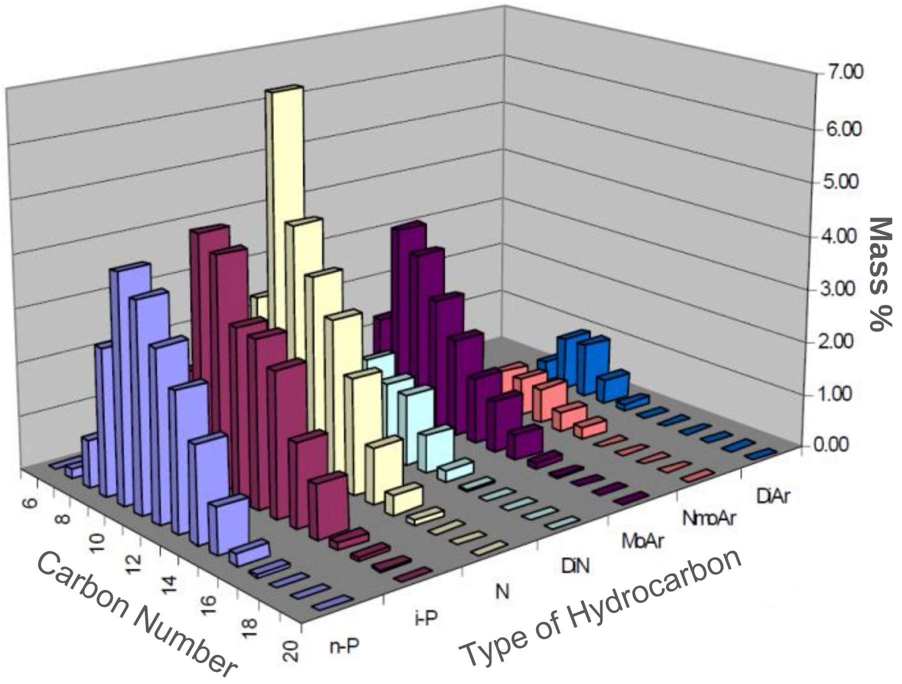
The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this presentation “Shell”, “Shell group” and “Royal Dutch Shell” are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words “we”, “us” and “our” are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. ‘‘Subsidiaries’’, “Shell subsidiaries” and “Shell companies” as used in this presentation refer to companies in which Royal Dutch Shell either directly or indirectly has control, by having either a majority of the voting rights or the right to exercise a controlling influence. The companies in which Shell has significant influence but not control are referred to as “associated companies” or “associates” and companies in which Shell has joint control are referred to as “jointly controlled entities”. In this presentation, associates and jointly controlled entities are also referred to as “equity-accounted investments”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect (for example, through our 23% shareholding in Woodside Petroleum Ltd.) ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management’s current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management’s expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as ‘‘anticipate’’, ‘‘believe’’, ‘‘could’’, ‘‘estimate’’, ‘‘expect’’, ‘‘intend’’, ‘‘may’’, ‘‘plan’’, ‘‘objectives’’, ‘‘outlook’’, ‘‘probably’’, ‘‘project’’, ‘‘will’’, ‘‘seek’’, ‘‘target’’, ‘‘risks’’, ‘‘goals’’, ‘‘should’’ and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell’s products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including potential litigation and regulatory measures as a result of climate changes; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional factors that may affect future results are contained in Royal Dutch Shell’s 20-F for the year ended 31 December, 2013 (available at www.shell.com/investor and www.sec.gov). These factors also should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, 21 March, 2014. Neither Royal Dutch Shell nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation. There can be no assurance that dividend payments will match or exceed those set out in this presentation in the future, or that they will be made at all.

