100% SAF
- initial reflections

CAAFI R&D Team

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Why 100% SAF?

Many in the aviation industry, from manufacturers to airlines, have announced “zero-emission” goals and plans. A reduced carbon (down to zero and even to negative) fuel is central to the discussion.

**Current major needs regarding SAF:**
- ramp-up SAF production (**availability**)
- establish SAF price parity with conventional jet (**cost**)
- level playing field with ground transportation for aviation (**regulatory framework**)

100% SAF is **not** an immediate need, however, this is the time to start the process to get ready for it
- technological & operational readiness
- standardization

Today, we will introduce the topic and raise relevant questions…a follow-on R&D team session is being considered to further the discussion in more detail.
What really is the case:

Synthetic Blend Component* + Conventional Blend Component = SAF Blend

(SAF*) (Jet A/A-1) (Jet A/A-1)

* Not all synthetic blend components are sustainable. For the purposes of this presentation the term SAF will be used.

Synthetic blend component, by itself, is not necessarily a finished aviation fuel that could be used in aircraft...

Multiple ways to produce the synthetic blend component today:
some like-jet, some similar to jet, some nothing like jet…

QUIZ

Which one is conventional jet fuel?
(carbon distribution)

Which ones are SAF?

1st one is petro-jet fuel, all others are SAF!!!
SAF blends are all the same product...

FT-SPK synth. blend comp’t (sbc) + Jet A/A-1 conv. blend comp’t (cbc)

- HEFA-SPK sbc + cbc
- HFS-SIP sbc + cbc
- FT-SKA sbc + cbc
- ATJ-SPK sbc + cbc
- CHJ sbc + cbc
- HC-HEFA-SPK sbc + cbc

When blended they all result in the one and the same product: Jet A/A-1
Unblended SAF (neat, 100%)…is it 🍎?

FT-SPK sbc
HEFA-SPK sbc
HFS-SIP sbc
FT-SKA sbc
ATJ-SPK sbc
CHJ sbc
HC-HEFA-SPK sbc

100%

Identical to Jet A/A-1 (fleetwide compatible, drop-in)

Like Jet A/A-1 (limited fleet compatible, non-drop-in)

Not-like Jet A/A-1 (not acceptable as a stand-alone jet fuel)

(depends on the producer)

<table>
<thead>
<tr>
<th>Property</th>
<th>FT-SPK sbc</th>
<th>HEFA-SPK sbc</th>
<th>HFS-SIP sbc</th>
<th>ATJ-SPK sbc</th>
<th>CHJ sbc</th>
<th>HC-HEFA-SPK sbc</th>
</tr>
</thead>
<tbody>
<tr>
<td>aromatics</td>
<td>~17%</td>
<td>~0%</td>
<td></td>
<td>(depends on the producer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>energy cont.</td>
<td>~43.2MJ/kg</td>
<td>+0-3%</td>
<td></td>
<td>(depends on the producer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>density</td>
<td>~800kg/m³</td>
<td>-0-8%</td>
<td></td>
<td>(depends on the producer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetane #</td>
<td>~45</td>
<td>±20-30%</td>
<td></td>
<td>(depends on the producer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>~500-800ppm</td>
<td>~0ppm</td>
<td></td>
<td>(depends on the producer)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Variation of composition among pathways and even among producers for a pathway
When unblended they do not all result in one and the same product
A specification is needed to define 100% SAF (in progress; early stages)
Pathways in the pipeline (no pun intended!)

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Blend Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATJ-SKA sbc</td>
<td>Identical to Jet A/A-1 (fleetwide compatible, drop-in)</td>
</tr>
<tr>
<td>HEFA-SKA sbc</td>
<td>Like Jet A/A-1 (limited fleet compatible, non-drop-in)</td>
</tr>
<tr>
<td>HDO-SAK sbc</td>
<td>Not-like Jet A/A-1 (not acceptable as a stand-alone jet fuel)</td>
</tr>
<tr>
<td>CPK-0 sbc</td>
<td></td>
</tr>
<tr>
<td>HTL sbc</td>
<td></td>
</tr>
<tr>
<td>SAK sbc + SPK sbc</td>
<td>Blending of approved blend components will open a door to get to drop-in 100% SAF by blending non-drop-in blend components</td>
</tr>
</tbody>
</table>

More pathways on the way…initially most, if not all, will be approved at 50% but could meet 100% drop-in SAF requirements when defined.

