MONTANUNIVERSITÄT LEOBEN

Development and optimization of alternative process routes to SAF with alcohols as feedstock

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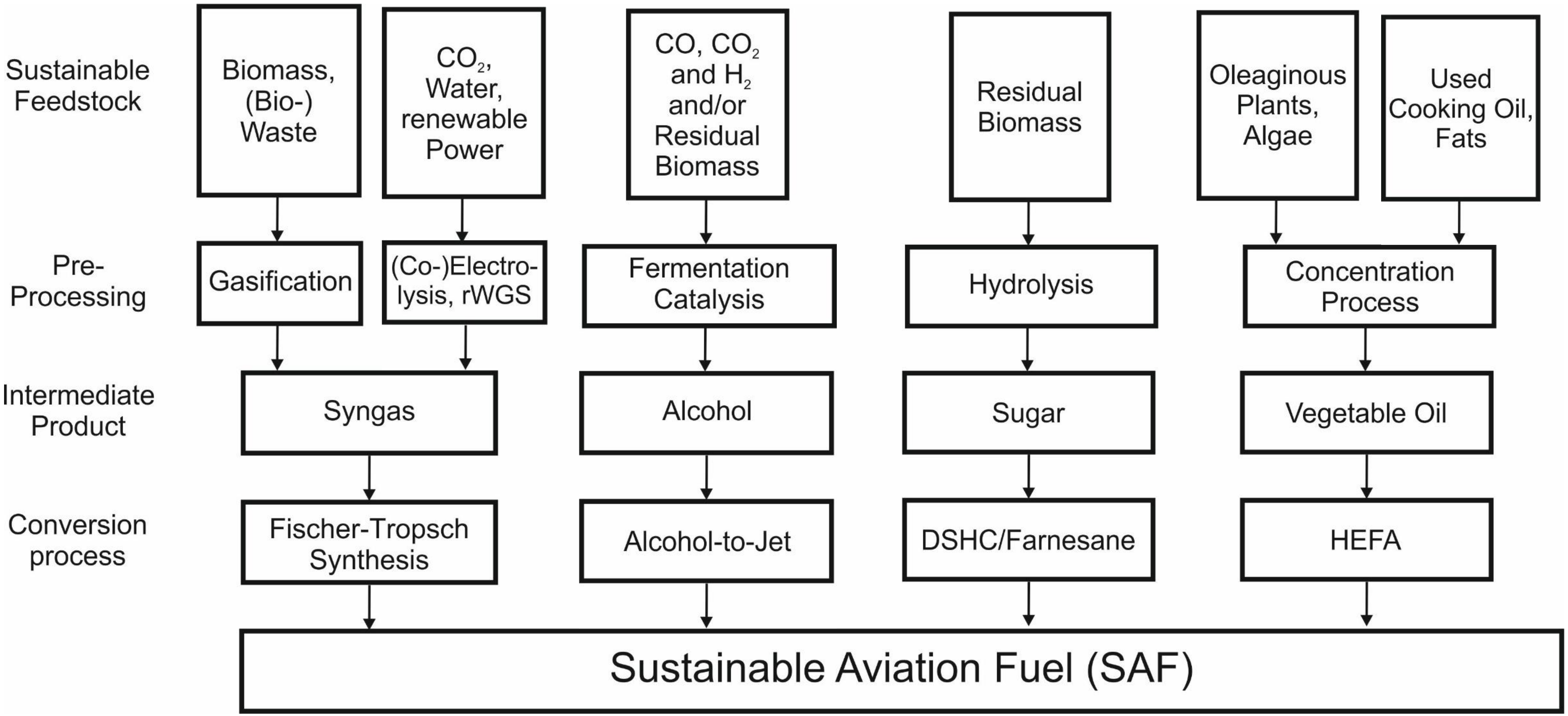
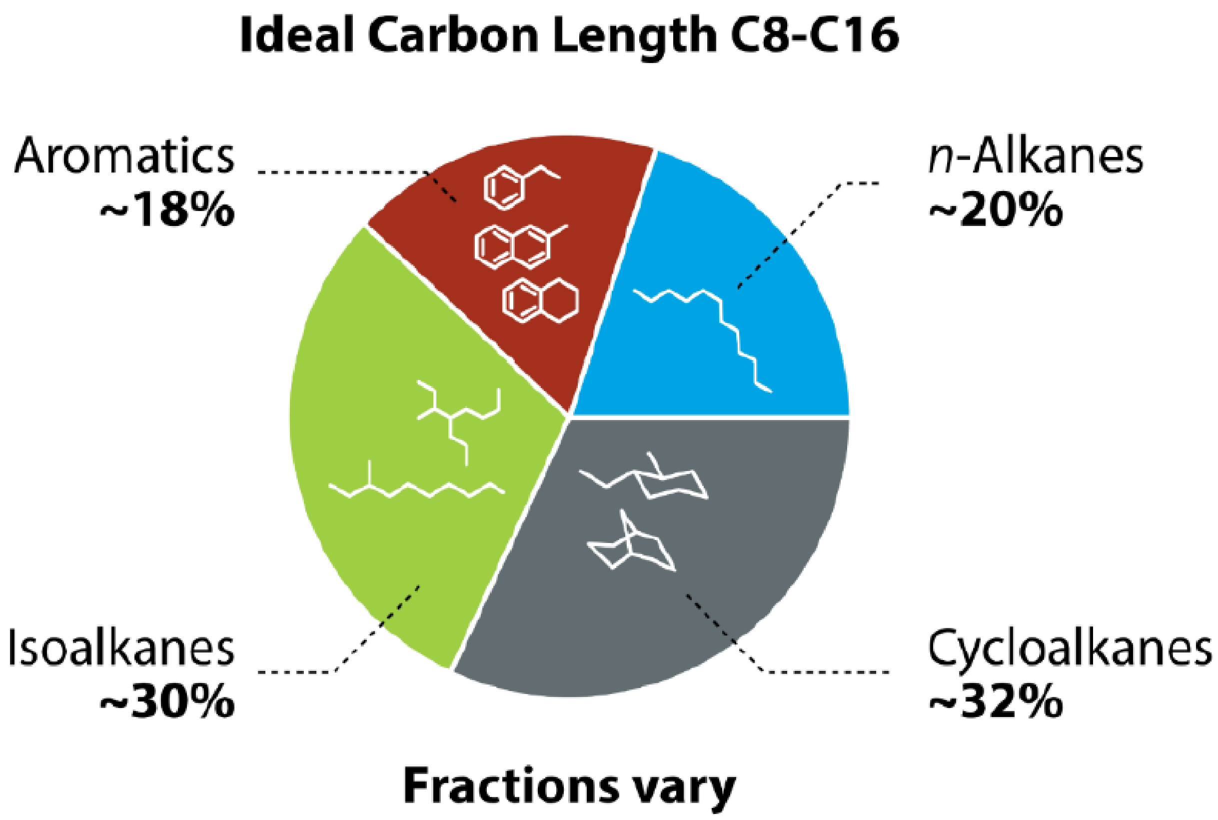
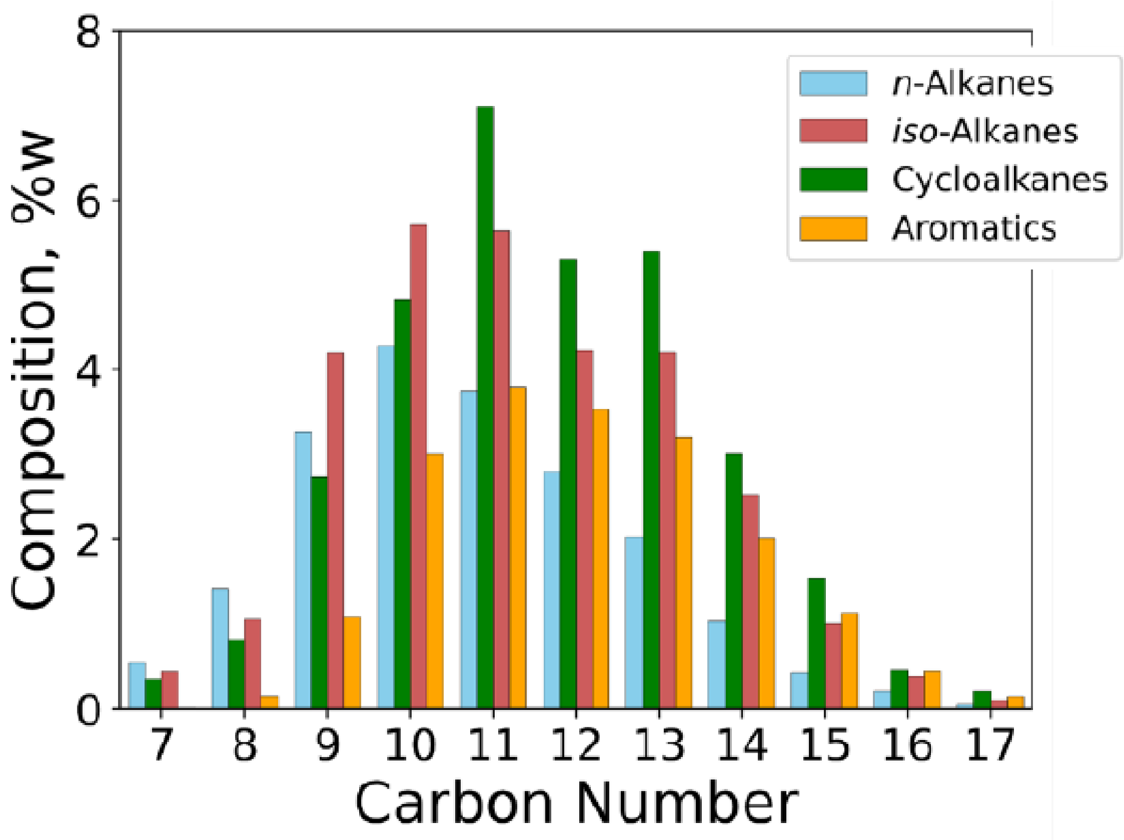
VTiU