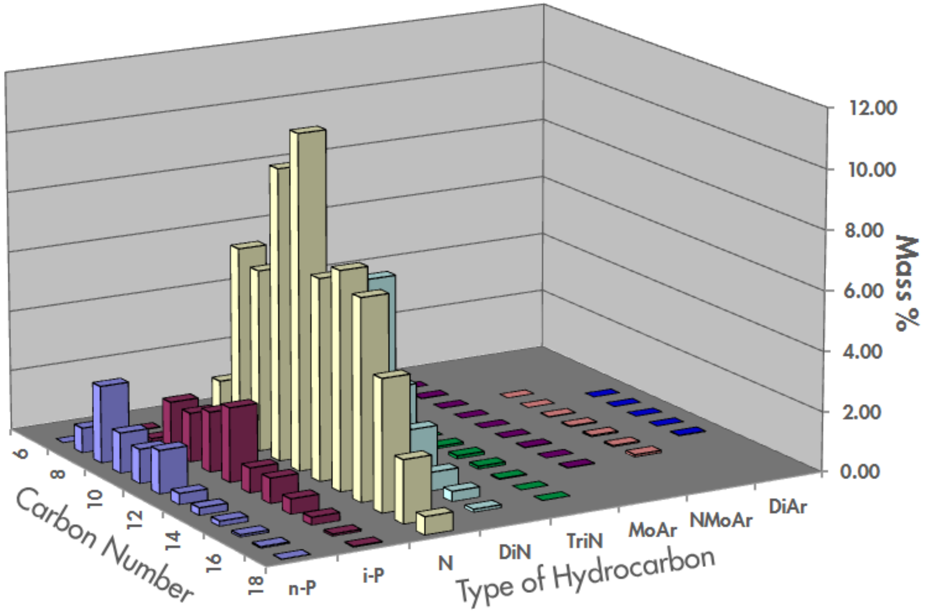
We use certain terms in this presentation, such as discovery potential, that the United States Securities and Exchange Commission (SEC) guidelines strictly prohibit us from including in filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain this form from the SEC by calling 1-800-SEC-0330.

What Makes a Good Jet Fuel?

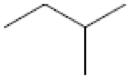
Typical Jet A-1



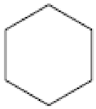
Virent Synthetic Kerosene



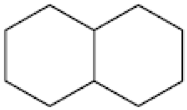
n-paraffin



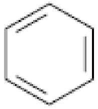
iso-paraffin



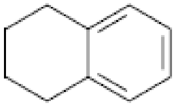
cycloparaffin
= naphthene
= cycloalkane



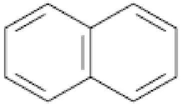
dicycloparaffin
= di-naphthene
= di-cycloalkane



