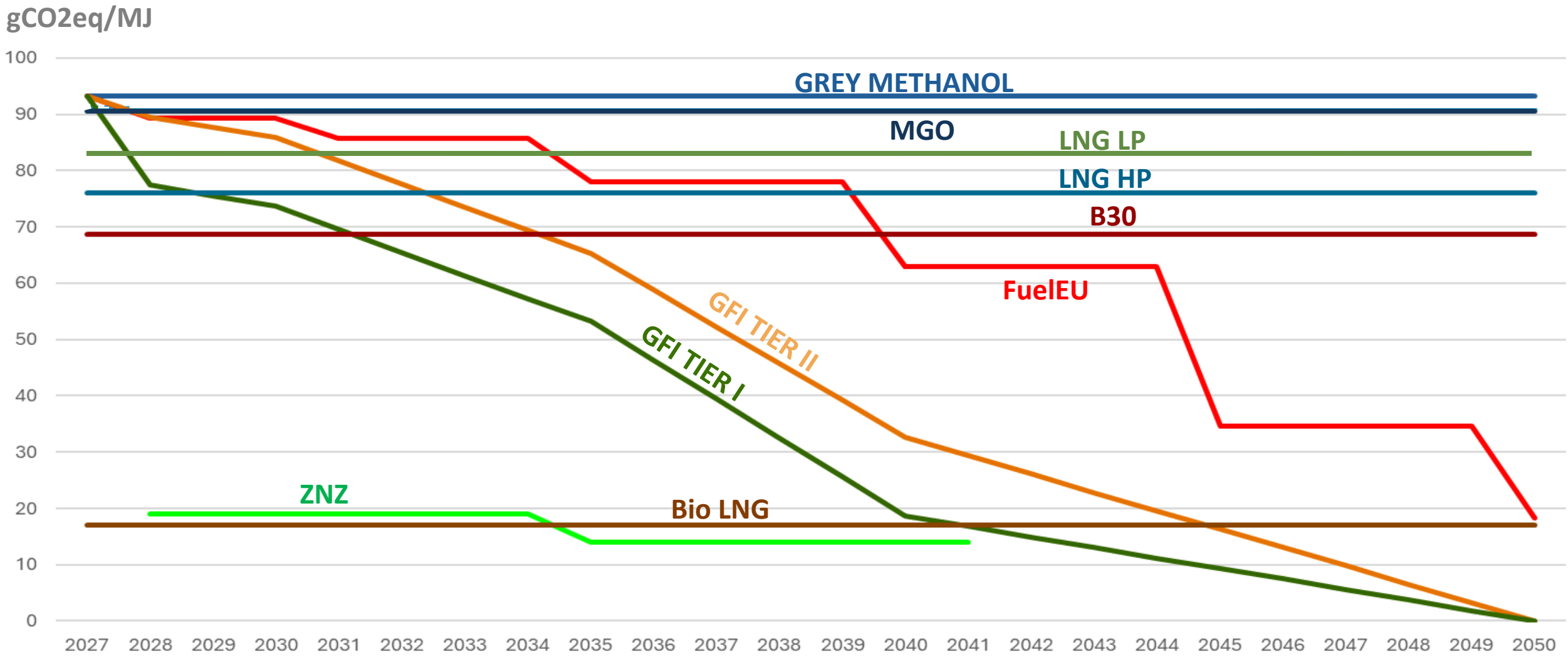
Greener Shipping Summit

Alternative fuels:
LNG, LPG, B30, B100, methanol
building experience through teething problems

Stavros Hatzigrigoris, Advanced Engineering Services; Zodiac Maritime

GHG Fuel Intensity (GFI) Reduction Trajectory with fuel types



Biofuels

- **Availability and price:** Limited production. Aviation may enter the market. Road transport needs may decrease with the use of EVs. First B24 **barge delivery in Greece** past month!
- **Chemical** tankers needed for bunkering B25 and above. Change proposed.
- **NOx** emissions: B30 and below treated as normal fossil. For above B30 if change NOX critical components need NTF revision (MEPC.1/Circ.795/Rev.6-8).
- Increased **consumption** ~5-6% for B30. (lower LCV and thus pmax, longer injection duration)
- Boiler makers do not offer warranty.
- Everllence warranty if ISO 8217 (up to 100% FAME)

