Experimental study on the impact of HVO addition to Jet A-1 on particulate matter emissions

PhD Eng. Paula Kurzawska-Pietrowicz

PRESENTATION PLAN

1. Motivation
2. HVO and HEFA-SPK
3. Materials and methods
4. Results
5. Conclusions

MOTIVATION

MOTIVATION: WHY HVO BLENDS WITH JET A-1?

2.5%

of global CO_2 emissions from aviation (2023)
3–4× higher effective climate impact when non-CO_2 effects are included

80%

of CO_2 emissions throughout the life cycle of a fossil fuel come from its combustion in the engine

up to 90%

reduction of CO_2 and PM emissions throughout the usage of Sustainable Aviation Fuels

Similar chemistry:

Similar group composition to HEFA-SPK

Availability:

Commercial HVO available in bulk;
certified SAF requires supply agreements

No certification barrier:

Laboratory engines are not type-certified; using non-ASTM D7566 fuel is permissible for research

Known limitation:

Results represent a surrogate, not a certified blend

HVO – Hydrotreated Vegetable Oil

HVO vs. HEFA-SPK

HVO vs. HEFA-SPK: PRODUCTION, COMPOSITION & PROPERTIES

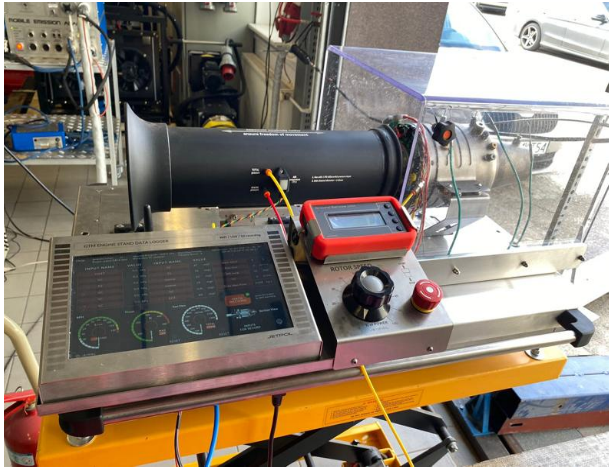
Common feedstock	Common process	HEFA-SPK only	Products
Vegetable oils Animal fats UCO/ waste	Hydrotreatment (HDO / decarboxylation) 300–400 °C, 30–130 bar	Hydroisomerisation (cracking to C_8–C_{16} + branching)	HVO diesel C_{15}–C_{18} HEFA-SPK C_8–C_{16}

Property	Jet A-1	HVO (diesel)	HEFA-SPK	Unit
Carbon range	C_8–C_{16}	C_{15}–C_{18}	C_8–C_{16}	—
Density 15°C	795–840	820–840	730–760	kg/m³
LCV	43.0–43.5	43.8–44.2	44.0–44.3	MJ/kg
Freeze point	≤ −47	−5 to −30	≤ −47	°C
Flash point	≥ 38	56–65	38–48	°C
Aromatics	14–22	< 0.5	< 0.5	vol%
Sulfur	250–600	< 5	< 5	mg/kg
n-paraffins	20–25	30–50	10–30	mass%
Iso-paraffins	30–40	50–70	65–90	mass%
Cycloparaffins	20–30	< 2	< 2	mass%
H/C ratio (atomic)	~1.92	~2.10	~2.14	—
ASTM D7566 certified	N/A (ref.)	No (diesel gr.)	Yes (≤50%)	—

MATERIALS AND METHODS

MATERIALS AND METHODS

Blends: 10% HVO, 30% HVO, 50% HVO and Jet A-1



GTM 400 engine

Test bench

Parameter	Value
Maximum thrust	400 N
Minimum thrust	15 N
Maximum spool rpm	85 000 rpm
Minimum spool rpm	27 000 rpm
Compression ratio	3,3:1
Mass air flow rate	770 g/s
Exhaust gas temperature	750 ºC
Fuel consumption (max thrust)	1200 g/min
Diameter	150 mm
Length	390 mm
Total weight	3200 g

GTM 400 parameters

Engine type: single-shaft turbojet
Compressor: single-stage centrifugal

MATERIALS AND METHODS

Blends: 10% HVO, 30% HVO, 50% HVO and Jet A-1

7% F	Idle / ground operations
30% F	Landing
50% F	Cruise phase
85% F	Climb-out

Operating points

- **Exhaust sampling**
  Stainless probe perpendicular to the exhaust flow
- **Dilution**
  Dilution ratio 1:100
- **Particles range**
  5.6 – 560 nm (32 channels)

