CAAFI Environment Team: Developing Tools & Means to Address Environmental Issues

January 28, 2014

Nancy Young and Jim Hileman
Co-Leads of CAAFI Environment Team
Refresher on the Environmental Imperative

* Overall Objectives for Alternative Fuel Deployment
  * Energy Security/Supply Reliability
  * Commodity Competitor to Petroleum
  * Environmental Benefit (our focus)

* Environmental Benefit
  * Life Cycle Greenhouse Gas (GHG) Emissions Improvements
  * Potential to Reduce Emissions with Air Quality Impact
  * Sustainability More Broadly: Do Not Induce Other Environmental Problems
    * Water use, land use, food-basket competition, etc.
GHG Life Cycle Analysis: Focus & Achievements to Date

* Confirmed We Know the Steps and How to Apply Them to Aviation (building on “Framework & Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels”)

* Strong basis established for how the U.S. federal government can use existing tools and methodologies for confirming compliance with Section 526 of the Energy Independence & Security Act (EISA) and how commercial aviation stakeholders can demonstrate life cycle benefit

* Integrated Jet Fuel into the Argonne National Labs’ GREET Model
GHG LCA: Ongoing Work

* Continue to Use GREET to Examine Additional Pathways

* TODAY: Review Progress in Our Project to Compare GHG LCA Results from Different Models/Tools

For now, accepted country-based tools are fine; but eventually will need mutual recognition for proper crediting of environmental benefit (alternative fuel for international flights)
Sustainability: Focus of Environment Team to Date

Environmental Aspects of Sustainability

- Reduce air emissions
- Ensure compliance with requirements
- Do not induce environmental harm

Note: The Team recognizes that there are other aspects of “sustainability” besides environment
Developed Sustainability “Impact Matrix” and Guidance

- Identified areas of concern and relevant metrics for reflecting potential impact
- Overview of existing regulatory and voluntary sustainability regimes
- “Impact Matrix” defines the potential impact risk and metrics along the alternative fuel supply chain

Developed Environmental Progression

- Puts “environmental readiness” on a scale with feedstock readiness and fuel readiness

TODAY: We Will Review These Products and Seek Your Input on them and Next Steps
Goals for Today

- Inform the Team on Progress
- Input on Sustainability Impact Matrix and Guidance and Environmental Progression Tool
  - What else should the Team do in this area?
- Input on the LCA Project
- Identify/Confirm Environment Team Focus and Actions for 2014
Sustainability Overview

January 28, 2014

Dr. Kristin C. Lewis
Kirsten van Fossen
Nancy Young
Dr. Jim Hileman
Sustainability to date

2061: "Sustainable" occurs an average of once per page.
2056: "Sustainable" occurs an average of once per page.
2109: All sentences are just the word "Sustainable" repeated over and over.

The word "Sustainable" is unsustainable.

Frequency of use of the word "Sustainable" in US English text, as a percentage of all words, by year.

Source: Google ngrams
3 Subareas of Sustainability

Source: http://www.probus-sigma.com/archives/1082
Stakeholder Role

- General public
- Regulators
- Users
- Standards developers
- Affected communities
- Bioenergy industry representatives
- Bioenergy industry workers
- Government policy makers
Rating Systems

CRITERIA AND INDICATORS
- Government Regulations
- International Standards
- Other Requirements

INPUTS
- Primary and Secondary Data
- Audit Evidence
- Supplier Reps. & Certs.

RATING SYSTEM OPERATOR
- Company/Group of Companies
- Industrial Sector or Trade Association
- Government Agency
- Independent/Other Organization

(Analysis/Modeling)
(Conformity Assessment)

OUTPUTS
- LCA Study
- Supplier Certification
- Supplier’s Declaration of Conformity
- Product Label
- Sustainability Product Declaration
Measurement Comparison

gCO2e/MJ
hectare conv./MJ
L H2O/MJ
Δ species

to
Local Context
Indicator Group

- GHG
- Air quality
- Water quality

Metric

gCO2e/MJ

Possible thresholds

Permitted levels or comparison with accepted standard petroleum baseline

Baseline

Minimization of total acceptable for given economic operator, based on local context

mass/unit energy or mass/unit operation
Withdrawal/consumption

Indicator: water use

Metric: \( \text{L H}_2\text{O/MJ} \)
- volume/unit energy
- volume/unit operation

Possible thresholds:
- Local water permits, comparison with standard petroleum or other alternative fuels

Baseline:
- Sustainable renewable water available to operator considering source
Land Use