monoaromatic

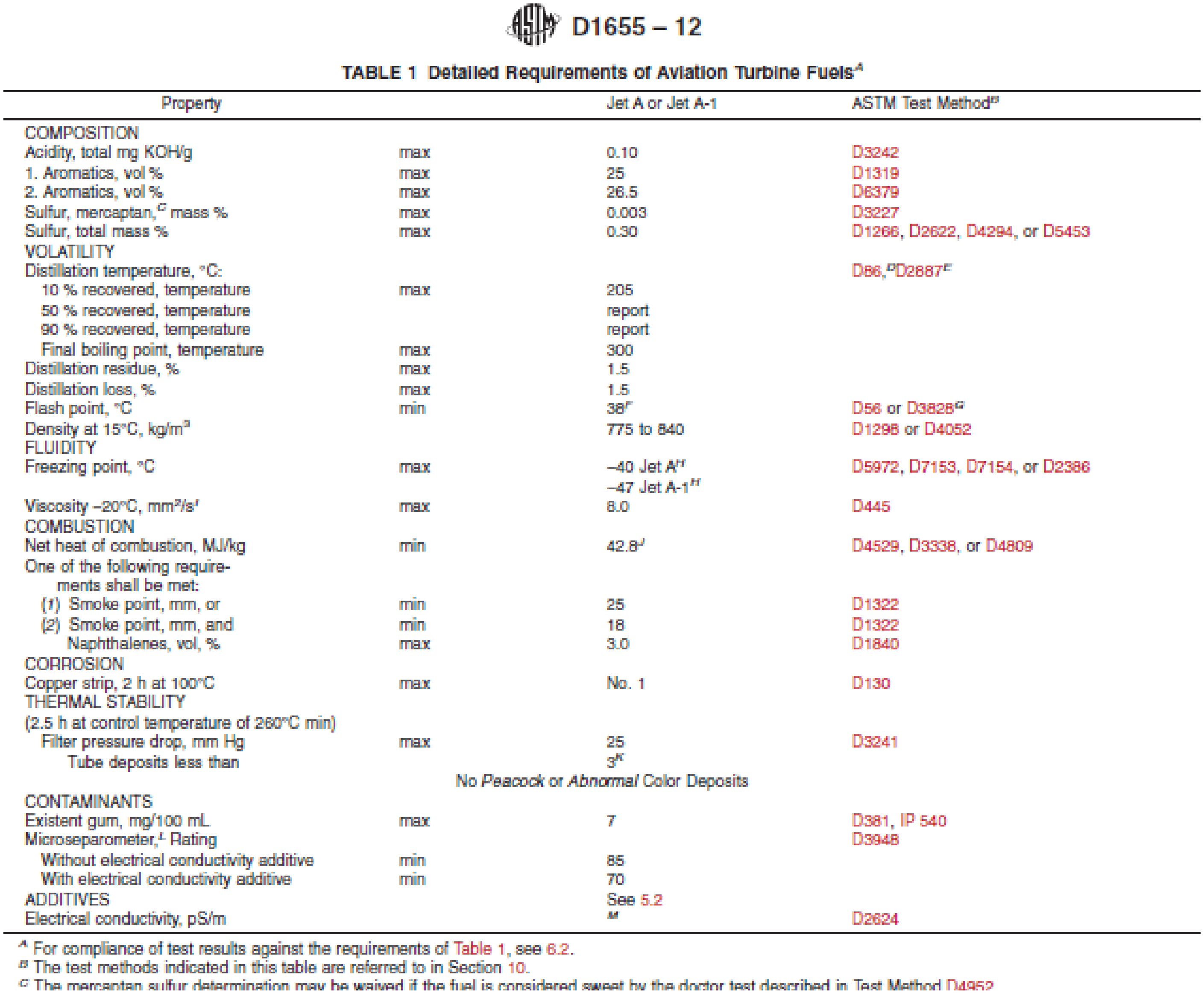


naphthenic mono-aromatic



diaromatic
= naphthalene

US Jet Fuel Spec: ~ 25 properties



D1655 – 12

TABLE 1 Detailed Requirements of Aviation Turbine Fuels[A]