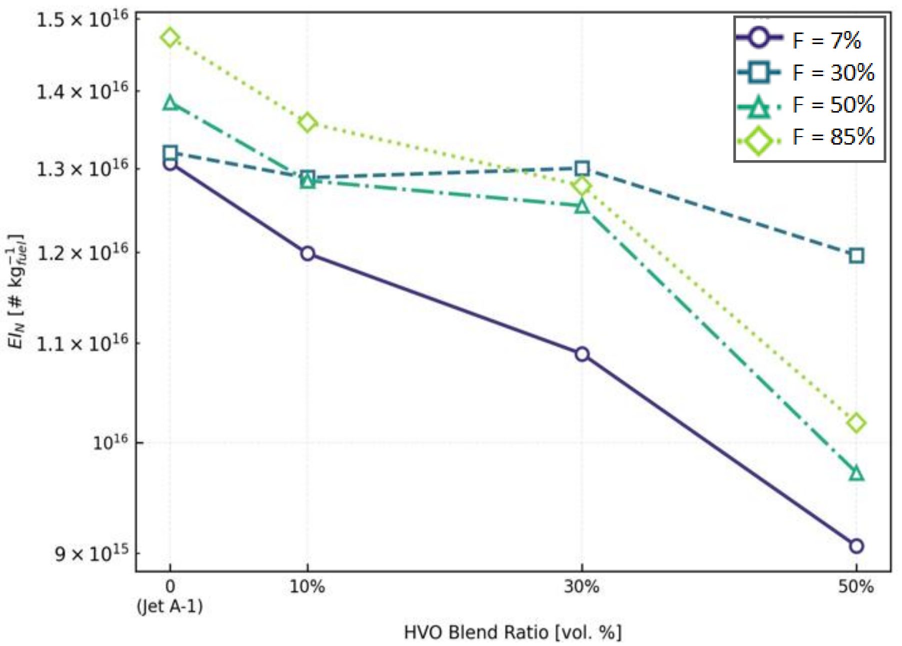
Measurement

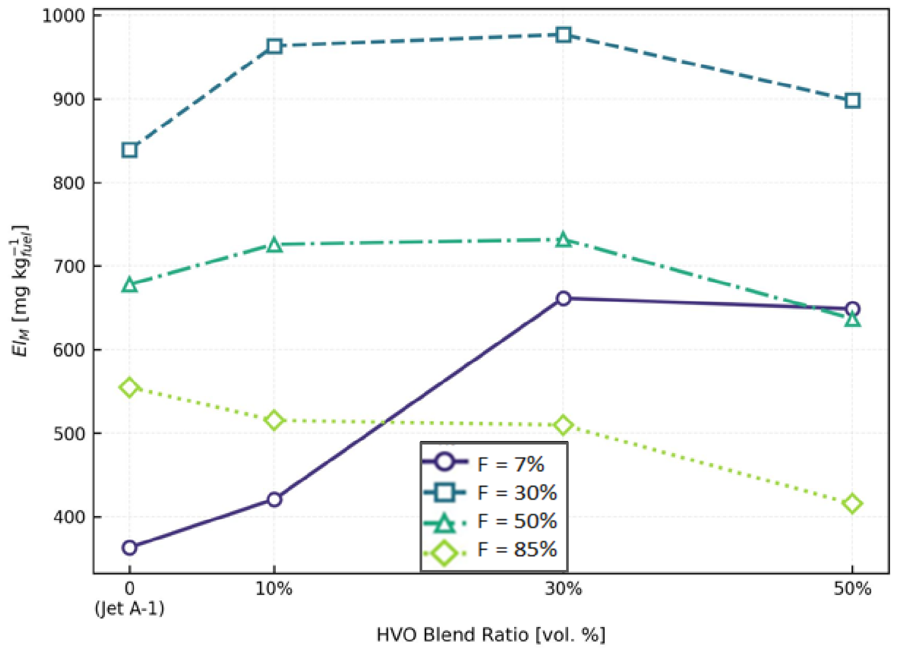
EEPS 3090

RESULTS

PM EMISSION INDICES

EI_N [#/kg$_{fuel}$]	EI_M [mg/kg$_{fuel}$]