ISO 8217 2017 FUEL STANDARD	EN 14214	D6751

Components	FAME FAME	Blends FAME/HVO + fossil fuel
Nitrogen [%]	~0.1	~0.1–0.4
Oxygen [%]	~10	~0–10
Sulphur [%]	~0	Low[1]
LCV [MJ/kg]	37	37–43
Kin. viscosity [mm²/s]	3–5 at 40°C	Low[1]
Pour point [°C]	<-6 to >+6[2]	[1]
Stability	Low-high[2]	Medium-high
Lubricity	Analyse[3]	Analyse[3]
Standard[3]	EN 14214, ASTM D6751	No standard[4] ISO 8217:2017: up to 7% FAME in DM

Everllence **SERVICE LETTERS**

The use of biofuel on existing MC or MC-C engines without significant engine modifications can give the following effects:

- A small specific fuel oil consumption (SFOC) increase can occur due to the longer than normal injection duration.
- The lower calorific value is expected to result in a lower cylinder maximum pressure (pmax). The injection timing should be adjusted accordingly to obtain the correct pmax.
- Liner temperatures could potentially increase slightly due to the longer injection duration. Careful drain oil monitoring is recommended to avoid potential issues.
- Individual cylinder units can get problems with reaching peak load. Primarily if the fuel pumps are heavily worn down and the fuel has a very low viscosity, i.e. a high drain leakage.
  - See SL2019-670 https://www.man-es.com/services/industries/marine/service-letters
- In general, biofuels are expected to produce less smoke, but increased smoke emissions can occur for certain types of biofuels.

FAME blends, for example a B30, give a smaller difference in heating value. The same effects as stated above are still valid, but the impact will be significantly smaller for the blends compared to B100.

