Authors:
Young Engineers Committee

Lorenzo Pilotti, Jon Runyon, Stefano Mori, Antonio Escamilla Perejon, Lennox Francis-Campusano, Giuseppe Tilocca, Sandra Richter

Alternative Fuels Taskforce

(Hydrogen and Alternative Fuels Working Group)

- Why was this group established?
  - **ETN user interest in non-H_2 fuels for decarbonisation, activity expands on H_2 work by ETN Young Engineers Committee (guided by WG members).**
- What is an “alternative low-carbon fuel”?
  - **Biogas / Biomethane**
  - **Biodiesel**
  - **HVO**
  - **Methanol**
  - **Ethanol**
  - **E-fuels**
  - **Ammonia***
  - …
- What is the purpose of this particular study?
  - **Quantitative method to evaluate specific fuels for a specific GT asset (“pre-feasibility”).**
- How can I get involved with this taskforce (or one of my <u>bright, young engineers</u>)?
  - **Contact the ETN office, speak with a co-author of this report , or YEC member**
- What have we done so far?

Outputs

- ETN IGTC-23 Paper/Presentation: “Prerequisites for the use of low-carbon alternative fuels in gas turbine power generation”
  - Demand and availability of alternative fuels
  - Cost, feedstocks, production pathways
  - Greenhouse gas (GHG) reduction (EU context)
  - Composition and impurities
  - Fuel production standards (e.g., EN, ASTM)

- GTEN 2023 Paper/Presentation – similar to the above but including a specific focus on the potential for alternative fuel use in Canada

Commercial operation & testing

Fuel	Country	Operator (T = Test / C = Commercial)	GT OEM	GT	GT Output (MWe)	Year
Methanol	UK	RWG/Siemens (T)	Siemens	SGT-A20	15	2023
	Israel	Israel Electric Corporation (C)	P&W	FT4C	50	2014
	USA	Southern California Edison (T)	P&W	FT4C	26	1979
	USA	Florida Power Corporation (T)	P&W	FT4C	24	1974
Ethanol	USA	LPP Combustion (T)	Capstone	C30	0.03	2014
	Brazil	Petrobras (C)	GE	LM6000PC	87	2010
	India	Reliance Energy (T)	GE	6B	48	2008
Biogas	Taiwan	Taipei Public Works Department (C)	Capstone	C30	0.03	2016
	Norway	Risavika Gas Centre (T)	Turbec	T100	0.1	2013
Biodiesel (FAME)	Switzerland	Groupe E (T)	GE	6B	36	2007
Biodiesel (HVO)	UK	Uniper (T)	Rolls-Royce	Olympus	17.5	2022
	Germany	Uniper (T)	KWU/Siemens	V93.1	63	2022
	Sweden	Göteborg Energi (T)	Siemens	SGT-800	45	2021
	Sweden	Uniper (T, C)	KWU/Siemens	V93.0	63	2021
Ammonia	Japan	AIST (T)	Toyota	TPC-50	0.05	2015
	USA	International Harvester Company (T)	Solar	T-350	250 hp	1966

SWOT analysis

Phone a GT friend

Ask the OEM

"How can we select the right low-carbon fuel for a given GT application?"

Join a research project

Pay a consultant

Resort to ChatGPT

Theory of Constraints (TOC)

- Problem-solving process that integrates both intuitive and analytical thinking.
- Identify and manage the most critical limiting factor (**constraint**) that hinders goal achievement.