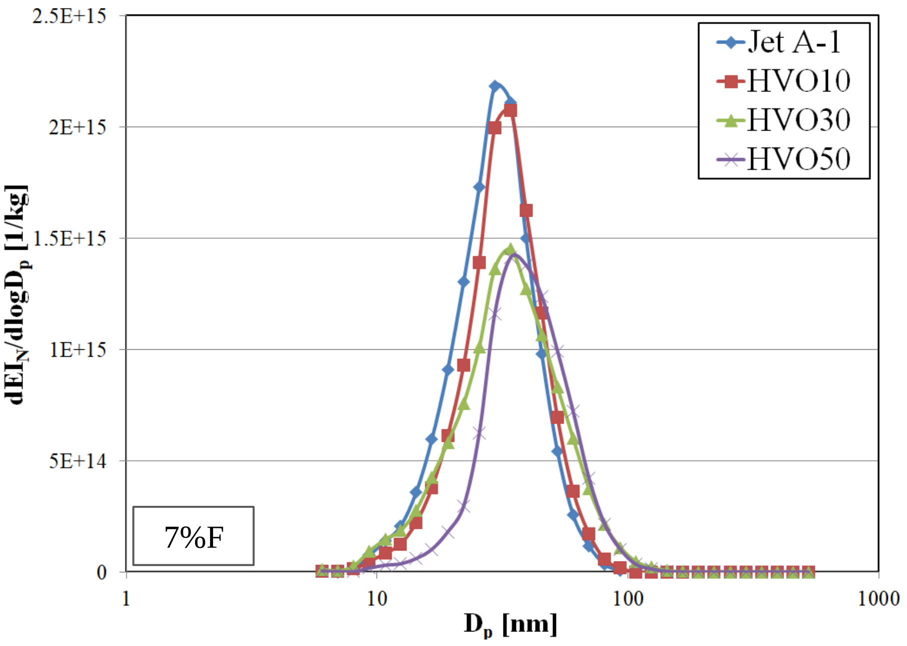


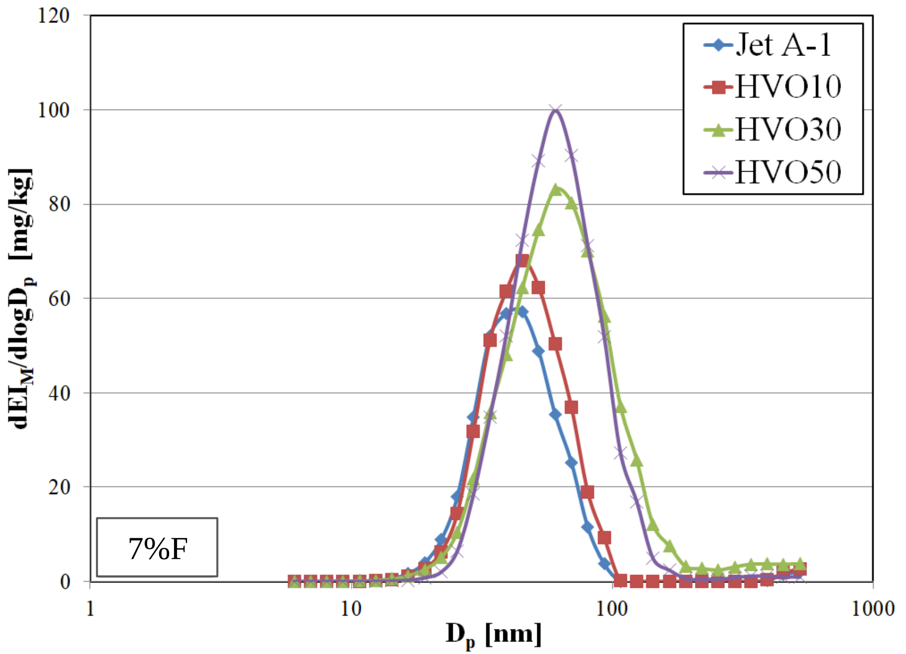
PARTICLE SIZE DISTRIBUTION

$dEI_N/dlogD_p$ [#/kg_{fuel}]

7% F

$dEI_M/dlogD_p$ [mg/kg_{fuel}]