Indicator Group

- land use
- soil quality

Metric

hectare conv./MJ
area/unit energy or soil impact/area

Possible thresholds

Minimization, comparison with other fuels

Baseline

Dependent on the initial condition of the land
Biodiversity

Indicator

Metric

Possible thresholds
Minimization, comparison with other fuels, zero impact on endangered/threatened species

Baseline
None

acres affected or Δspecies/facility?
Best Practices
Trade-offs
## Impact Matrix

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Feedstock Producer</th>
<th>Feedstock Processor</th>
<th>Fuel Producer</th>
<th>Fuel Blender/Distributor</th>
<th>Fuel End User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Use (Balance)</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Greenhouse Gases</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Air quality</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Land Use</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Water quality (Pollutants, Eutrophication)</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Freshwater use (Consumption)</td>
<td>High*</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Soil quality</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Most likely related to irrigation for first generation biofuels, less likely for advanced biofuels.
Environmental Progression

January 28, 2014

Dr. Kristin C. Lewis
Kirsten van Fossen
Dr. Jim Hileman
Nancy Young
Motivation

* What environmental analyses might be expected and/or required for alternative jet fuel production?

* When in pathway development can/should analyses be performed?

* NOT prescriptive of outcomes (no thresholds)
Capture Supply Chain
Capture Indicators

- Energy use
- Air quality
- Land use
- GHG
- Water use
- Water quality
- Biodiversity
- Soil quality
# FRL, FSRL & EP

<table>
<thead>
<tr>
<th>Fuel Readiness Level</th>
<th>Feedstock Readiness Level</th>
<th>Env. Progression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Principles</td>
<td>Basic Principles</td>
<td>Basic Principles</td>
</tr>
<tr>
<td>Concept Formulated</td>
<td>Concept Formulated</td>
<td>Concept Formulated</td>
</tr>
<tr>
<td>Proof of Concept</td>
<td>Proof of Concept</td>
<td>Proof of Concept</td>
</tr>
<tr>
<td>Preliminary</td>
<td>Preliminary</td>
<td>Preliminary</td>
</tr>
<tr>
<td>Process Validation</td>
<td>Production System Validation</td>
<td>Scale up Validation of Initial Assessments</td>
</tr>
<tr>
<td>Full-scale</td>
<td>Full-scale Production Initiation</td>
<td>Full-scale Feedstock Impact Evaluation</td>
</tr>
<tr>
<td>Technical Evaluation</td>
<td>Feedstock Availability</td>
<td>Full-scale Fuel Producer Impact Evaluation</td>
</tr>
<tr>
<td>Certification</td>
<td>Commercialization</td>
<td>Commercialization</td>
</tr>
<tr>
<td>&amp; Fuel Approval</td>
<td>Sustainable Feedstock</td>
<td>Sustainable Feedstock and Fuel Supply Established</td>
</tr>
<tr>
<td>Commercialization</td>
<td>Production Capacity</td>
<td></td>
</tr>
<tr>
<td>Established</td>
<td>Established</td>
<td></td>
</tr>
</tbody>
</table>

Sustainable Feedstock
Production Capacity Established
Assessing & Managing Risk

* Risk Assessment
  * Pro-active and iterative assessment of environmental impacts as information becomes available
    * Feedstock
    * Fuel Producer
    * Life Cycle

* Risk Management
  * Develop management plans, comply with regulations and standards, develop & implement best management practices
    * Feedstock
    * Fuel Producer
### Overview

#### Environmental Progression

<table>
<thead>
<tr>
<th>Basic Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Formulated</td>
</tr>
<tr>
<td>Proof of Concept</td>
</tr>
<tr>
<td>Preliminary Technical Evaluation</td>
</tr>
<tr>
<td>Scale up Validation of Initial Assessments</td>
</tr>
<tr>
<td>Full-scale Feedstock Impact Evaluation</td>
</tr>
<tr>
<td>Full-scale Fuel Producer Impact Evaluation</td>
</tr>
<tr>
<td>Commercialization</td>
</tr>
<tr>
<td>Sustainable Feedstock and Fuel Supply Established</td>
</tr>
</tbody>
</table>

#### Risk Assessment

1. **initial screening**
2. **estimates, rigorous study**
3. **comprehensive analysis**

#### Risk Management

1. **BMPs developed**
2. **permitting**
3. **reporting, continuous improvements**
## Risk Assessment