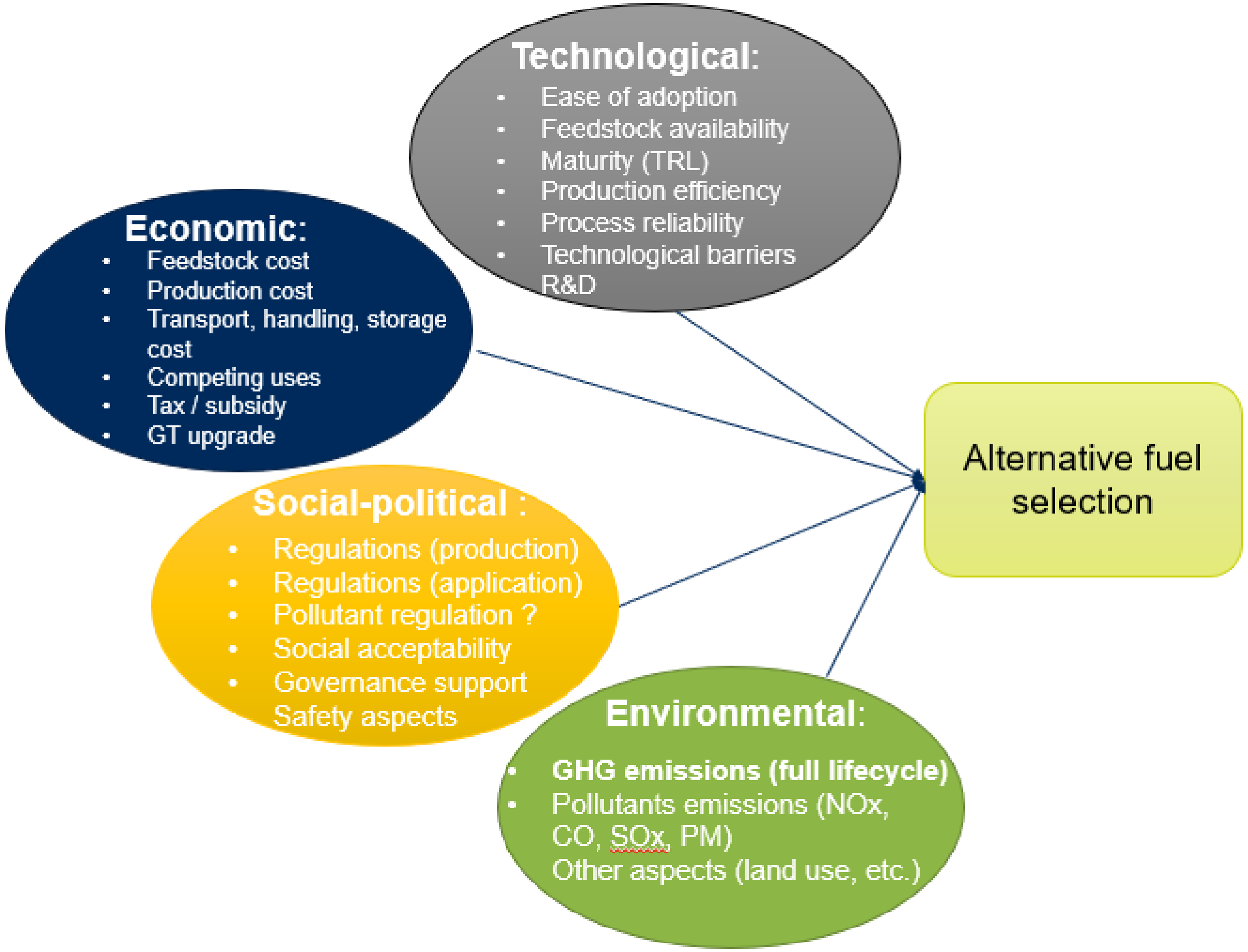
- <u>For alternative fuels</u>:
  - Identify the primary constraint among numerous factors which impacts competitiveness in a specific scenario

  - Understand the overall effect of different constraints on the adoption of alternative fuels compared to others.