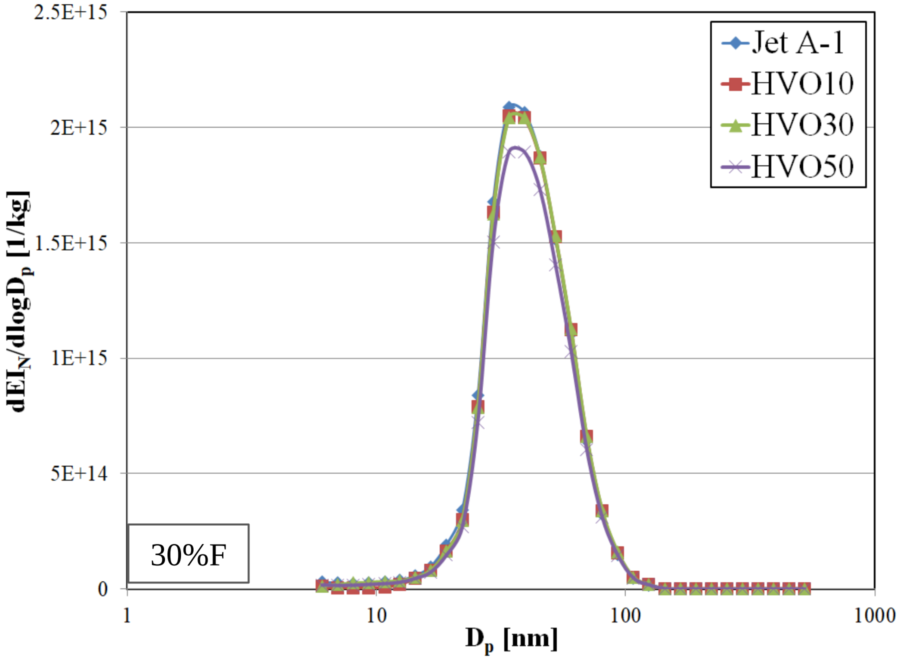


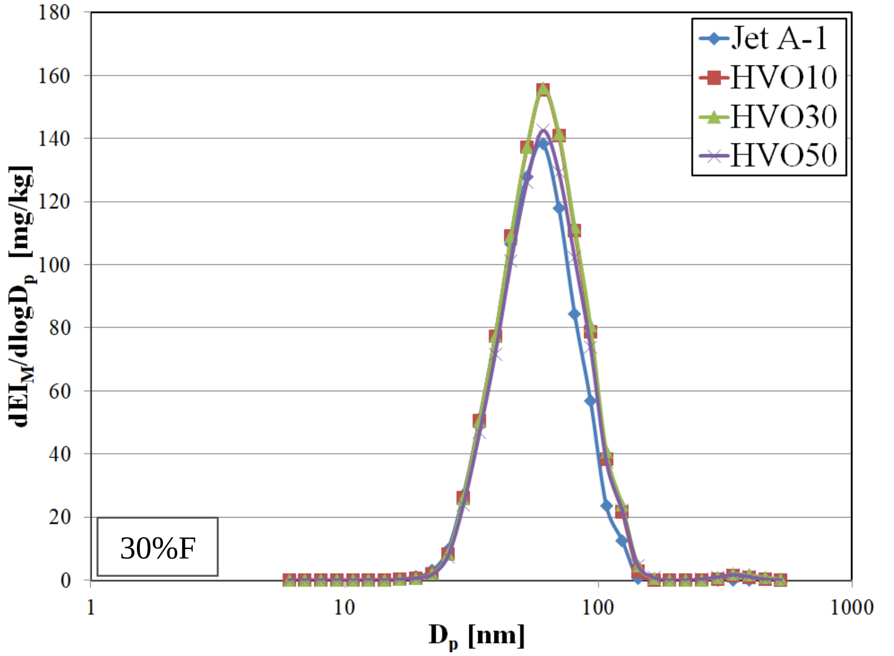
PARTICLE SIZE DISTRIBUTION

$dEI_N/dlogD_p$ [#/kg_{fuel}]

30% F

$dEI_M/dlogD_p$ [mg/kg_{fuel}]