SAF Production Options

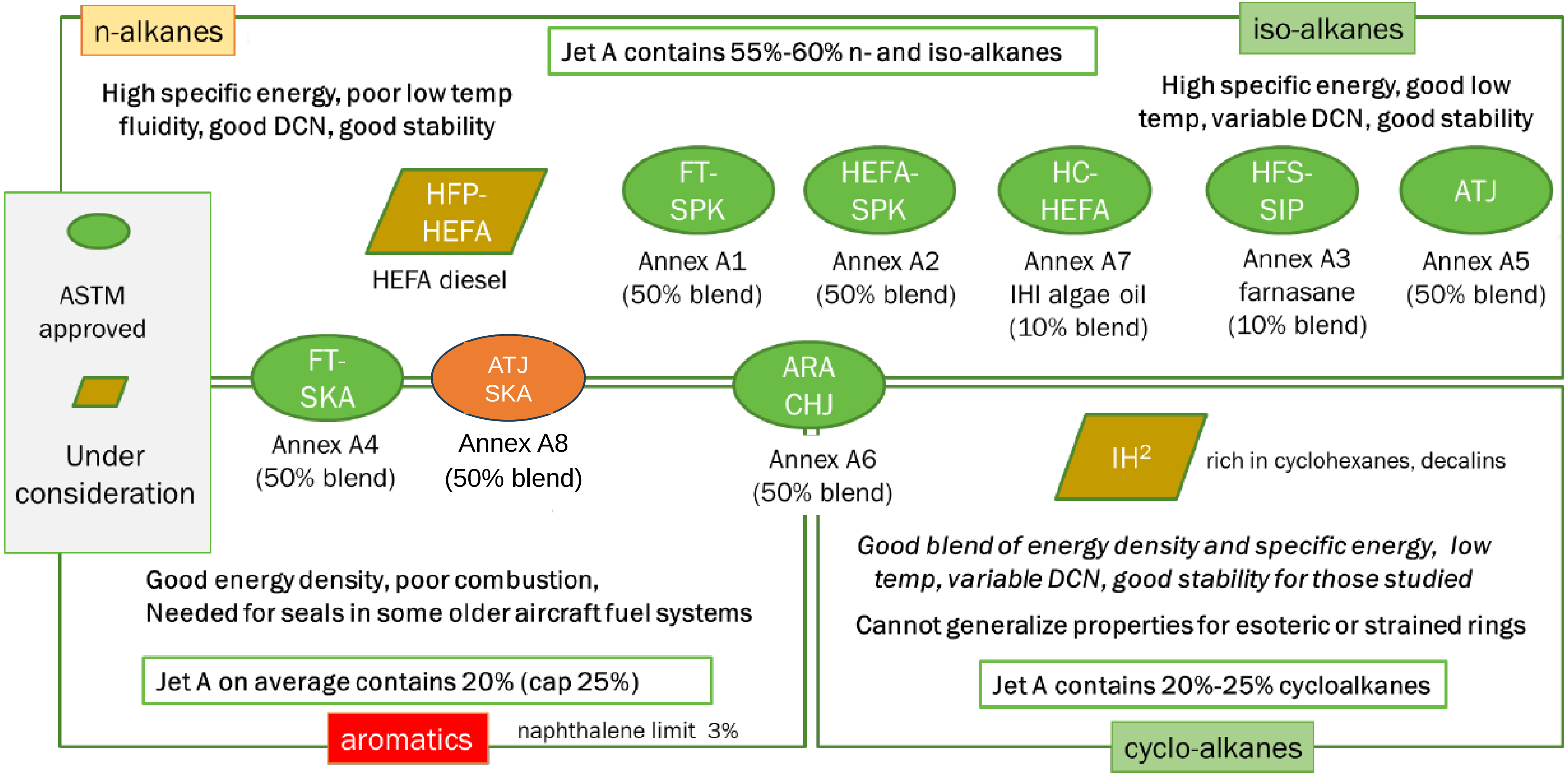


Composition of Average Jet-A (fossil)





Classes of Hydrocarbons and Yield of SAF Production Routes



ASTM D7566 Annex 1 – 8 certified SAF Fuels

ASTM D7566	Pathways and processes	Feedstock options	Producers (example)	Date of approval	Blending limit
Annex A1	Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	biomass (forestry residues, grasses, municipal solid waste)		2009	up to 50%
Annex A2	Hydroprocessed Esters and Fatty Acids (HEFA-SPK)	algae, jatropha, camelina	Alt Air	2011	up to 50%
Annex A3	Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)	microbial conversion of sugars to hydrocarbon	Amyris	2014	up to 10%
Annex A4	FT-SPK with aromatics (FT-SKA)	renewable biomass such as municipal solid waste, agricultural wastes and forestry residues, wood and energy crops		2015	up to 50%
Annex A5	Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK)	agricultural waste products (stover, grasses, forestry slash, crop straws) – feedstock: isobutanol and ethanol	Gevo LanzaTech	2016 2018	up to 30% up to 50%
Annex A6	Catalytic hydrothermolysis synthetic jet fuel (ARA-CHJ)	Triglyceride-based feedstocks (plant oils, waste oils, algal oils, soybean oil, jatropha oil, camelina oil, carinata oil and tung oil)	ARA and Euglena	2020	up to 50%
Annex A7	High Hydrogen Content Synthetic Paraffinic Kerosene (HC-HEFA)	biologically derived hydrocarbons such as algae	IHI World	2020	up to 10%