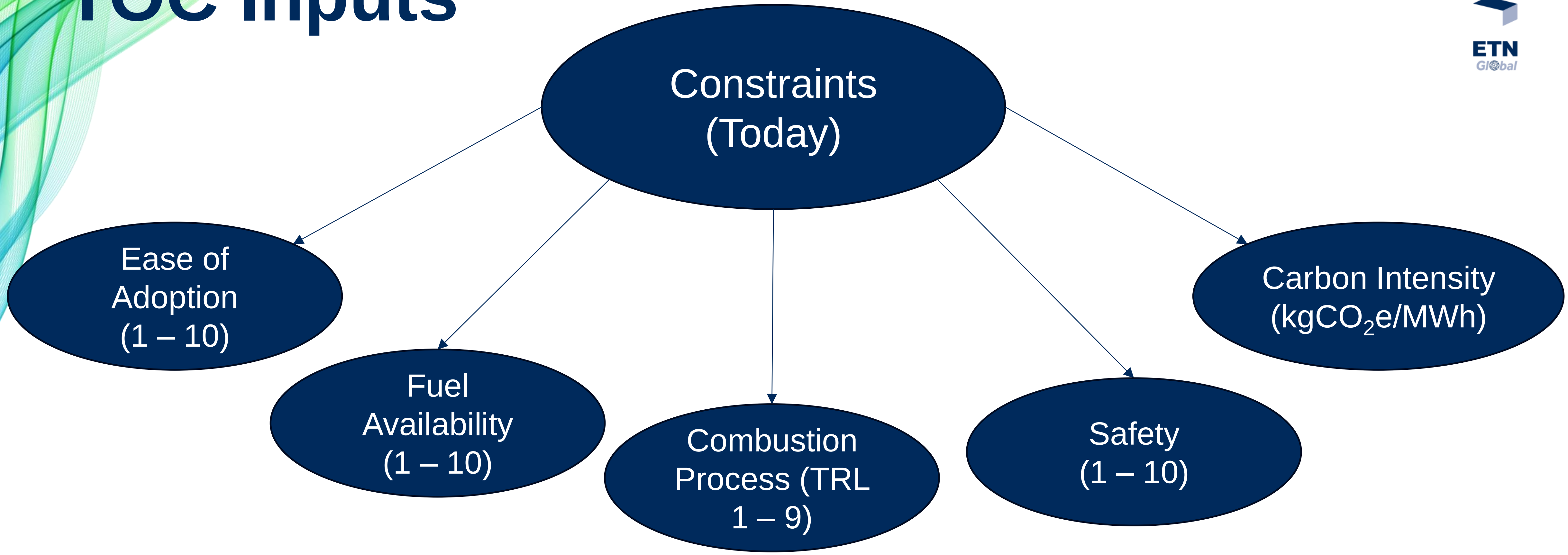
Theory of Constraints (TOC)

- Identifies the weakest link in achieving **“ideal”** conditions (maximizing/minimizing KPIs).
- Applies a uniform scale to the different penalties identified, highlighting those with higher impacts.
- Utilizes a single quantitative scale (0-1) that combines both quantitative and qualitative parameters.
- Offers flexibility to select different aspects/considerations based on the specific case.