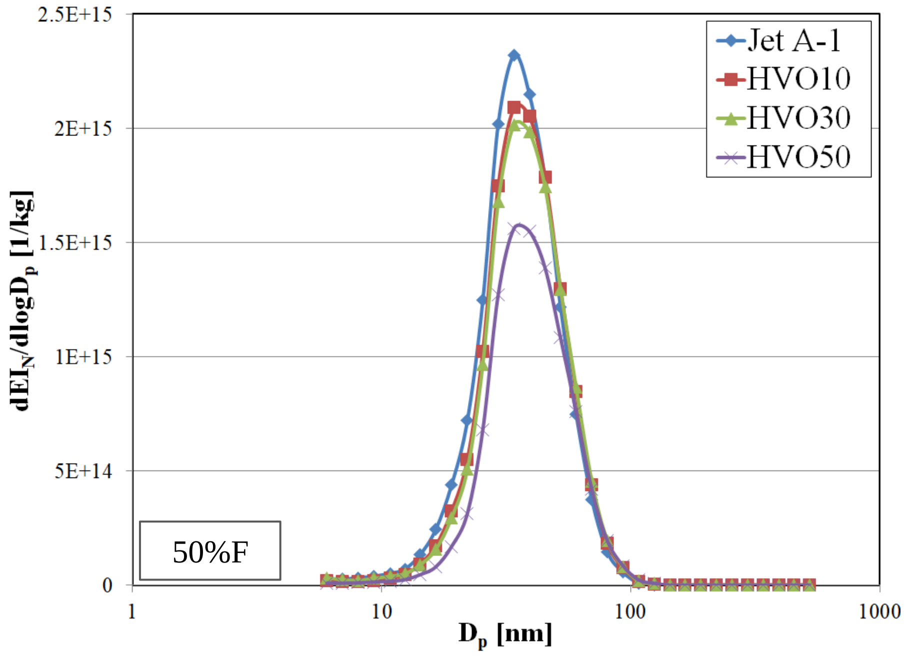


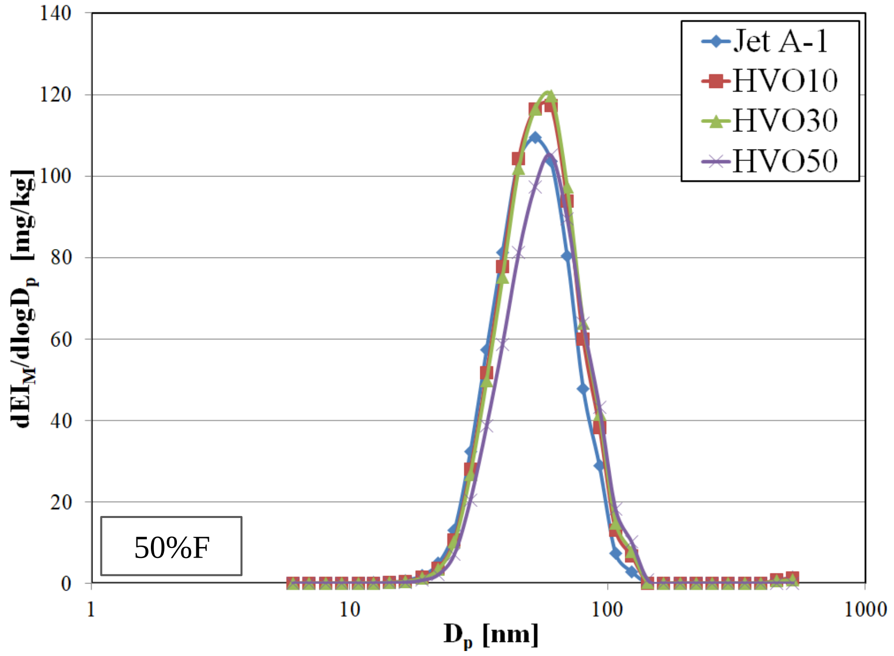
PARTICLE SIZE DISTRIBUTION

$dEI_N/dlogD_p$ [#/kg_{fuel}]

50% F

$dEI_M/dlogD_p$ [mg/kg_{fuel}]