### Environmental Progression

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Principles</td>
<td>Initial screening</td>
</tr>
<tr>
<td>Concept Formulated</td>
<td>Comprehensive analysis</td>
</tr>
<tr>
<td>Proof of Concept</td>
<td>Initial screening</td>
</tr>
<tr>
<td>Preliminary Technical Evaluation</td>
<td>Comprehensive analysis</td>
</tr>
<tr>
<td>Scale up Validation of Initial Assessments</td>
<td>Initial screening</td>
</tr>
<tr>
<td>Full-scale Feedstock Impact Evaluation</td>
<td>Comprehensive analysis</td>
</tr>
<tr>
<td>Full-scale Fuel Producer Impact Evaluation</td>
<td>Initial screening</td>
</tr>
<tr>
<td>Commercialization</td>
<td>Comprehensive analysis</td>
</tr>
<tr>
<td>Sustainable Feedstock and Fuel Supply Established</td>
<td>Comprehensive analysis</td>
</tr>
</tbody>
</table>

### Context

- Sustainable Feedstock and Fuel Supply Established

---

29
## Risk Management

### Environmental Progression

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Best Management Practices developed
- reporting, continuous improvements

---

**CAAFI**
### Environmental Progression

<table>
<thead>
<tr>
<th>Environmental Progression</th>
<th>Risk Assessment</th>
<th>Risk Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Principles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept Formulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proof of Concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Technical Evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale up Validation of Initial Assessments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-scale Feedstock Impact Evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-scale Fuel Producer Impact Evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercialization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable Feedstock and Fuel Supply Established</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Environmental Factors:**
  - Land Use
  - Air Quality
  - Water Quality
  - Water Use
  - Soil Quality
  - Biodiversity
- **Energy Use**
- **GHG**
- **Risk Assessment**
- **Risk Management**
Review Scope

- Covers Feedstock, Fuel Production and Life Cycle
- Covers energy use, air quality, land use, GHG emissions, water use, water quality, biodiversity and soil quality
Discussion

* How can we improve utility?
* Additions?
* Specific issues/concerns?
Life Cycle GHG Emissions – Report out from Environment Team Workshop
January 28, 2014

Jim Hileman (FAA) & Nancy Young (A4A)
Co-Leads of CAAFI Environment Team
Refresher on the Environmental Imperative

* Overall Objectives for Alternative Fuel Deployment
  * Energy Security/Supply Reliability
  * Commodity Competitor to Petroleum
  * **Environmental Benefit (our focus)**

* Environmental Benefit
  * **Potential Life Cycle Greenhouse Gas (GHG) Emissions Improvements (our focus here)**
  * Potential to Reduce Emissions with Air Quality Impact
  * Sustainability More Broadly: Do Not Induce Other Environmental Problems
    * Water use, land use, food-basket competition, etc.
**Aviation’s Commitment to Continued and Verifiable GHG Emissions Improvement**

* **Strong Record on Fuel Efficiency & Emissions Savings**
  * Globally, aviation accounts for 2% of man-made CO2
  * U.S. aviation = 2% of the U.S. GHG inventory, while accounting for 5% of GDP
    * U.S. airlines improved their fuel efficiency ~120% between 1978 and 2012 (saved 3.4 billion metric tons of CO2)

* **The Aviation Industry Has Committed to Aggressive CO2 Emissions Targets Going Forward**
  * Premised on government investment and airline ability to invest so technology, operations & infrastructure improvements flourish
  * FAA aspirational goal - carbon neutral growth by 2020 compared to 2005

---

Annual Fuel Efficiency improvements thru 2020  
Carbon Neutral Growth from 2020  
50% Reduction in 2050 Relative to 2005 levels
State-Specific & Regional Regulatory Initiatives

* e.g., European Union Emissions Trading Scheme
* e.g., U.S. requirement for federal/military procurement of fuels
  * Can only procure alternative fuels with lifecycle emissions better than or equal to conventional fuels (EISA Section 526)

States Are Working on a Global Agreement for Addressing Aviation GHG Emissions through the International Civil Aviation Organization (ICAO)

* Includes carbon neutral growth from 2020 goal
* Working on a potential global market-based measure
How Do We Meet Our Targets? Technology, Alt Fuels, Operations & Infrastructure

MAPPING OUT THE INDUSTRY COMMITMENTS

1. improve fleet fuel efficiency by 1.5% per year from now until 2020
2. cap net emissions from 2020 through carbon neutral growth
3. by 2050, net aviation carbon emissions will be half of what they were in 2005