Constraints* for Alternative Fuels

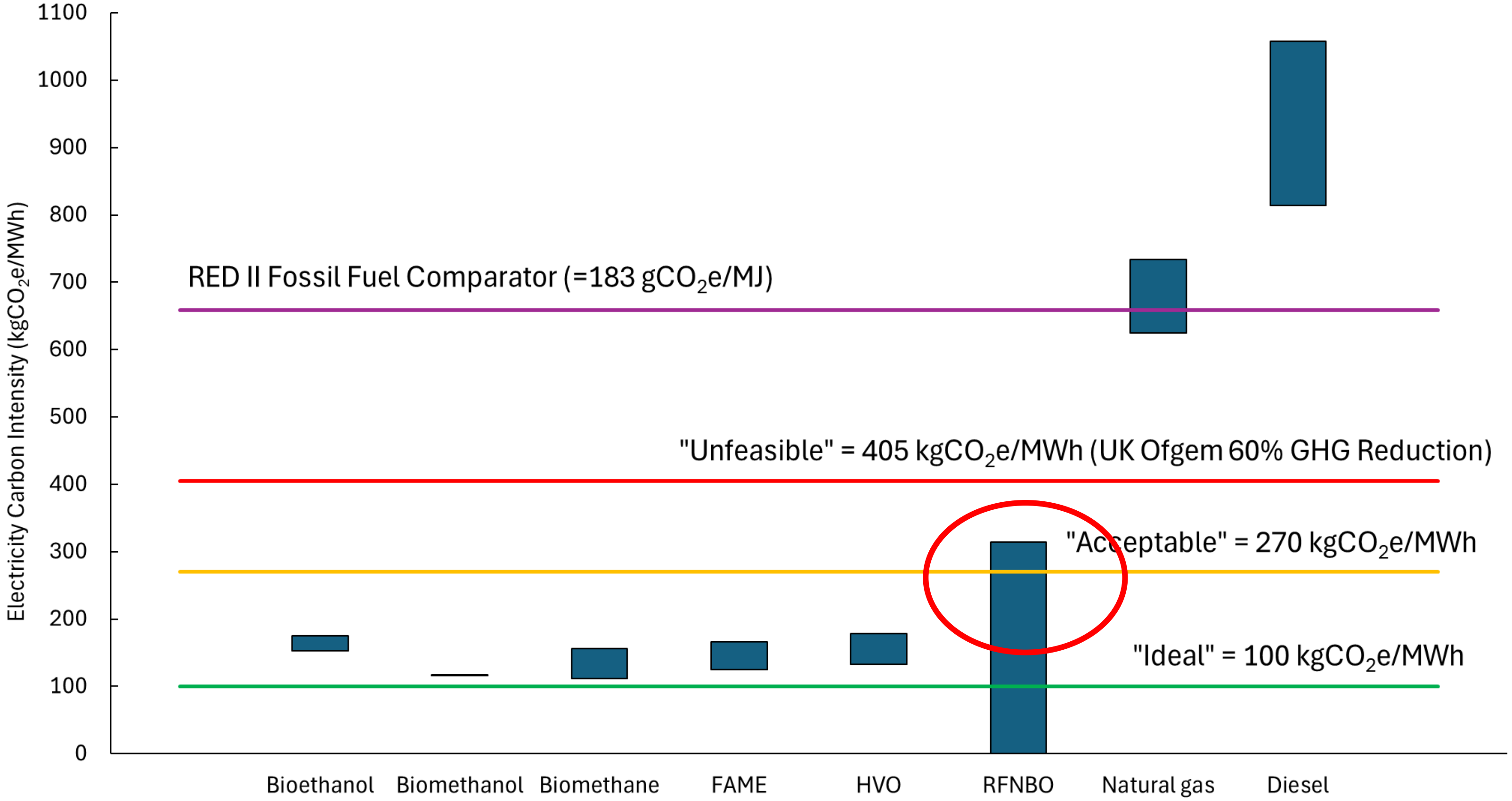


TOC Inputs*



- For each constraint, set an “Ideal”, “Acceptable”, and “Unfeasible” limit for the GT application.
- For each fuel, set an actual “Minimum” and “Maximum” value for each constraint.

Constraints – Carbon Intensity/GHG Reduction



- Calculated using efficiency of test case OCGT (parameters on next slide)
- One alternative fuel production pathway selected with default & typical carbon intensities (CI) from RED II – even lower CI is possible in practice!