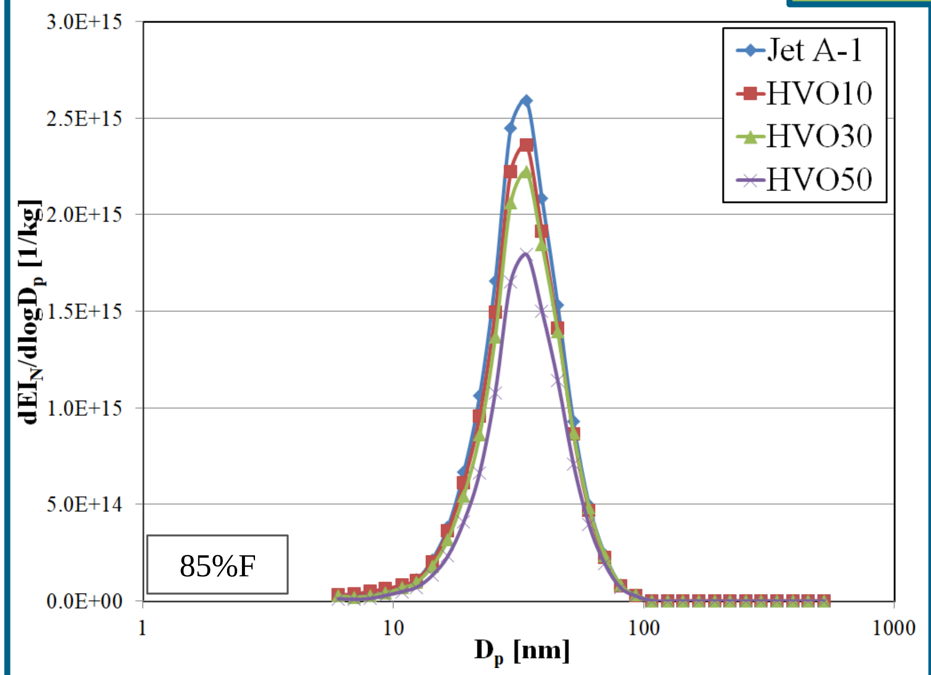




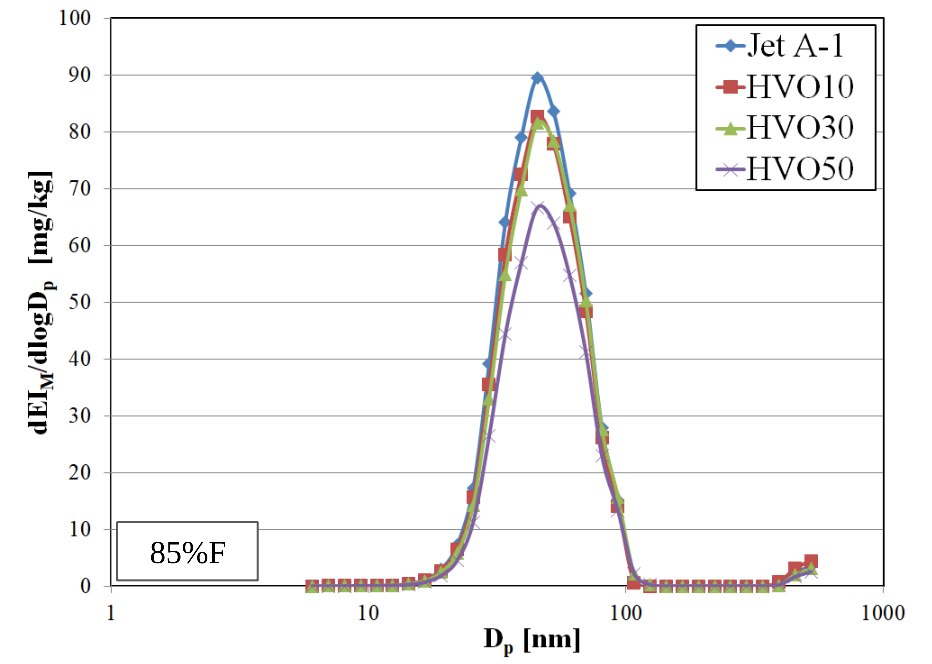
PARTICLE SIZE DISTRIBUTION

85% F

$dEI_N/dlogD_p$ [#/kg_{fuel}]

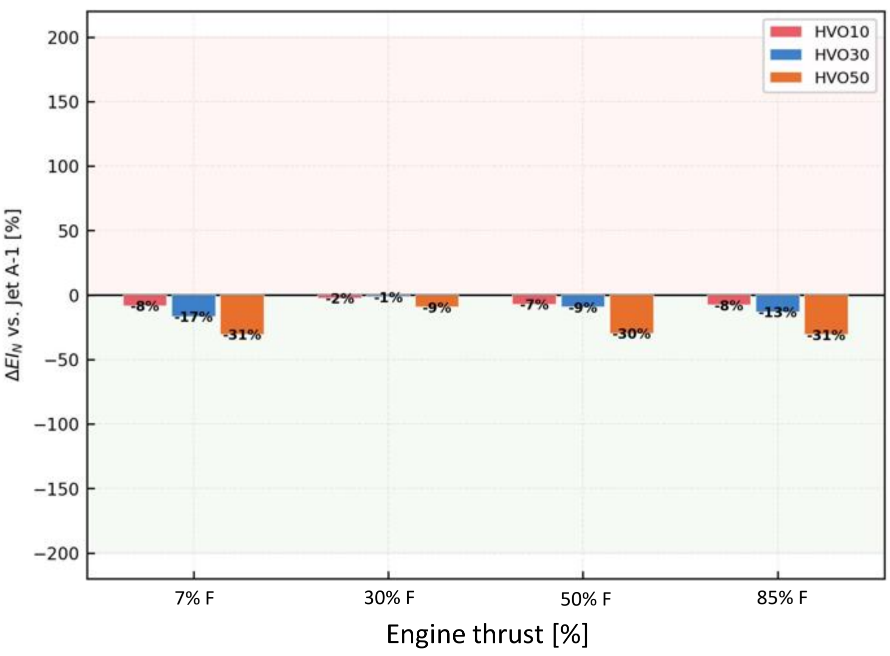


$dEI_M/dlogD_p$ [mg/kg_{fuel}]