Annex A8	Alcohol-to-Jet Synthetic Kerosene and Aromatics (ATJ-SKA)	agricultural waste products (stover, grasses, forestry slash, crop straws) – feedstock: mixed alcohols	Swedish Biofuels	2023	up to 50% (target: 100%)

On the way to 100% SAF – Drop-in SAF versus Non-Drop-in SAF

- “100% drop-in SAF” refers to a synthetic kerosene, which chemically and functionally duplicate fossil Jet-A.
- ”100% non-drop-in SAF” refers to a synthetic kerosene, which fulfils all functional requirements of jet engines while not being a chemical duplicate of fossil Jet-A.
- Drawback of 100% non-drop-in SAF: Each item of equipment in the fuel chain must gain certification for safely handling!
- Benefits of 100% non-drop-in SAF: reductions in particle emissions, fuel-burn improvements resulting from its higher heat content than drop-in SAF, and potential greater availability.

On the way to 100% SAF – Important Considerations

- Restructuring of ASTM D7566 for the provision of specifications for the fuel properties, i.e.“maximums and minimums” for energy density, lubricity, ignition, freezing points, etc.
- ”100% SAF” probably will consist of a blend of paraffinic and aromatic synthetic (bio-)fuels.
- Certification regulations for both of 100% SAF options are still missing.
- Also, the knowledge on functional requirements are still limited, therefore, in a first step, 100% drop-in SAF is targeted.
- However, for the next decade(s), blending with fossil kerosene will prevail due to missing production capacities for SAF.