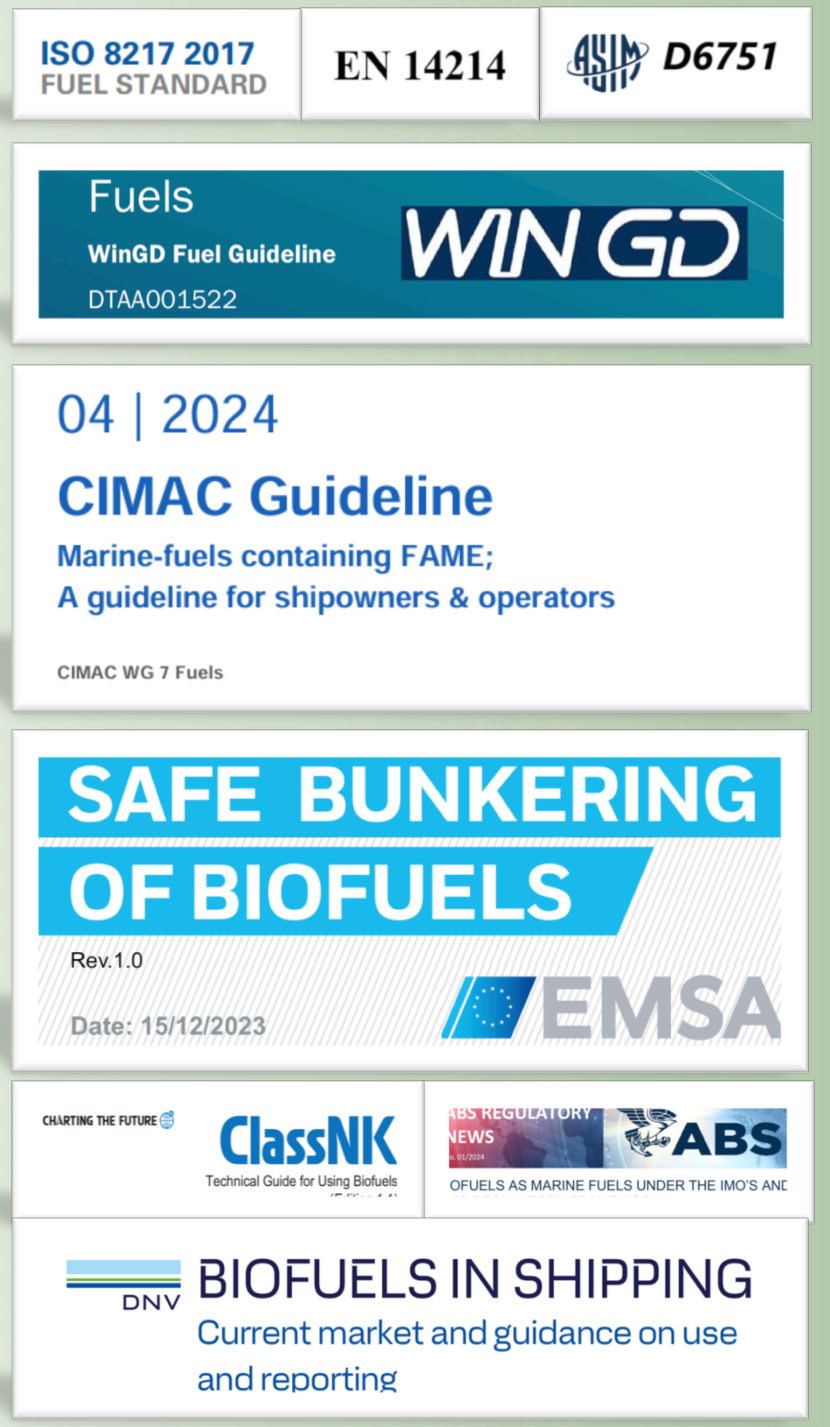
Best regards
MAN Energy Solutions

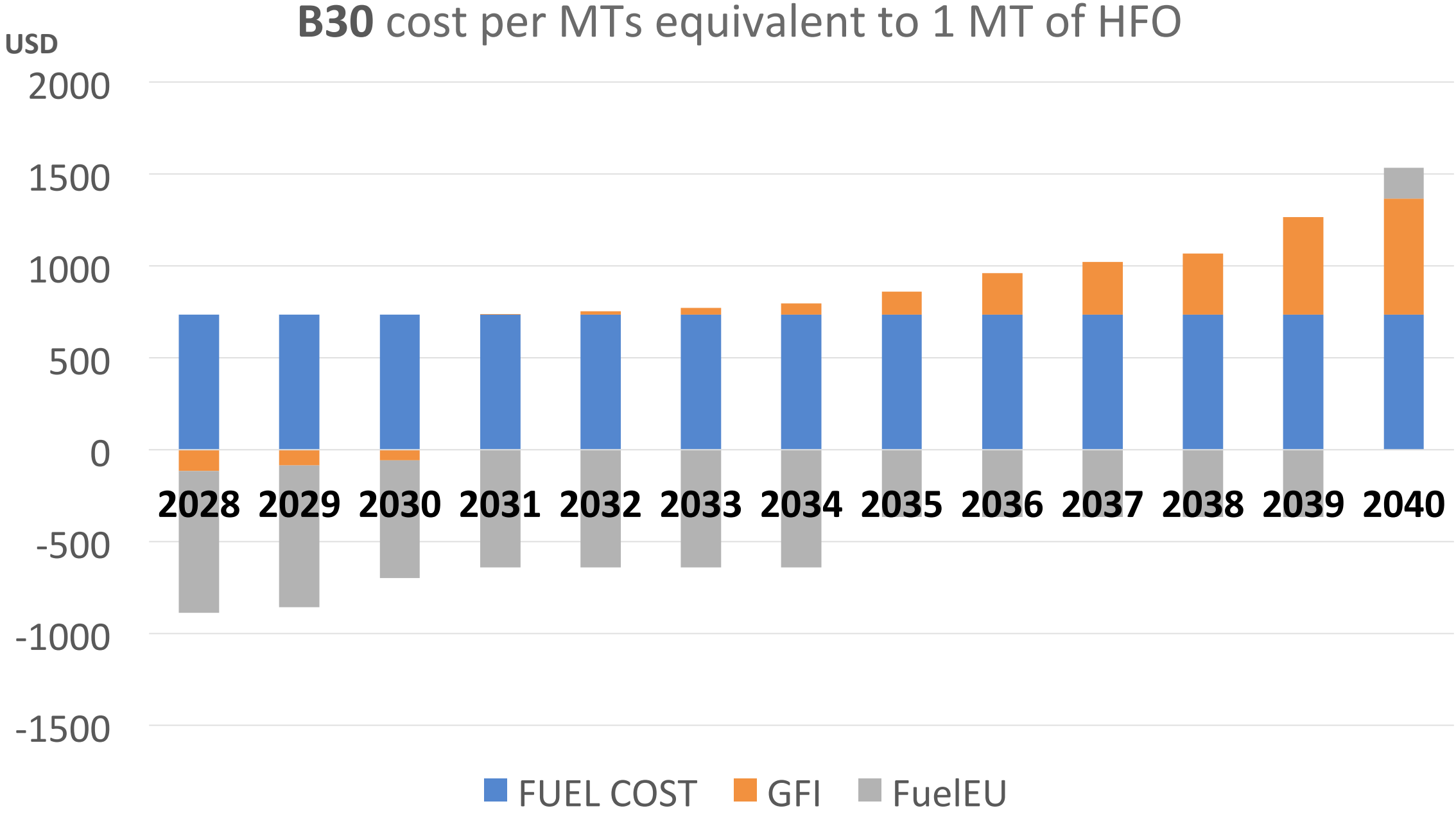
Brian Østergaard Sørensen

Michael Finch Pedersen

Biofuels

- **Limited challenges experienced**. Can be limited when the following recommendations
- To Consider: **Purifier setting, gasket materials, filter clogging.** Need to follow the **standards.** Ex. High Acid number damage FIVs. **Cold flow properties. Corrosion & Bacteria.**
- **Phenolic epoxy** painted fuel tanks recommended.
- **Liner temperatures** could potentially increase slightly due to the longer injection duration. Careful drain oil monitoring is recommended to avoid potential issues.
- Individual cylinder units can get problems with reaching peak load. Primarily if the **fuel pumps** are worn down and the fuel has a very low viscosity, i.e. a high drain leakage.
- In general, biofuels are expected to produce **less smoke**, but increased smoke emissions can occur for certain types of biofuels.