28 January 2014
Aviation Has a Unique Need for Future Acceptance of GHG LCA Results Across Borders

- Obviously, Aircraft Are Mobile Sources that Cross Borders
- System of CO2 Monitoring, Reporting & Verification needed for Global Aviation CO2 Programs
- GHG LCA Results Will be a Key Part of any Global Scheme
- Need Means for “Mutual Recognition” Among States and Perhaps, Ultimately, Harmonization
- Key Starting Point: Understand the Differences Between LCA Regulatory Approaches and Tools
Jan 2014 Environment Team Workshop

Goal and Process

* Examine variations in life cycle greenhouse gas (GHG) emissions due to:
  * Using different Life Cycle Analysis (LCA) methods, tools, and data
  * Meeting varied purposes and regulatory regimes
* Goal:
  * Identify elements that lead to variations in LC GHG emissions results
  * Develop actions that could be taken to yield more harmonized results
* Process:
  * Briefings explored how life cycle GHG emissions varied with different tools and purposes
  * Group discussion is feeding into an LCA Issue Matrix spreadsheet
    * Captured key elements leading to differences in LC GHG emissions for the varied fuel pathways under consideration by the alternative jet fuel community.
    * Worked through four areas: Baseline, Data Source, Accounting, and System Boundaries
  * The spreadsheet is a tool to help us identify what is leading to variations in results (filling in all of the blanks is not the goal)
## Jan 2014 Environment Team Workshop Agenda

<table>
<thead>
<tr>
<th>Topic</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening Remarks (Overview of Issues and Review of Workshop Objectives)</td>
<td>Nancy Young (A4A) and Jim Hileman (FAA)</td>
</tr>
<tr>
<td>A comparison of LC GHG accounting for alternative fuels in the US and EU</td>
<td>Robert Malina (MIT) and Michael Wang (ANL)</td>
</tr>
<tr>
<td>Review of EPA/OTAQ Biofuel LCA Work for the RFS Program</td>
<td>Vince Camobrecro (EPA)</td>
</tr>
<tr>
<td>Case Studies on Variability in LC GHG Emissions of Biofuels</td>
<td>David Shonnard (Michigan Tech)</td>
</tr>
<tr>
<td>ICAO CAEP Alternative Fuels Task Force: Scope of Work &amp; Experiences from Spain in LCA</td>
<td>Cesar Velarde (SENASA)</td>
</tr>
<tr>
<td>RSB GHG Calculator</td>
<td>Mireille Faist (Quantis)</td>
</tr>
<tr>
<td>Group Discussion on LCA Issue Matrix</td>
<td>CAAFI Leadership</td>
</tr>
<tr>
<td>Does the &quot;element&quot; contribute to differences in LC GHG emissions results for this &quot;fuel pathway&quot;?</td>
<td>Yes</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Does the &quot;element&quot; impact a &quot;fuel pathway's&quot; qualification under a reduced LC GHG emissions policy (e.g., RFS2)?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Baseline for Comparison</th>
<th>Soybean HEFA (good for comparison)</th>
<th>Rapeseed HEFA</th>
<th>Jatropha HEFA</th>
<th>Camelina HEFA (rotation crop)</th>
<th>Tallow/FDG HEFA (waste product)</th>
<th>Algae HEFA</th>
<th>Forestry waste F-T</th>
<th>Forestry waste HDICI (pyrolysis)</th>
<th>Ag waste F-T</th>
<th>Energy grass F-T</th>
<th>Natural gas F-T</th>
<th>Sugar cane</th>
<th>Alcohol To Jet</th>
<th>Sugar cane bagasse HDICI (pyrolysis)</th>
<th>Waste gas (CO)</th>
<th>Alcohol To Jet</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Soybean HEFA (good for comparison)</th>
<th>Rapeseed HEFA</th>
<th>Jatropha HEFA</th>
<th>Camelina HEFA (rotation crop)</th>
<th>Tallow/FDG HEFA (waste product)</th>
<th>Algae HEFA</th>
<th>Forestry waste F-T</th>
<th>Forestry waste HDICI (pyrolysis)</th>
<th>Ag waste F-T</th>
<th>Energy grass F-T</th>
<th>Natural gas F-T</th>
<th>Sugar cane</th>
<th>Alcohol To Jet</th>
<th>Sugar cane bagasse HDICI (pyrolysis)</th>
<th>Waste gas (CO)</th>
<th>Alcohol To Jet</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Accounting</th>
<th>Soybean HEFA (good for comparison)</th>
<th>Rapeseed HEFA</th>
<th>Jatropha HEFA</th>
<th>Camelina HEFA (rotation crop)</th>
<th>Tallow/FDG HEFA (waste product)</th>
<th>Algae HEFA</th>
<th>Forestry waste F-T</th>
<th>Forestry waste HDICI (pyrolysis)</th>
<th>Ag waste F-T</th>
<th>Energy grass F-T</th>
<th>Natural gas F-T</th>
<th>Sugar cane</th>
<th>Alcohol To Jet</th>
<th>Sugar cane bagasse HDICI (pyrolysis)</th>
<th>Waste gas (CO)</th>
<th>Alcohol To Jet</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>System Boundary (attributional versus consequential analysis)</th>
<th>Soybean HEFA (good for comparison)</th>
<th>Rapeseed HEFA</th>
<th>Jatropha HEFA</th>
<th>Camelina HEFA (rotation crop)</th>
<th>Tallow/FDG HEFA (waste product)</th>
<th>Algae HEFA</th>
<th>Forestry waste F-T</th>
<th>Forestry waste HDICI (pyrolysis)</th>
<th>Ag waste F-T</th>
<th>Energy grass F-T</th>
<th>Natural gas F-T</th>
<th>Sugar cane</th>
<th>Alcohol To Jet</th>
<th>Sugar cane bagasse HDICI (pyrolysis)</th>
<th>Waste gas (CO)</th>
<th>Alcohol To Jet</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Does the &quot;element&quot; contribute to differences in LC GHG emissions results for this &quot;fuel pathway&quot;?</th>
<th>Yes</th>
<th>Maybe</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the &quot;element&quot; impact a &quot;fuel pathway's&quot; qualification under a reduced LC GHG emissions policy (e.g., RFS2)?</td>
<td>Yes</td>
<td>Maybe</td>
<td>No</td>
</tr>
</tbody>
</table>
### Questions of Interest:

- **Does the "element" contribute to differences in LC GHG emissions results for this "fuel pathway"?**
- **Does the "element" impact a "fuel pathway's" qualification under a reduced LC GHG emissions policy (e.g., RFS2)?**
- **Following workshop input, we will refine questions to better reflect different purposes for conducting life cycle GHG analysis.**

<table>
<thead>
<tr>
<th>Fuel Pathways</th>
<th>Baseline for Comparison</th>
<th>Data Sources</th>
<th>Elements</th>
<th>Accounting</th>
<th>System Boundary (attributional versus consequential analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean HEFA</td>
<td>Average barrel or marginal barrel of conv fuel</td>
<td>Emission factors (e.g., grid electricity)</td>
<td>Oil-Meal system co-product allocation</td>
<td>Direct land use change</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
</tr>
<tr>
<td>Rapeseed HEFA (relatively large N2O)</td>
<td>Geographical basis of baseline (domestic or international)</td>
<td>Process efficiencies</td>
<td>Lignin-cellulosic system co-product allocation</td>
<td>Indirect land use change</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
</tr>
<tr>
<td>Jatropha HEFA</td>
<td>Is LC value relative to a threshold or an absolute LC value?</td>
<td>Differences in farming practices</td>
<td>Refinery/Facility energy co-product allocation</td>
<td>Time window for emissions allocation (from LUC)</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
</tr>
<tr>
<td>Camelina HEFA (rotation crop)</td>
<td>N2O emissions factor</td>
<td>Emissions factor time scale (GWP 30, 100, 500 years)</td>
<td>Inclusion of building infrastructure (i.e., refinery)</td>
<td>Time window for emissions allocation (from LUC)</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
</tr>
<tr>
<td>Tallow/FDG HEFA (waste product)</td>
<td>Time window for normalizing long term emissions</td>
<td>Including consequences of alt fuel production</td>
<td>Including consequences of alt fuel production</td>
<td>Displacement by alt fuel co-products</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
</tr>
<tr>
<td>Algae HEFA</td>
<td>Transportation logistics</td>
<td>Is a waste still a waste if you don’t waste it?</td>
<td>Displacement by alt fuel co-products</td>
<td>Is the &quot;element&quot; a waste if you don’t waste it?</td>
<td>Yes</td>
</tr>
<tr>
<td>Forestry waste F-T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Forestry waste HDCJ (pyrolysis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Ag waste F-T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Energy grass F-T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Natural Gas F-T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Sugar cane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Alcohol To Jet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Sugar cane bagasse HDCJ (pyrolysis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Waste gas (CO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Alcohol To Jet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