Blending of approved blending components is an important path.
## Drop-in vs non-drop-in SAF

<table>
<thead>
<tr>
<th>Description:</th>
<th>Fully formulated Jet A/A-1 composition</th>
<th>Compositional subset of Jet A/A-1 composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicability:</td>
<td>Fleet Wide drop-in</td>
<td>Targeted or Limited for designated aircraft/engines only, not fleet-wide compatible</td>
</tr>
<tr>
<td>Specification:</td>
<td>ASTM D7566</td>
<td>New standard needed</td>
</tr>
<tr>
<td>FAA Certification:</td>
<td>Not required</td>
<td>Required for each intended aircraft/engine model</td>
</tr>
<tr>
<td>Supply chain/handling/storage:</td>
<td>Separate supply chain/handling/storage not required</td>
<td>Separate supply chain/handling/storage required</td>
</tr>
</tbody>
</table>
Examples of OEM experience with 100% SAF

- Swedish MoD Gripen flight with GKN RM12 engine (GE F404 derivative) – 100% CHJ.
- Boeing 777 EcoDemonstrator flight with GE90 engines. On-wing engine tests – 100% HEFA-SPK.
- Multiple engine tests with Rolls-Royce Trent & Pearl engines – 100% HEFA-SPK.
- NRC Canada Falcon 20 flights with GE CF700 engines – 100% HEFA-SPK/HDO-SAK blend & CHJ.

- Multiple ground/on-wing GE F414 engine tests – 100% CHJ.
- Bell Ranger helicopters frequent flights with Pratt & Whitney engines in 80s – 100% FT-SPK.
- Boeing EA-18G Growler flight (Secretary of NAVY) with GE F414 engines – 100% CHJ.
- Many combustor rig tests by OEMs – 100% HEFA-SPK, ATJ-SPK, ATJ-SKA, blends of blend components, others...

Additional flights/tests among OEMs/airlines in work – 100% drop-in & non-drop-in SAF
ASTM Standardization
Specify 100% SAF* via a standard

ASTM Task Force formed in Q1 ‘21:
• Main effort: Modify ASTM D7566 drop-in standard to allow 100% SAF
  – Establish a new set of requirements for 100% SAF (e.g., new Table)
  – 1st step: approval of CHJ at 100%
  – Next: other pathways & blending of blend components (only already approved blend components allowed)
  – Effort is approval of 100% SAF as Jet A/A-1

• Possible secondary (later) effort: Establish another standard ASTM Dxxxx for 100% non-drop-in SAF
  – Effort is for establishing a standard defining a particular synthetic fuel
  – Not approval of 100% non-drop-in SAF, but development for it a standard that could be used by the OEMs to certify their equipment with if they so desire

• Multi-year effort (2-5 years for both)

*Standard is for synthetic fuels, sustainable or not. For the purposes of this presentation the term SAF is used synonymously with synthetic fuel.
100% SAF White Paper and Webinar

**Intent:** Frame stakeholder discussions on key issues concerning 100% SAF

**Questions/Issues to Discuss:**

- Why 100% SAF – reasons for pursuing (GHG, LCA, nvPM)
- Approaches to achieve 100% SAF (single fuels, blends)
- Approach to Drop-In/Fungibility (100% drop-in, relax certain properties)
- Desired production, sustainability, environmental characteristics
- Critical safety, operability, performance characteristics
- Potential changes to certification and qualification
- Milestones, next steps, timelines
- Possible unknown unknowns

**Webinar:** More details on questions, solicit feedback
Thank You!