Operability and Drop-in Requirements (ASTM D1655)

Property	Unit	Description/Relevance	Minimum acc. to ASTM D1655	Maximum acc. to ASTM D1655
Kinematic Viscosity at -20°C	$mm^2\ s^{-1}$	Important for flow performance, particularly at cold temperatures	-	8
Density at 15°C	$kg\ m^{-3}$	Used in calculating tank volumes	775	840
Freeze point	°C	Inhibits freezing of the fuel in flight at an altitude	-	-40 for Jet-A -47 for Jet-A1
Flash point	°C	Safe handling	38	-
Boiling point (distillate temperature)	°C	Enables sufficient volatility of a fuel	-	300
Total aromatics	Vol.%	Ensure swelling of nitrile O-rings and seals previously exposed to aromatics, however cause sooting	-*	25 - 26.5 (dep. on method)
Derived cetane number (DCN)	-	Important for lean blowout limit stability	n/a	n/a
Surface tension	$mN\ m^{-1}$	High values can inhibit spray break-up and atomization	n/a	n/a

n/a: Not currently included as part of the ASTM D1655 specification

*Minimum aromatics content not specified, since no issue in fossil fuels. However, ASTM D7566 states 8 - 8.4 Vol.%.

„Tailoring“ of SAF:
Fuel Properties and Molecular Structure Relationship

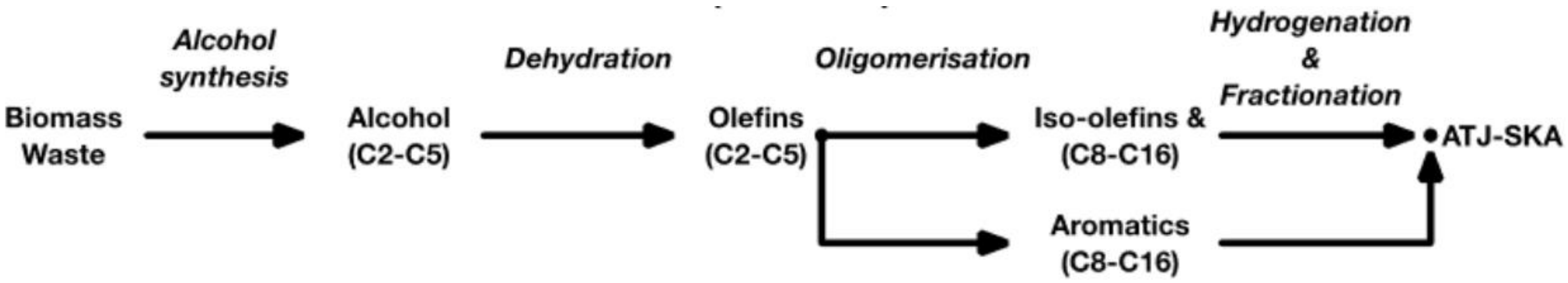
		n-Alkanes	Iso-Alkanes weakly branched	Iso-Alkanes strongly branched	Cycloalkanes monocyclic	Cycloalkanes fused bicyclic	Aromatics
Performance	Specific energy [MJ/kg]	++	++	++	+	O	-
	Energy density [MJ/L]	-	-	-	+	++	++
	Thermal stability	+	+	+	+	+	
	Sooting	++	++	++	+	+	--
Operability	DCN	++	+	-			-
	Density	-	-	-	+	++	+
	Freeze point	-	+	+	+	+	+