## Feedstock-to-Fuel Pathways

### Data sources
- Emission factors (e.g., grid electricity)
- Process efficiencies
- Differences in farming practices
- N2O emissions factor
- Emissions factor time scale (GWP 30, 100, 500 years)
- Time window for normalizing long term emissions
- Transportation logistics

### Elements
- Oil-Meal system co-product allocation
- Lignin/cellulosic system co-product allocation
- Refinery/Facility energy co-product allocation (liquid fuels, electricity, heat, steam)

### System Boundary (attributional versus consequential analysis)
- Direct land use change
- Indirect land use change
- Time window for emissions allocation (from LUC)
- Inclusion of building infrastructure (i.e., refinery)
- Including consequences of alt fuel production
- Displacement by alt fuel co-products
- Is a waste still a waste if you don’t waste it?

### Fuel Pathways

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Fuel Pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean HEFA</td>
<td>Rapeseed HEFA (relatively large N2O)</td>
</tr>
<tr>
<td>Jatropha HEFA</td>
<td>Camelina HEFA (rotation crop)</td>
</tr>
<tr>
<td>Tallow/FOG HEFA (waste product)</td>
<td>Algae HEFA</td>
</tr>
<tr>
<td>Forest waste F-T</td>
<td>Ag waste F-T</td>
</tr>
<tr>
<td>Energy grass F-T</td>
<td>Natural Gas F-T</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>Alcohol To Jet</td>
</tr>
<tr>
<td>Sugar cane bagasse HDCJ (pyrolysis)</td>
<td>Waste gas (CO)</td>
</tr>
</tbody>
</table>

### Baseline for Comparison
- Average barrel or marginal barrel of conv fuel
- Geographical basis of baseline (domestic or international)
- Is LC value relative to a threshold or an absolute LC value?
### Jan 2014 Environment Team Workshop

#### LCA Issue Matrix

<table>
<thead>
<tr>
<th>Elements</th>
<th>Fuel Pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the &quot;element&quot; contribute to differences in LC GHG emissions results for this &quot;fuel pathway&quot;?</td>
<td>YES</td>
</tr>
<tr>
<td>Does the &quot;element&quot; impact a &quot;fuel pathway's&quot; qualification under a reduced LC GHG emissions policy (e.g., RFS2)?</td>
<td>YES</td>
</tr>
</tbody>
</table>

#### Baseline for Comparison

- Average barrel or marginal barrel of conv fuel
- Geographical basis of baseline (domestic or international)
- Is LC value relative to a threshold or an absolute LC value?

#### Data Sources

- Emission factors (e.g., grid electricity)
- Process efficiencies
- Differences in farming practices
- N2O emissions factor
- Emissions factor time scale (GWP 30, 100, 500 years)
- Time window for normalizing long term emissions
- Transportation logistics

#### Accounting

- Oil-Meal system co-product allocation
- Lignin/Cellulosic system co-product allocation
- Refinery/Facility energy co-product allocation (liquid fuels, electricity, heat, steam)

#### System Boundary (attributional versus consequential analysis)

- Direct land use change
- Indirect land use change
- Time window for emissions allocation (from LUC)
- Inclusion of building infrastructure (i.e., refinery)
- Including consequences of alt fuel production
- Displacement by alt fuel co-products
- Is a waste still a waste if you don't waste it?

---

**“Elements” that could lead to variations in LC GHG emissions results**

Workshop focused on identifying these “elements” (preliminary list shown here)
<table>
<thead>
<tr>
<th>Does the &quot;element&quot; contribute to differences in LC GHG emissions results for this &quot;fuel pathway&quot;?</th>
<th>YES</th>
<th>MAYBE</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the &quot;element&quot; impact a &quot;fuel pathway's&quot; qualification under a reduced LC GHG emissions policy (e.g., RFS2)?</td>
<td>YES</td>
<td>MAYBE</td>
<td>NO</td>
</tr>
</tbody>
</table>

### Baseline for Comparison

- Average barrel or marginal barrel of conv fuel
- Geographical basis of baseline (domestic or international)
- Is LC value relative to a threshold or an absolute LC value?