B30 cost per MTs equivalent to 1 MT of HFO
USD
2000
1500
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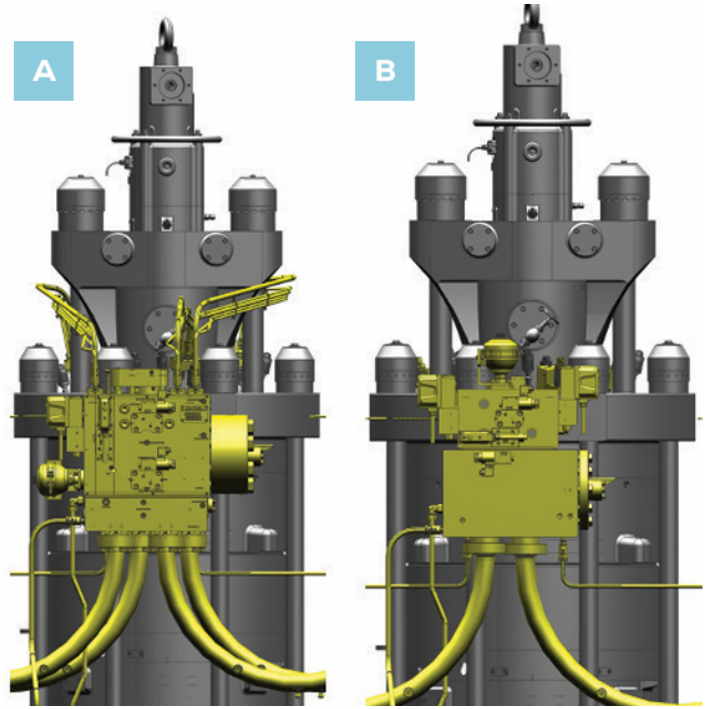
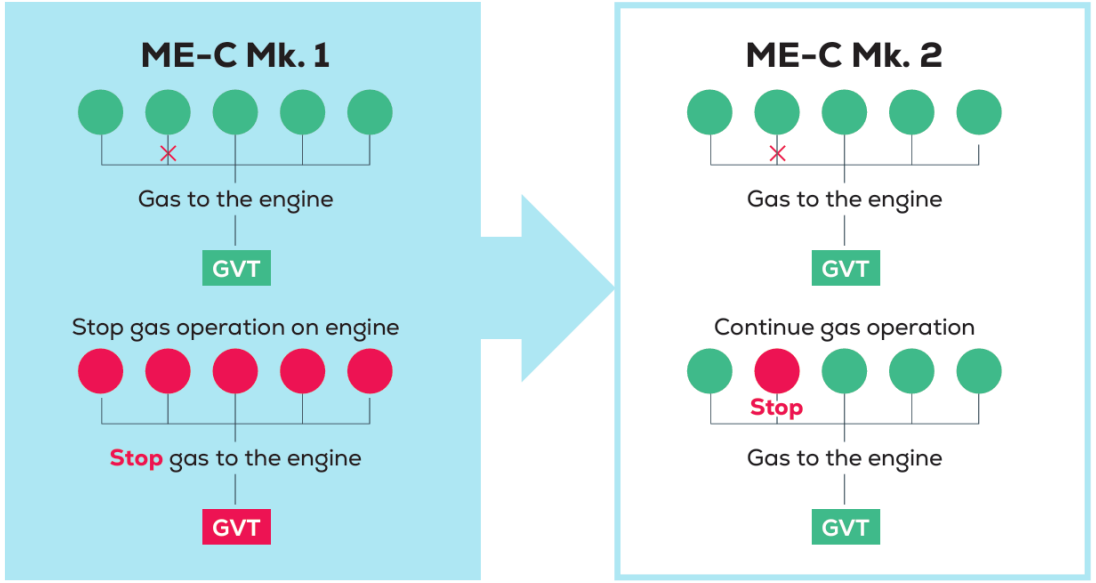
FUEL COST
GFI
FuelEU

LNG HP

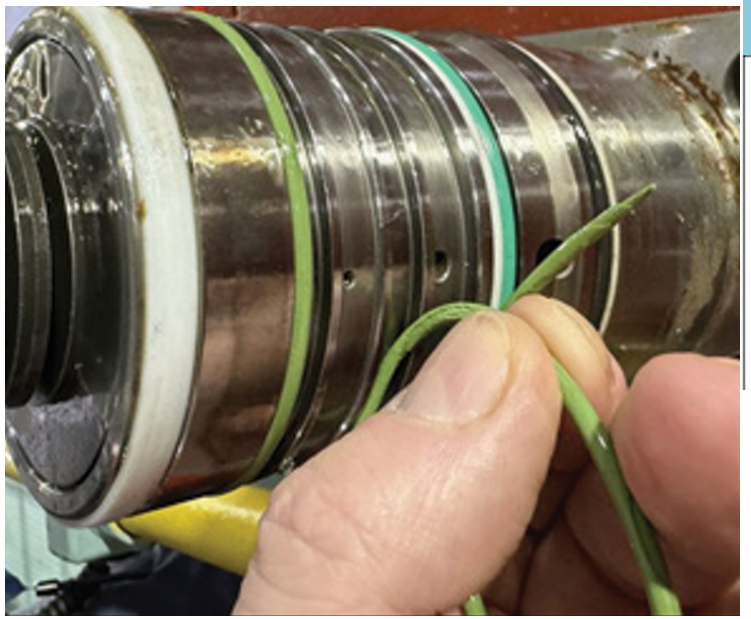
- Low Methane slip compared to LP engines → reduced penalties on FuelEU and GFI.
- Increased pressure from 300bar to 325bar, and recently further to 380bar
- Problems are present, but resolving.
- Complexity and leakage in Mk.1 design → Mk.2 introduced simplified gas block and chain pipe layout, rerouted sealing/control oil bores for better reliability and space.
- Single-cylinder failure causing full gas shutdown → Added Gas Cylinder Cut-Out (GCCO) feature — isolates one faulty cylinder while others continue dual-fuel operation.