++ strongly positive; + positive; O neutral; - negative; -- strongly negative

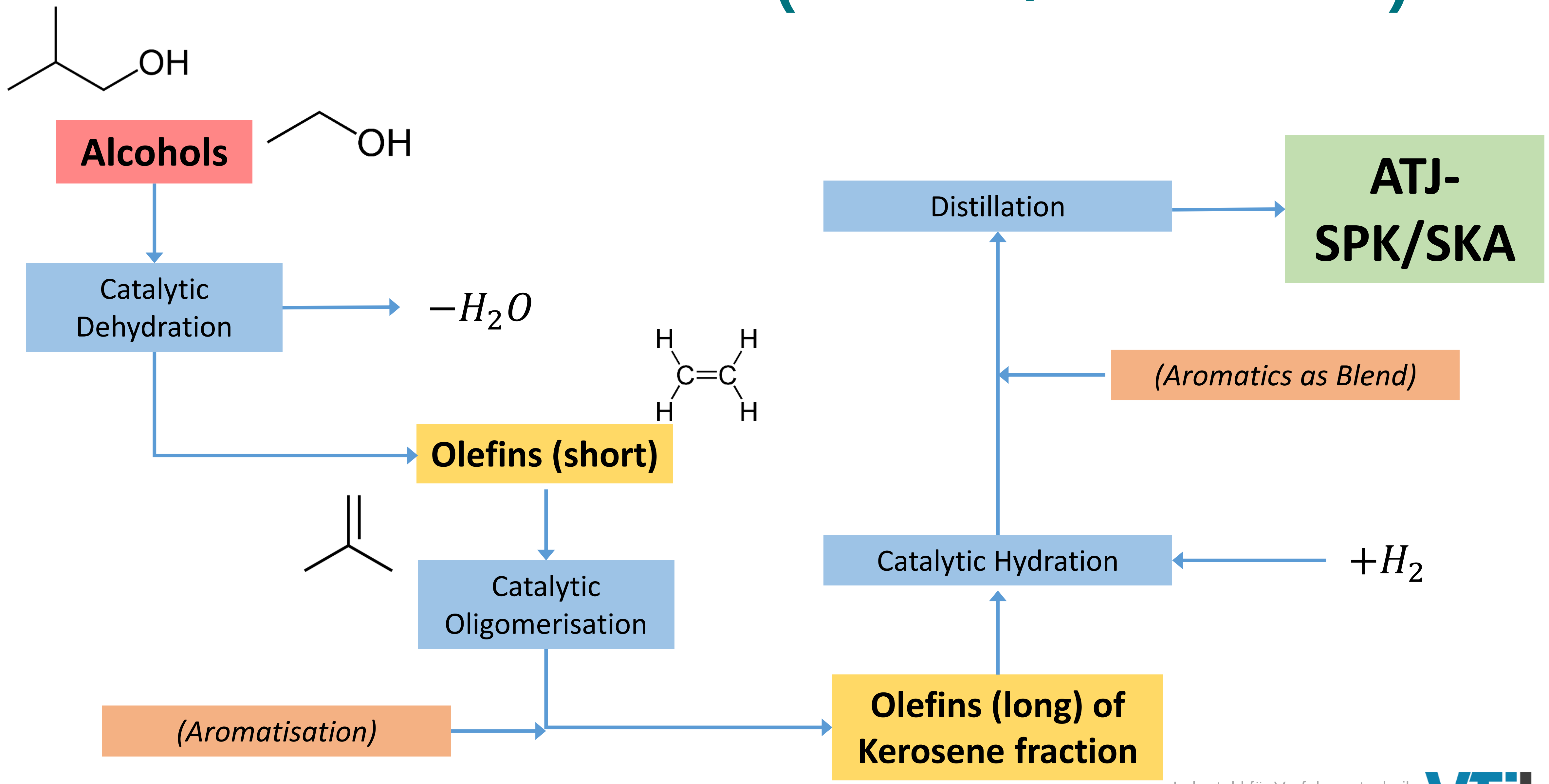
Alcohol-to-Jet (ATJ) Processes – Feedstock Ethanol/Iso-Butanol

ATJ-SPK

ATJ-SKA



ATJ – Process Chain (Ethanol/Iso-Butanol)



Alcohol-to-Jet (ATJ) Processes – Aromatisation

- Only small amounts of aromatics are produced in the ATJ processes due to the moderate temperatures in the oligomerization step (<350°C), since dehydrogenation to aromatics only occurs effectively at temperatures >400°C.
- One strategy to increase the share of aromatics is the implementation of a separate aromatization step after oligomerization.
- Aromatics can be produced with higher temperatures up to 500 °C, for example with Ga-ZSM-5 or Ni-ZSM-5 doped catalysts.
- Another strategy is the selective hydrogenation of olefins without destruction of aromatics, however, only minor publications are available so far.

Summary

- 100% drop-in SAF requires a minimum share of aromatic compounds which is currently not produced in the established SAF production pathways, including the ATJ pathway.
- Different strategies exist to achieve 100% SAF drop-in fuels which are functionally and chemically duplicates of fossil Jet-A.
- However, ASTM D7566 is currently not developed for 100% SAF, but a modification of the specifications is under development.
- As long as the production capacities for SAF are generally limited, SAF will be mixed with shares of fossil Jet-A which solves the aromatics problem.
- Production pathways for 100% non-drop-in SAF are an interesting field of research, however the hurdles for their approval are currently challenging.

Thank you for your attention!

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