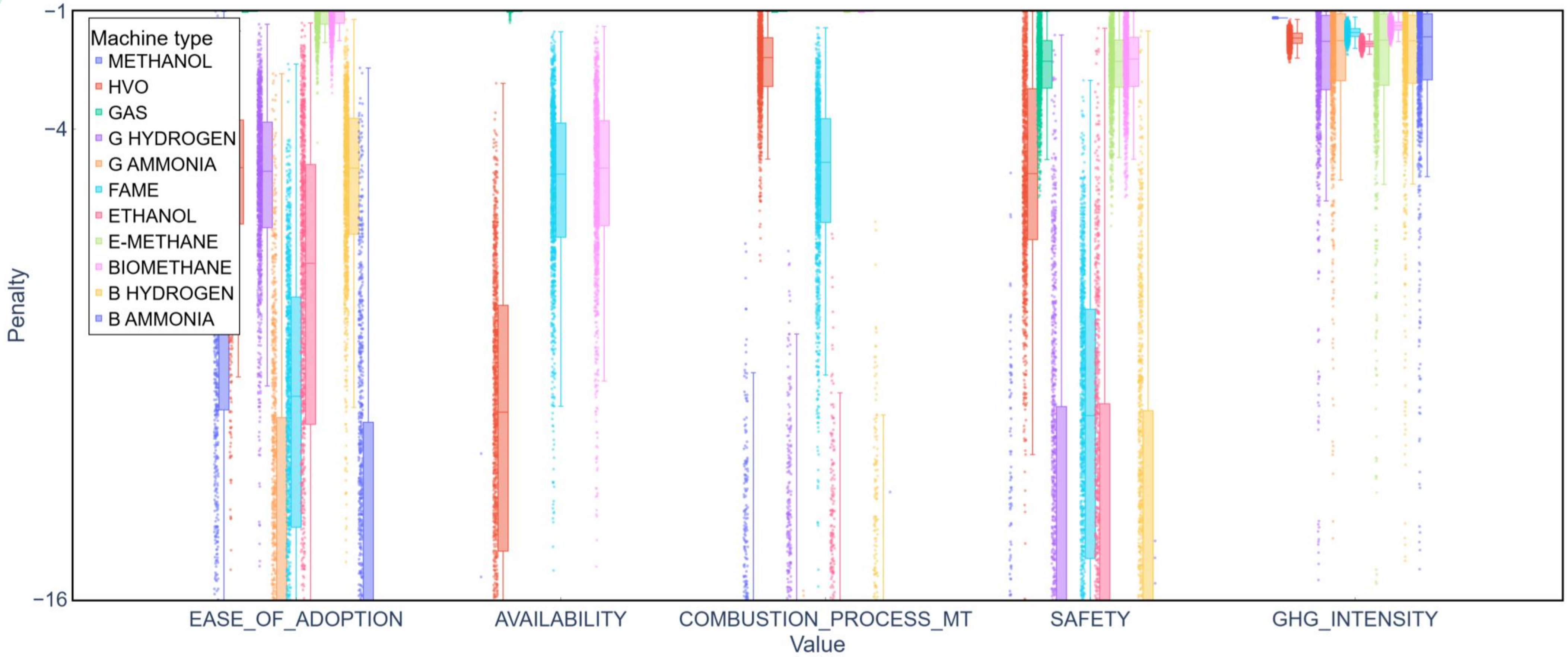
UK Natural Gas OCGT (144 MW)

Siemens SGT5-2000E (COD = 1992), < 500 hours/year

Parameter	Value	Unit
Base Load Power Output[1]	144	MW_e
Base Load Natural Gas Mass Flow	9.2	kg/s
Natural Gas Lower Heating Value	48.35	MJ/kg
Fuel Net Thermal Input (calculated)	445	MW_{th}
Compressor Air Mass Flow	495	kg/s
Compressor Outlet Temperature	596	K
Compressor Pressure Ratio	10.7:1	-
OCGT Base Load Efficiency (calculated)	32.36	%
Guaranteed Maximum Turbine Inlet Temperature[2]	1333	K
Base Load Turbine Outlet Temperature	826	K