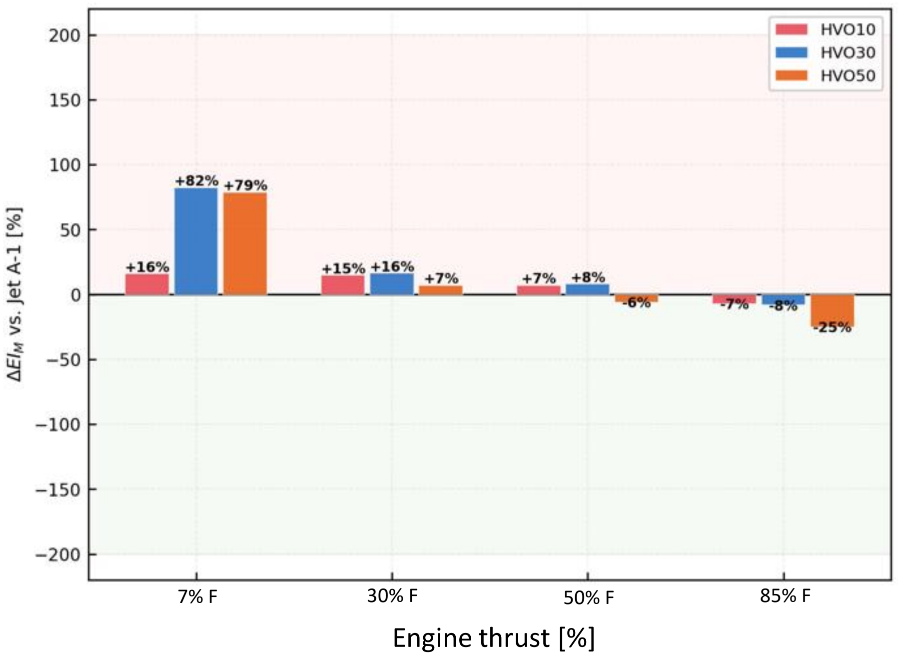


PM EMISSION INDICES

ΔEI_N vs. Jet A-1 [%]