### Data Sources

- Emission factors (e.g., grid electricity)
- Process efficiencies
- Differences in farming practices
- N2O emissions factor
- Emissions factor time scale (GWP 30, 100, 500 years)
- Time window for normalizing long term emissions
- Transportation logistics

### Accounting

- Oil-Meal system co-product allocation
- Lignincellulosic system co-product allocation
- Refinery/Facility energy co-product allocation (liquid fuels, electricity, heat, steam)

### System Boundary (attributional versus consequential analysis)

- Direct land use change
- Indirect land use change
- Time window for emissions allocation (from LUC)
- Inclusion of building infrastructure (i.e., refinery)
- Including consequences of alt fuel production
- Displacement by alt fuel co-products
- Is a waste still a waste if you don’t waste it?

### Fuel Pathways

| Soybean HEFA (good for comparison) | Rapeseed HEFA (relatively large N2O) | Jatropha HEFA | Camelina HEFA (rotation crop) | Tallow/FOG HEFA (waste product) | Algae HEFA | Forestry waste F-T | Forestry waste HDCJ (pyrolysis) | Ag waste F-T | Energy grass F-T | Natural Gas F-T | Sugar cane | Alcohol To Jet | Sugar cane bagasse HDCJ (pyrolysis) | Waste gas (CO) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

### Seeking answer to each Question for each Element and Fuel Pathway

| YES | MAYBE | NO |
### LCA Issue Matrix

#### Fuel Pathways

<table>
<thead>
<tr>
<th>Soybean HEFA</th>
<th>Rapeseed HEFA</th>
<th>Jatropha HEFA</th>
<th>Camelina HEFA</th>
<th>Tallow/FOG HEFA</th>
<th>Algae HEFA</th>
<th>Forestry waste F-T</th>
<th>Forestry waste HDCJ (pyrolysis)</th>
<th>Ag waste F-T</th>
<th>Energy grass F-T</th>
<th>Natural Gas F-T</th>
<th>Sugar cane</th>
<th>Alcohol To Jet</th>
<th>Sugar cane bagasse HDCJ (pyrolysis)</th>
<th>Waste gas (CO)</th>
</tr>
</thead>
</table>

#### Baseline for Comparison

- Average barrel or marginal barrel of conv fuel
- Geographical basis of baseline (domestic or international)
- Is LC value relative to a threshold or an absolute LC value?

#### Data Sources

- Emission factors (e.g., grid electricity)
- Process efficiencies
- Differences in farming practices
- N2O emissions factor
- Emissions factor time scale (GWP 30, 100, 500 years)
- Time window for normalizing long term emissions
- Transportation logistics

#### Accounting

- Oil-Meal system co-product allocation
- Lignin-cellulosic system co-product allocation
- Refinery/Facility energy co-product allocation (liquid fuels, electricity, heat, steam)

#### System Boundary (attributional versus consequential analysis)

- Direct land use change
- Indirect land use change
- Time window for emissions allocation (from LUC)
- Inclusion of building infrastructure (i.e., refinery)
- Including consequences of alt fuel production
- Displacement by alt fuel co-products
- Is a waste still a waste if you don’t waste it?

#### Will use

**YES | MAYBE | NO**

answers to identify elements that lead to variations in LC GHG emissions results
Workshop discussion focused on four categories of “elements” that could lead to LC GHG variation:

* Baseline for Comparison / What is the Question you are Answering?
* Data sources
* Allocation
* System Boundary (in a loose sense, this is a question of attributional versus consequential analysis)

Workshop outputs are covered in following slides
**Baseline for Comparison**

What is the Question you are Answering?

- Are you considering the average barrel or marginal barrel of petroleum-based conventional fuel?
- Time when baseline is defined (e.g., is it based on a fixed point in time such as 2005 for EPA RFS2 versus a target in the future with a % reduction of emissions relative to a fixed year)
- Geographical basis of petroleum baseline - is production of concern company-specific, region, domestic-national or international?
- All issues below need to be addressed for the petroleum baseline (this includes transportation, refining product allocation, etc.)
- What is included in the baseline (e.g., conventional petroleum-based fuel, unconventional petroleum-based fuel, etc.)?
- Is LC value of alt fuel relative to a threshold or an absolute lc value?
- Production scale for the alt fuel being considered - facility-specific value (pilot scale, first of a kind facility, or n^th^ plant) versus industry-wide average value
- Note: Need to ensure that analysis is based on petroleum-baed jet fuel instead of “petroleum-based diesel fuel as a surrogate for jet"
- Need to communicate uncertainty in baseline definition – in reality, it is not a point value
Data Sources (1 of 2)