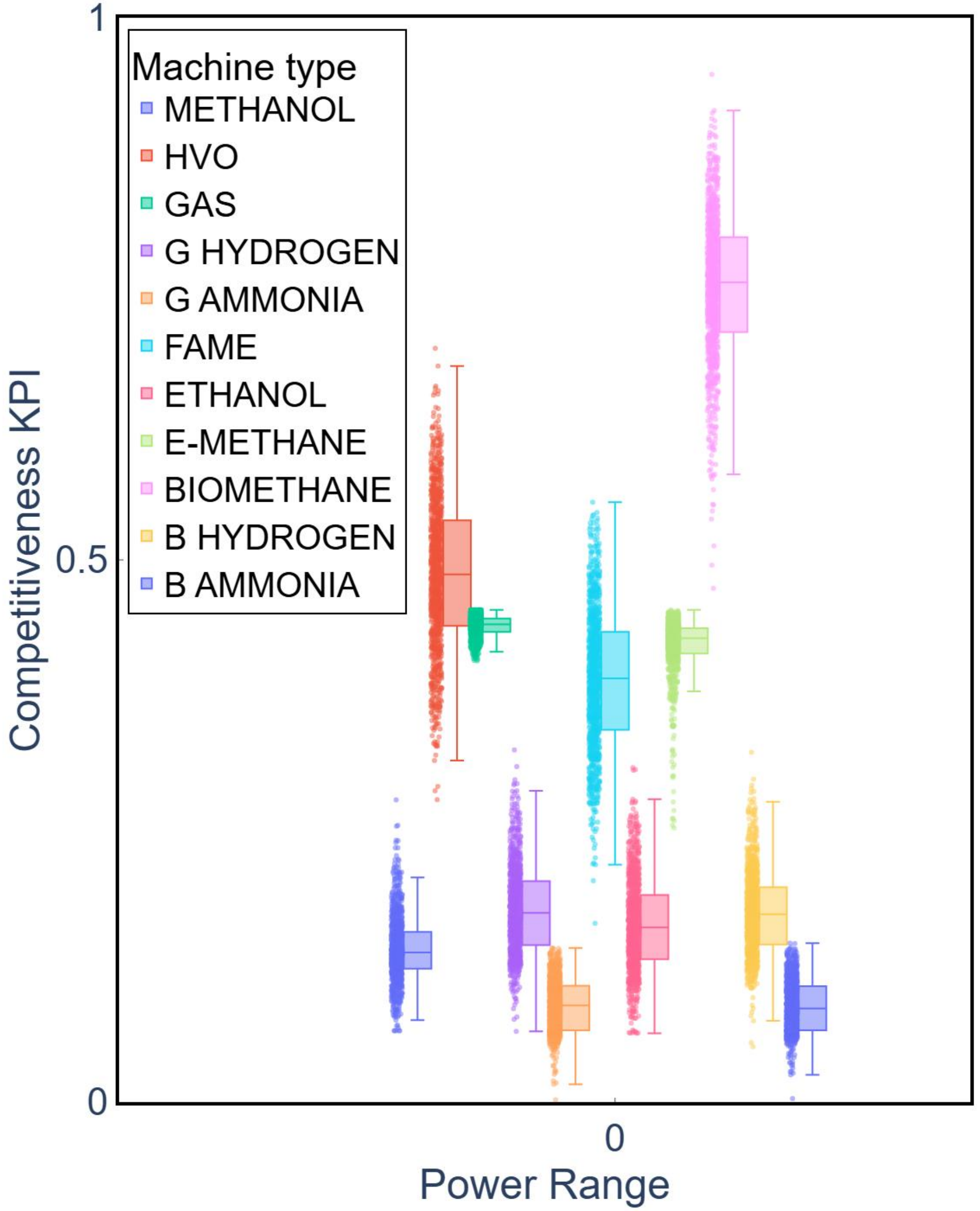
Results – Penalty Factors

- Lower penalty factor = further away from the “Ideal” requirement



Results - Overall

- Competitiveness KPI indicates the "winner" based on a combination of the requirements set out.
- KPI = 1: Most preferred fuel
- KPI = 0: Least preferred fuel
- Ranking (excluding "Gas", i.e., nat. gas):
  - Biomethane
  - HVO
  - E-methane
  - FAME
  - Green/blue hydrogen
  - Ethanol
  - Methanol
  - Green/blue ammonia



Next steps

- Further analysis considering wider range of inputs (e.g., LCOF)
- Sensitivity analysis on GT output and expected timescales (e.g., 2030, 2050)
- Complete and submit draft paper to Fuel journal (open access)
- Evaluate further alternative fuels interest from WG and ETN members