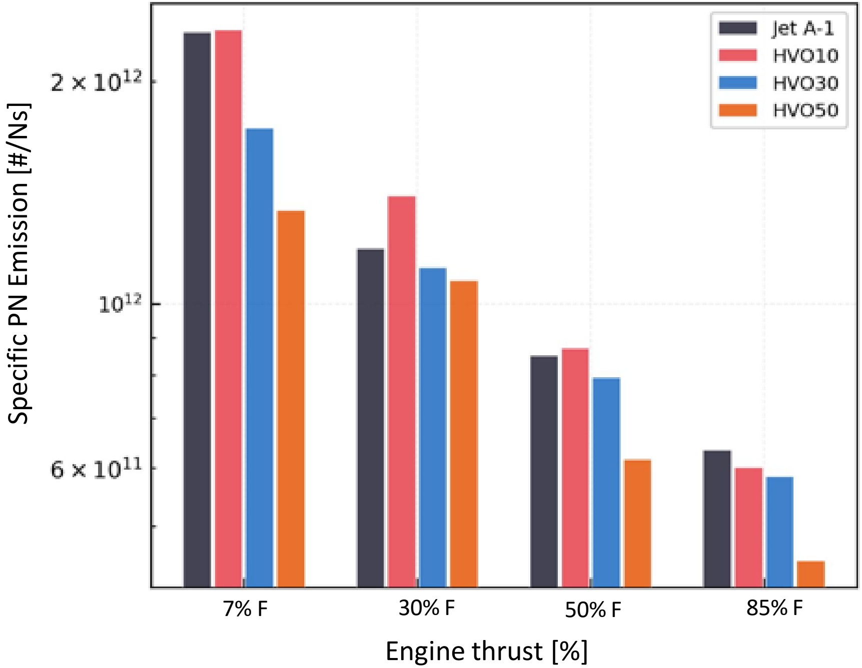


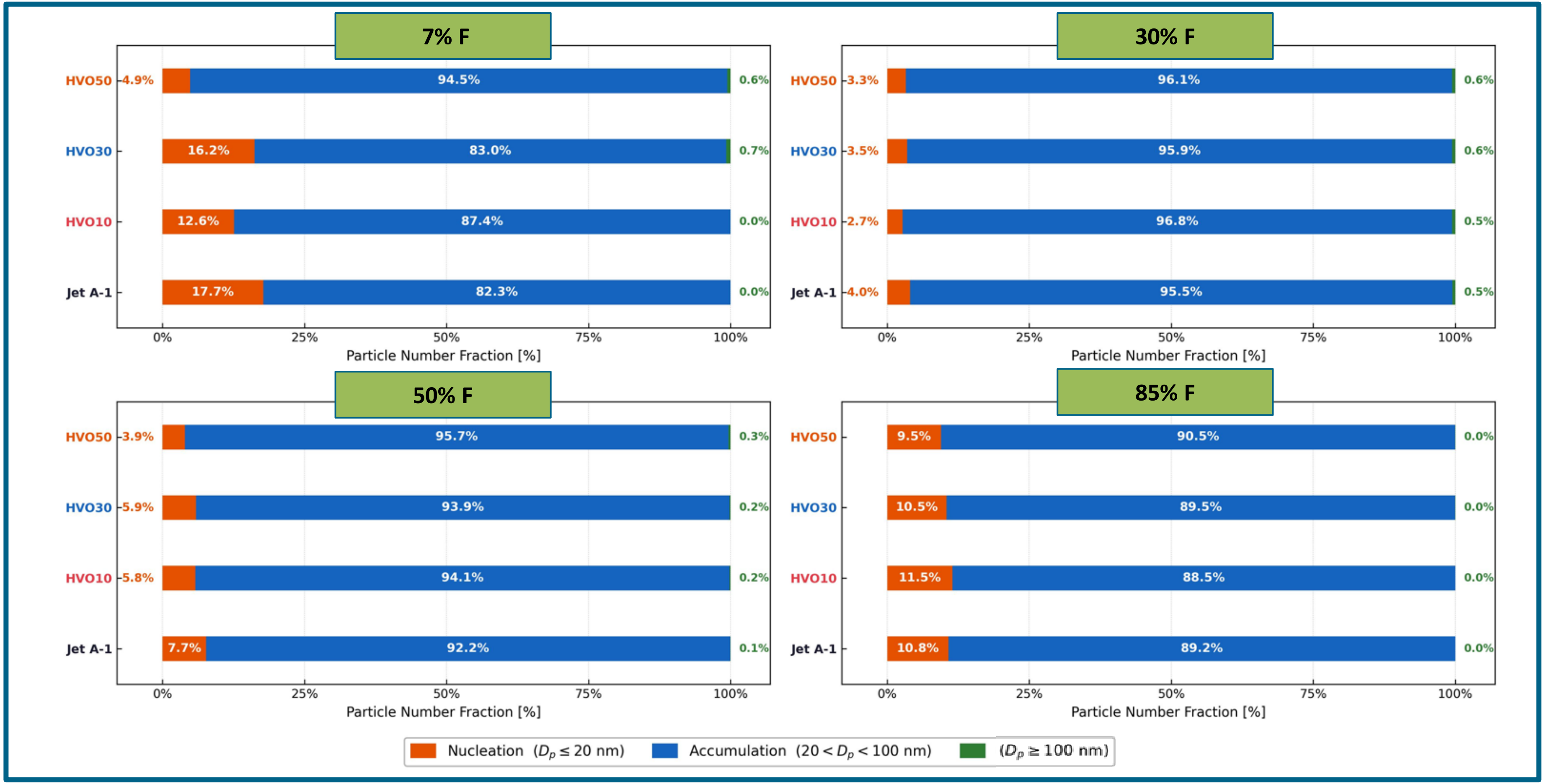
ΔEI_M vs. Jet A-1 [%]



PM EMISSION INDICES

Specific PN Emission [#/Ns]




7% F
HVO50 4.9% 94.5% 0.6%
HVO30 16.2% 83.0% 0.7%
HVO10 12.6% 87.4% 0.0%
Jet A-1 17.7% 82.3% 0.0%
30% F
HVO50 3.3% 96.1% 0.6%
HVO30 3.5% 95.9% 0.6%
HVO10 2.7% 96.8% 0.5%
Jet A-1 4.0% 95.5% 0.5%
50% F
HVO50 3.9% 95.7% 0.3%
HVO30 5.9% 93.9% 0.2%
HVO10 5.8% 94.1% 0.2%
Jet A-1 7.7% 92.2% 0.1%
85% F
HVO50 9.5% 90.5% 0.0%
HVO30 10.5% 89.5% 0.0%
HVO10 11.5% 88.5% 0.0%
Jet A-1 10.8% 89.2% 0.0%
0% 25% 50% 75% 100%
Particle Number Fraction [%]
Nucleation ($D_p \leq 20$ nm)
Accumulation ($20 < D_p < 100$ nm)
($D_p \geq 100$ nm)

CONCLUSIONS

CONCLUSIONS

- HVO and HEFA-SPK are chemically similar in the properties most relevant to PM formation: both contain <0.5 vol% aromatics and <5 mg/kg sulfur
- HVO addition consistently reduces particle number emission index at all tested operating points (up to − 31% for HVO50)
- Effect on particulate mass emission is thrust-dependent: HVO increases EI_M at low thrust, but reduces it at high thrust (up to −25% for HVO50 at 85% F)
- HVO shifts the size distribution toward the accumulation mode – fewer but larger particles at low thrust
- HVO is most beneficial during high-thrust flight phases
- Usage of HVO in blends with Jet A-1 requires further research

Experimental study on the impact of HVO addition to Jet A-1 on particulate matter emissions

PhD Eng. Paula Kurzawska-Pietrowicz