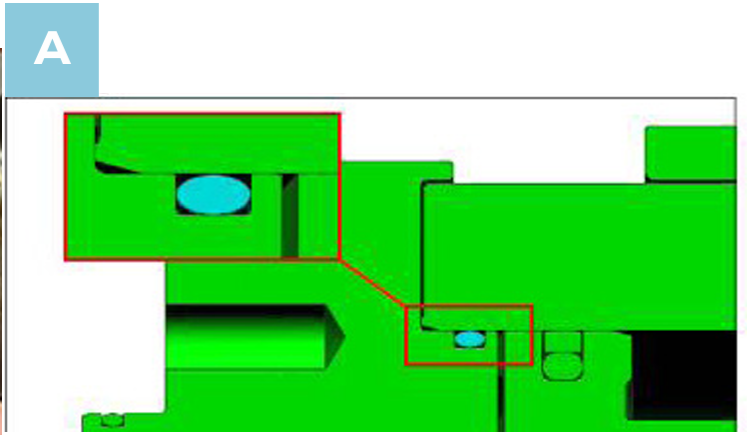


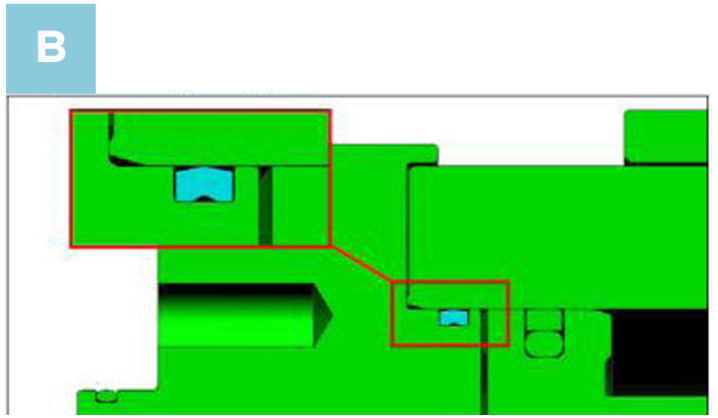


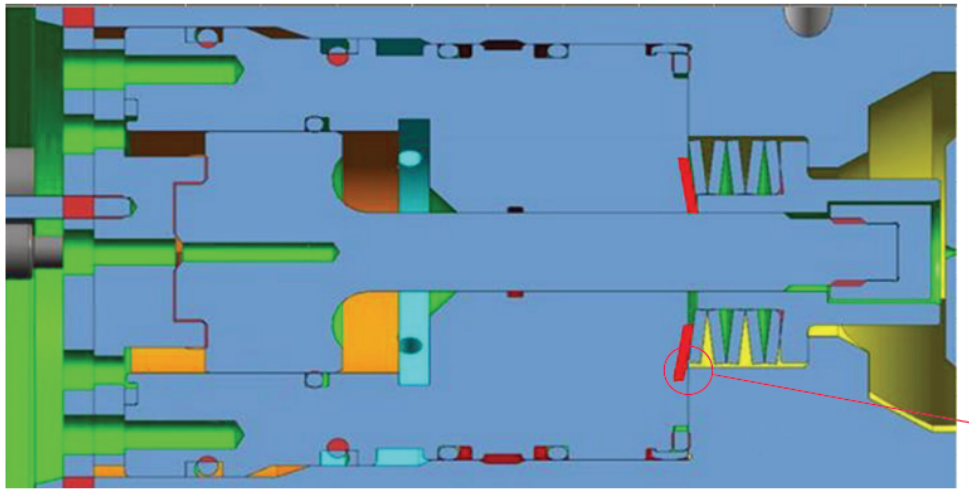
LNG HP

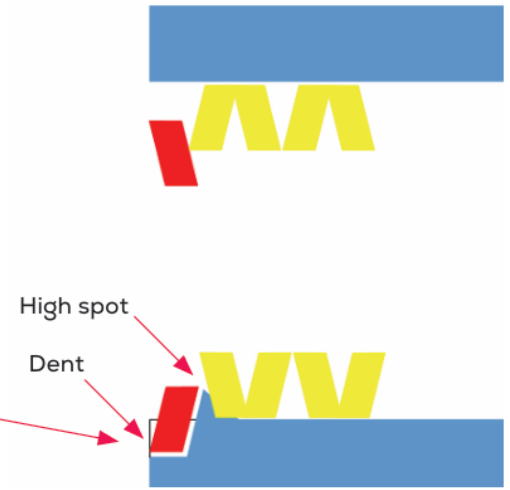
- Hydraulic oil leakage from PBIV top cover → Replaced Viton O-ring with durable PU seal, eliminating early disintegration and leakage.
- Spring dislodgement in Window Valve Forced Close (WVFC) → Added spring cup to prevent spring drop-down and gas block damage.
- O-ring failure and internal oil leaks in WVFC → Changed O-ring material and added uncut backup ring installed with expander tool.