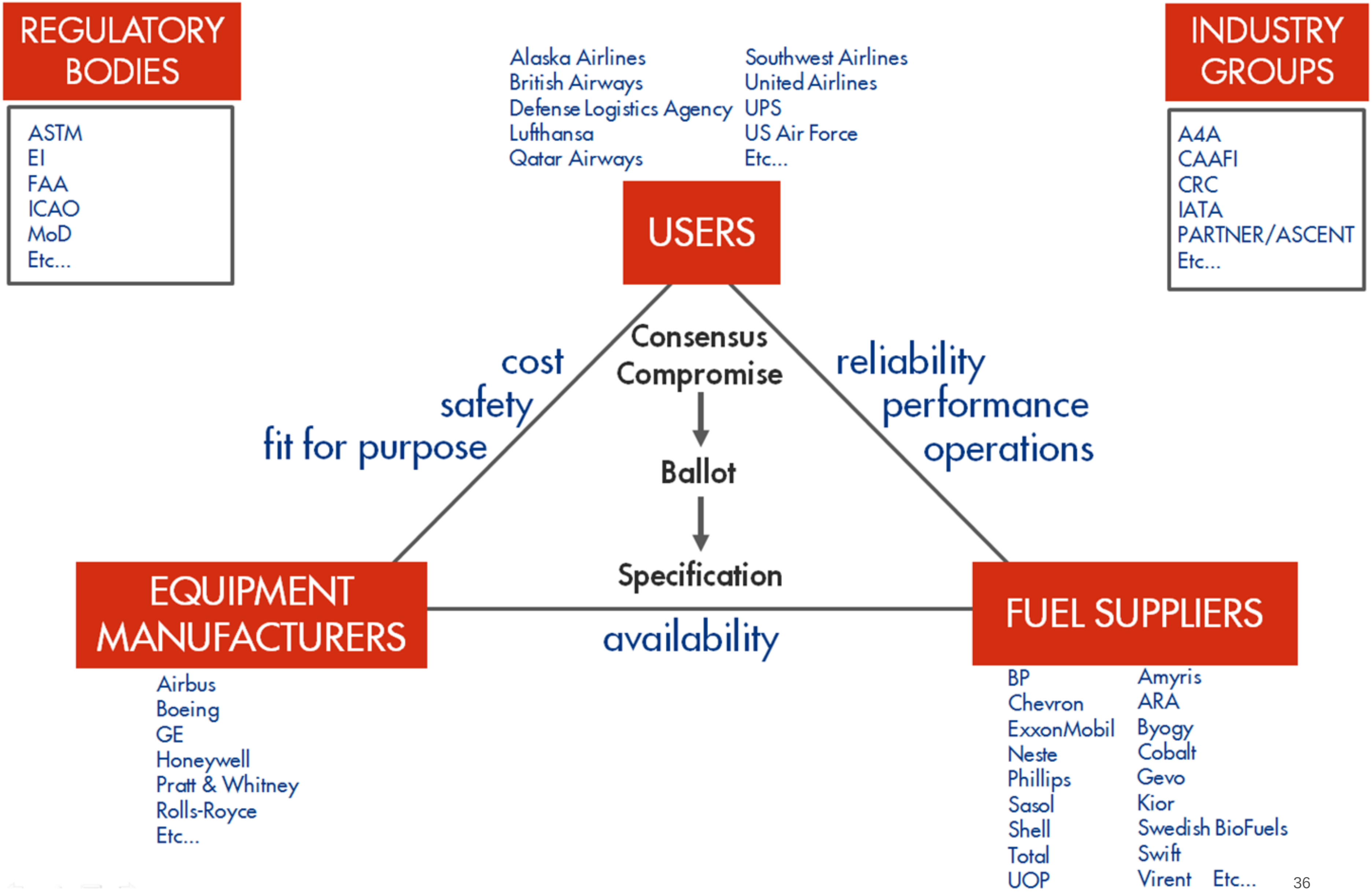
Property		Jet A or Jet A-1	ASTM Test Method[B]
COMPOSITION			
Acidity, total mg KOH/g	max	0.10	D3242
1. Aromatics, vol %	max	25	D1319
2. Aromatics, vol %	max	26.5	D6379
Sulfur, mercaptan,[C] mass %	max	0.003	D3227
Sulfur, total mass %	max	0.30	D1266, D2622, D4294, or D5453
VOLATILITY			
Distillation temperature, °C:			D86,[D] D2887[E]
10 % recovered, temperature	max	205	
50 % recovered, temperature		report	
90 % recovered, temperature		report	
Final boiling point, temperature	max	300	
Distillation residue, %	max	1.5	
Distillation loss, %	max	1.5	
Flash point, °C	min	38[F]	D56 or D3828[G]
Density at 15°C, kg/m^3		775 to 840	D1298 or D4052
FLUIDITY			
Freezing point, °C	max	–40 Jet A[H] –47 Jet A-1[H]	D5972, D7153, D7154, or D2386
Viscosity –20°C, mm^2/s[I]	max	8.0	D445
COMBUSTION			
Net heat of combustion, MJ/kg	min	42.8[J]	D4529, D3338, or D4809
One of the following requirements shall be met:			
(*1*) Smoke point, mm, or	min	25	D1322
(*2*) Smoke point, mm, and	min	18	D1322
Naphthalenes, vol, %	max	3.0	D1840
CORROSION			
Copper strip, 2 h at 100°C	max	No. 1	D130
THERMAL STABILITY			
(2.5 h at control temperature of 260°C min)			
Filter pressure drop, mm Hg	max	25	D3241
Tube deposits less than		3[K] No *Peacock* or *Abnormal* Color Deposits	
CONTAMINANTS			
Existent gum, mg/100 mL	max	7	D381, IP 540
Microseparometer,[L] Rating			D3948
Without electrical conductivity additive	min	85	
With electrical conductivity additive	min	70	
ADDITIVES		See 5.2	
Electrical conductivity, pS/m		[M]	D2624

[A] For compliance of test results against the requirements of Table 1, see 6.2.

[B] The test methods indicated in this table are referred to in Section 10.

[C] The mercaptan sulfur determination may be waived if the fuel is considered sweet by the doctor test described in Test Method D4952

How a New Jet Fuel Gets Approved in ASTM



REGULATORY BODIES

- ASTM
- EI
- FAA
- ICAO
- MoD
- Etc…

INDUSTRY GROUPS

- A4A
- CAAFI
- CRC
- IATA
- PARTNER/ASCENT
- Etc…

USERS

- Alaska Airlines
- British Airways
- Defense Logistics Agency
- Lufthansa
- Qatar Airways
- Southwest Airlines
- United Airlines
- UPS
- US Air Force
- Etc…