- Emission factors (e.g., grid electricity)
- Emissions factor from key inputs (e.g., fertilizer production (especially N), hydrogen, catalysts)
- Differences in farming practices
- Process efficiencies
- N2O emissions factor
- Note: Inclusion of black carbon as a climate factor (note that it is not included in accounting for RED, RFS2) – from fuel combustion perspective, there is a similar to other non-Co2 impacts – for ground sources, there is now bc information from IPCC
- Emissions factor time scale (GWP 30, 100, 500 years) and discounting
- Transportation logistics (truck, pipeline, rail, barge) and distances - note this could be important for some feedstock-to-fuel pathways
- Variation in local laws, regulations, etc.
- Scope of eligibility under framework (e.g., RFS certifies a pathway from feedstock to fuel while RED is certified according to company providing feedstock and fuel)
Data Sources (2 of 2)

- Time frame for determining data inputs (is it averaged over a day, growing season, year, several years?) -- often LCA are based on long-term average values (several growing seasons, years, etc.)
- Time window for normalizing long term emissions (discrepancy between RED (20 yrs) and RFS2 (30 yrs) timescales – this is DIFFERENT from GWP time factors)
- NOTE: some data ARE different as they are representative of different regions - need to find a way to identify those elements that are choices as opposed to being representative of the system
- NOTE: we need accurate data and to understand any factors that are being applied to the data (e.g., EC introduced a factor for the JRC WTW values to make data points more conservative with the hope that it would encourage producers to provide more accurate values)
- NOTE: It is important to consider uncertainty and variability in data inputs
Allocation

- Oil-Meal system co-product allocation / displacement of other comparable products in the broader economy (HEFA, Green Diesel)
- Corn stover, starch, oil system co-product / displacement while accounting for DGS use
- Lignocellulosic system co-product allocation / displacement of other comparable products in the broader economy
- Refinery/Facility energy co-product allocation / displacement of other comparable products in the broader economy (liquid fuels, electricity, heat, steam)
- Handling of co-products that are plastics and chemicals (bio-plastics, biochemicals and petroleum equivalents)
- Is a waste still a waste if you don't waste it? (is a co-product or feedstock a waste stream with zero GHG, a co-product with some GHG value that is accounted for in another LC system, or is it a feedstock to this LC system?) (there are regulatory requirements for how to handle wastes and this reality needs to be taken into account by the LCA practitioner)
- NOTE: Is everything within the system a “co-product”? If so, how do we allocate emissions to all of these co-products of the fuel and related systems?
System Boundary (in a loose sense, this is a question of attributional versus consequential analysis)

- Direct land use change (this is always domestic)
- Indirect (induced) land use change (this can be either domestic or international)
- Soil carbon data
- Time window for allocating land use change emissions (need consistency with other time windows – see data sources)
- Inclusion of the creation of infrastructure (e.g., refinery) (note that this is generally thought to be small but could be larger for algae PBR)
- Co-product displacement - this is tied to elements relating to allocation within “Accounting” topic area
- Including consequences of large-scale alt fuel production that could displace production of other energy sources or products in the broader market (beyond LUC)
- Alternative use question - Including consequences of not using wastes, (e.g., tallow being used for other purposes, waste gases being vented, agricultural residue being pulled from the field, forest residue not being pulled from the forest)
- NOTE: it is critical to communicate uncertainty regarding indirect effects (from a consequential analysis) as they have large uncertainty
Examine variations in life cycle greenhouse gas (GHG) emissions due to:
- Using different Life Cycle Analysis (LCA) methods, tools, and data
- Meeting varied purposes and regulatory regimes

**Goal:**
- Identify elements that lead to variations in LC GHG emissions results
- **Develop actions that could be taken to yield more harmonized results**

**Process:**
- Briefings explored how life cycle GHG emissions varied with different tools and purposes
- Group discussion is feeding into an LCA Issue Matrix spreadsheet
  - Captured key elements leading to differences in LC GHG emissions for the varied fuel pathways under consideration by the alternative jet fuel community.
  - Worked through four areas: Baseline, Data Source, Accounting, and System Boundaries
- The spreadsheet is a tool to help us identify what is leading to variations in results (filling in all of the blanks is not the goal)
Questions for the Group

- Have we missed any major “Elements”?
- Do you have recommendations for how we construct the “YES | MAYBE | NO” questions to be answered for each element and fuel pathway?
- Do you have recommendations for how we further develop this LCA Issue Matrix? (online survey, additional face-to-face meetings, etc.)
- Do you have thoughts on “actions that could be taken to better understand differences in LC GHG results”?
- What should the CAAFI Environment Team do next?