EQUIPMENT MANUFACTURERS

- Airbus
- Boeing
- GE
- Honeywell
- Pratt & Whitney
- Rolls-Royce
- Etc…

FUEL SUPPLIERS

- BP
- Chevron
- ExxonMobil
- Neste
- Phillips
- Sasol
- Shell
- Total
- UOP
- Amyris
- ARA
- Byogy
- Cobalt
- Gevo
- Kior
- Swedish BioFuels
- Swift
- Virent
- Etc…

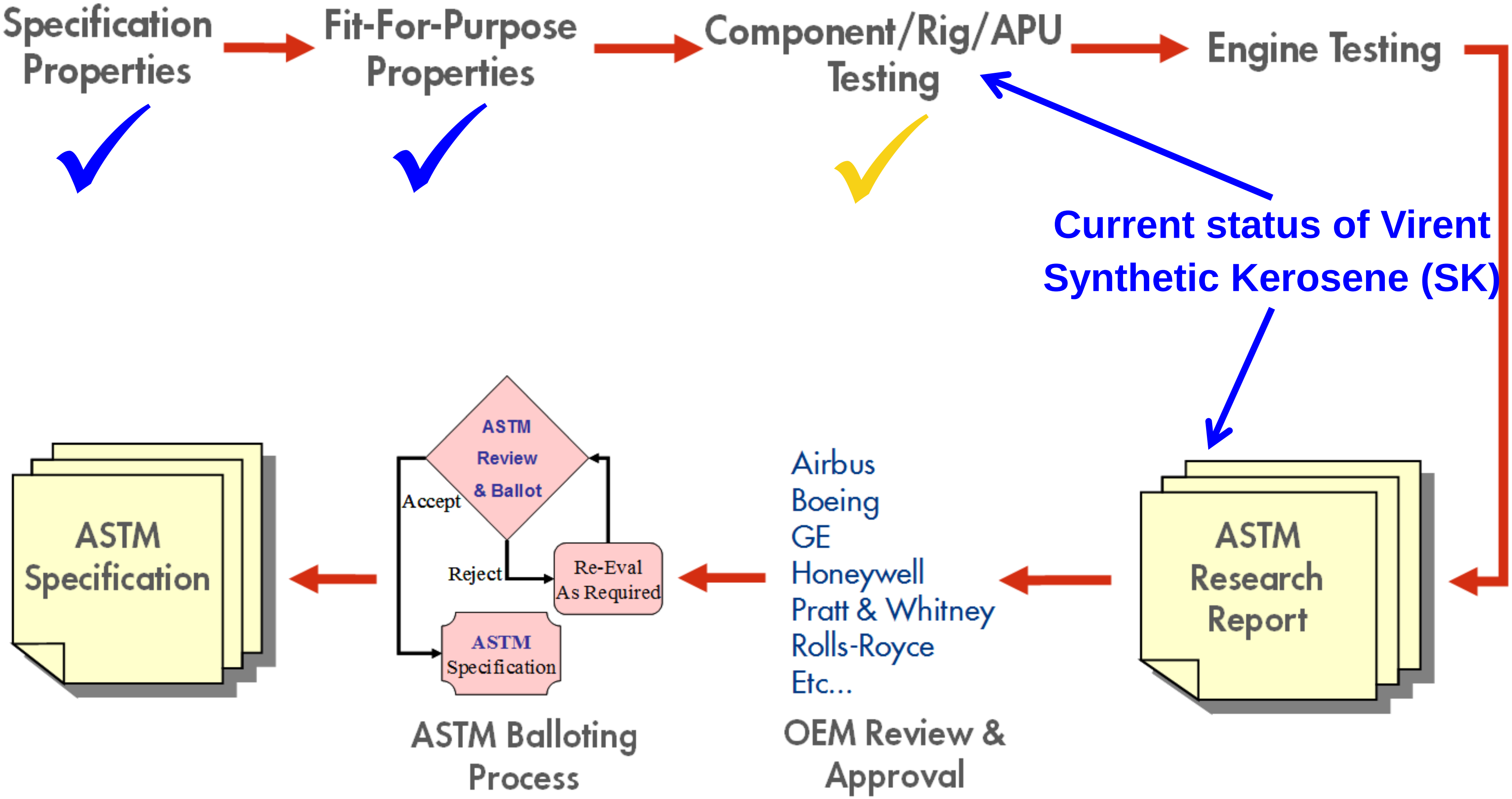
Users – Equipment Manufacturers: cost, safety, fit for purpose

Users – Fuel Suppliers: reliability, performance, operations

Equipment Manufacturers – Fuel Suppliers: availability

Consensus Compromise → Ballot → Specification

Industry Jet Fuel Qualification Process (ASTM D4054)



Specification Properties ✓

Fit-For-Purpose Properties ✓

Component/Rig/APU Testing ✓

Engine Testing

Current status of Virent Synthetic Kerosene (SK)

ASTM Research Report

Airbus
Boeing
GE
Honeywell
Pratt & Whitney
Rolls-Royce
Etc…

OEM Review & Approval

ASTM Balloting Process

ASTM Specification

Courtesy Mark Rumizen (FAA)

Virent SK: Test Results

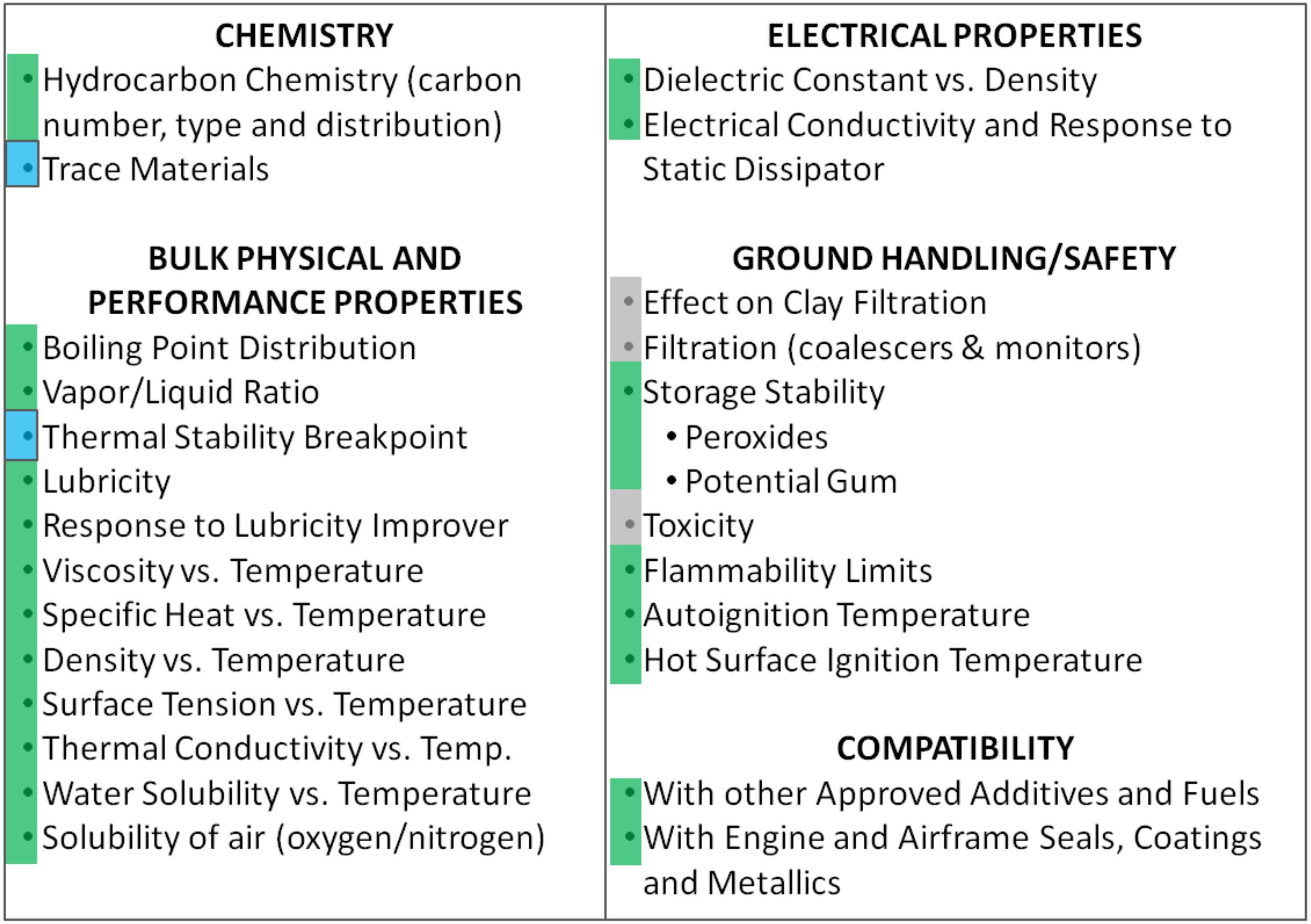
	Test Method		ASTM D1655	10-gal SK (Neat) *	Jet A / SK 50/50 Blend	Jet A
COMPOSITION						
Acidity, Total (mg KOH/g) **	D3242	Max.	0.10	0.003	0.005	▨
Aromatics (vol %)	D1319	Max.	25	0.8	8.3	16
Sulfur, Mercaptan (mass %)	D3227	Max.	0.003	▨	<0.0003	▨
Sulfur, Total (mass %)	D4294	Max.	0.30	0.00	0.034	0.08
VOLATILITY						
Distillation	D86					
Initial BP (°C)				159	160	▨
Temp @ 10% Rec. (°C)		Max.	205	178	177	176
Temp @ 50% Rec. (°C)		Max.	report	213	211	210
Temp @ 90% Rec. (°C)		Max.	report	260	267	253
Final BP (°C)		Max.	300	280	279	274
T50-T10 (°C)		Min.	15	35	34	34
T90-T10 (°C)		Min.	40	82	90	77
Residue (vol %)		Max.	1.5	1.2	1.3	▨
Loss (vol %)		Max.	1.5	0.8	0.1	▨
Flash Point (°C)	D93	Min.	38	50	47	47
Density, 15°C (kg/m3)	D4052		775 - 840	812	810	806
FLUIDITY						
Freezing Point (°C)	D5972	Max.	-40/-47	<-80	-52.7	-44
Viscosity @ -20°C (cSt)	D445	Max.	8.0	6.1	5.1	4.9
COMBUSTION						
Smoke Point (mm) **	D1322	Min.	18	27.0	26.0	25
THERMAL STABILITY						
JFTOT Breakpoint (°C)	D3241	Min.	260	>=325	335	290

🟦 Advantaged
🟩 As Expected
🟨 Pending
▨ Not tested
🟥 Fail

NB: Specs apply only to final fuel blends, not neat SK

** DEF STAN 91-91 more constrained:
- TAN max 0.015 mg KOH/g
- Smoke point max 25mm or 19mm with Naphthalenes max 3.00% v/v

Virent SK: Fit-For-Purpose Properties



CHEMISTRY

- 🟩 Hydrocarbon Chemistry (carbon number, type and distribution)
- 🟦 Trace Materials

BULK PHYSICAL AND PERFORMANCE PROPERTIES

- 🟩 Boiling Point Distribution
- 🟩 Vapor/Liquid Ratio
- 🟦 Thermal Stability Breakpoint
- 🟩 Lubricity
- 🟩 Response to Lubricity Improver
- 🟩 Viscosity vs. Temperature
- 🟩 Specific Heat vs. Temperature
- 🟩 Density vs. Temperature
- 🟩 Surface Tension vs. Temperature
- 🟩 Thermal Conductivity vs. Temp.
- 🟩 Water Solubility vs. Temperature
- 🟩 Solubility of air (oxygen/nitrogen)

ELECTRICAL PROPERTIES

- 🟩 Dielectric Constant vs. Density
- 🟩 Electrical Conductivity and Response to Static Dissipator

GROUND HANDLING/SAFETY

- ⬜ Effect on Clay Filtration
- ⬜ Filtration (coalescers & monitors)
- 🟩 Storage Stability
  - Peroxides
  - Potential Gum
- ⬜ Toxicity
- 🟩 Flammability Limits
- 🟩 Autoignition Temperature
- 🟩 Hot Surface Ignition Temperature

COMPATIBILITY

- 🟩 With other Approved Additives and Fuels
- 🟩 With Engine and Airframe Seals, Coatings and Metallics

🟦 Advantaged
🟩 As Expected
🟨 Pending
⬜ Not tested
🟥 Fail

Virent SK: Status

- Specification and Fit-For-Purpose Testing Complete
- Report Available Soon
- All Properties within Experience
- Rig Testing at Honeywell – in progress
  - Atomizer Cold Spray
  - Combustor Rig
  - Cold & Altitude Starting
- Seeking opportunities to produce additional volumes for certification

Thank You. Questions?

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Cynthia Ginestra, PhD, Aviation Fuels Research Engineer