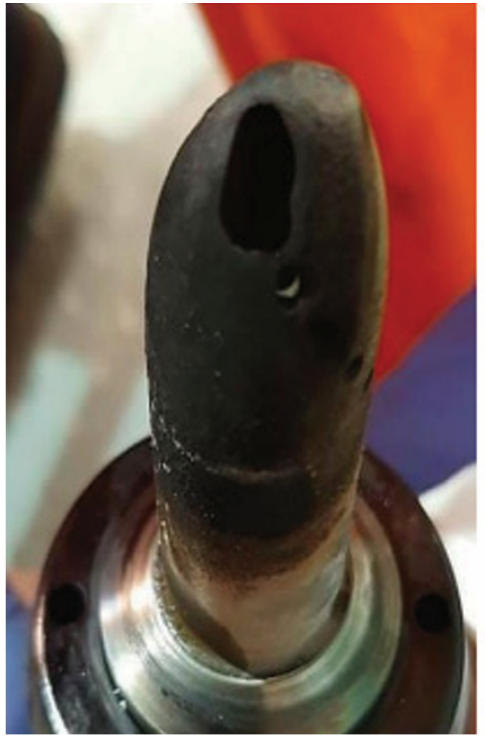


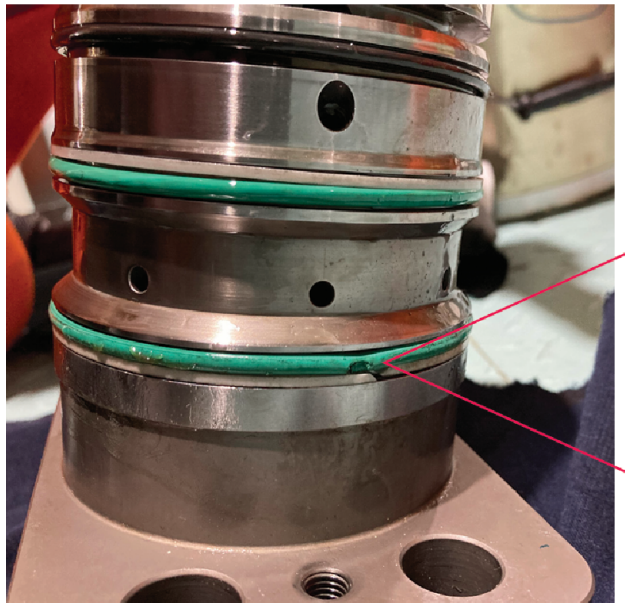


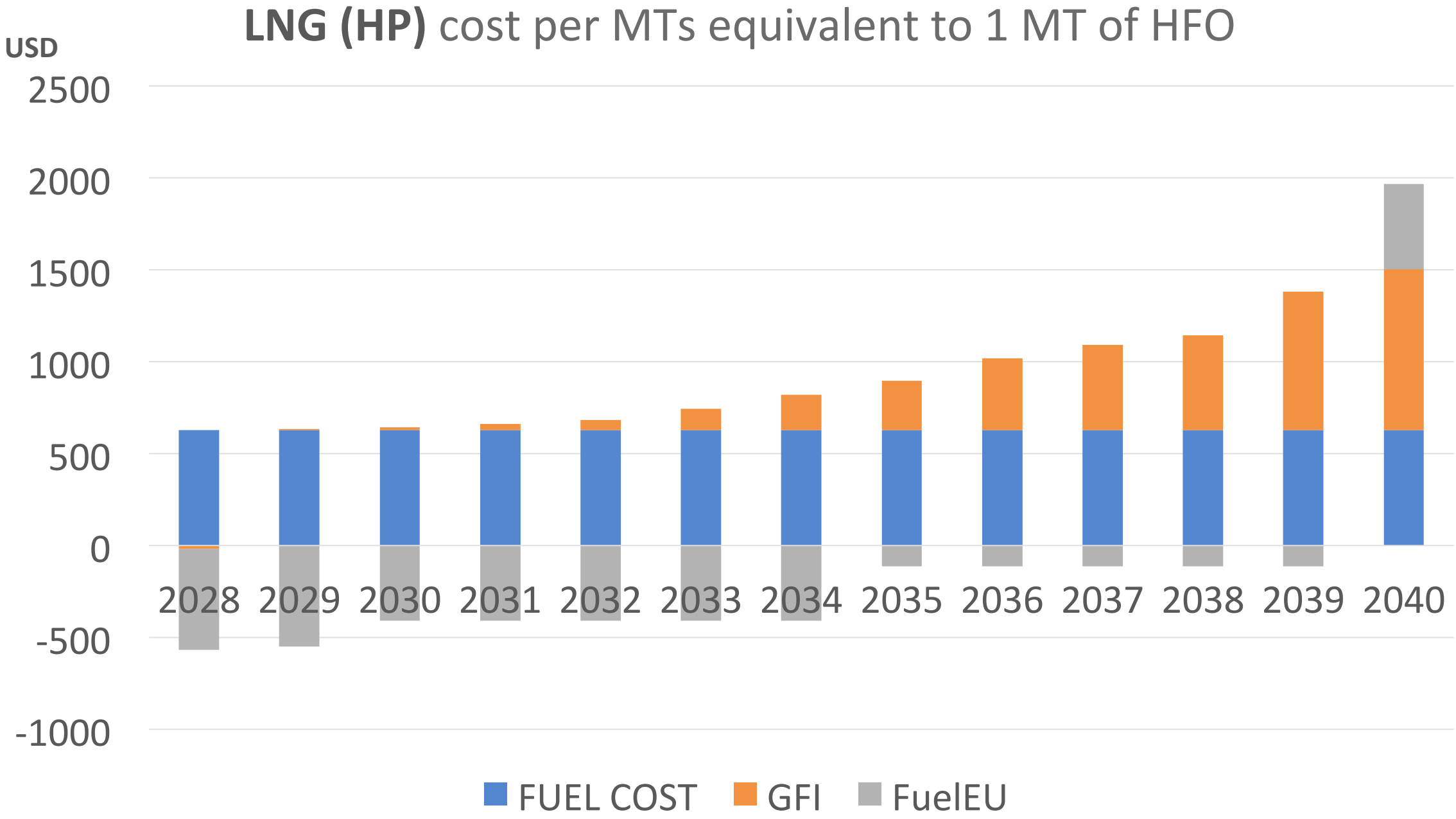


LNG HP

- External sealing oil leaks from window valve → New uncut backup ring design and updated sealing arrangement at eight positions.
- Hot corrosion and clogging of long gas nozzles → Extra-short nozzle design adopted, balancing corrosion resistance and flow.
- PIV nozzle cracking and clogging → Switched to H13 tool steel nozzles with larger/more injection holes; interim RELI deactivation reduces clogging risk.
- Premature wear of piston ring coating → Improved cermet coating and optimized maintenance extended overhaul intervals to 32,000 hrs (dock-to-dock).






LNG (HP) cost per MTs equivalent to 1 MT of HFO
USD
2500
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LNG LP

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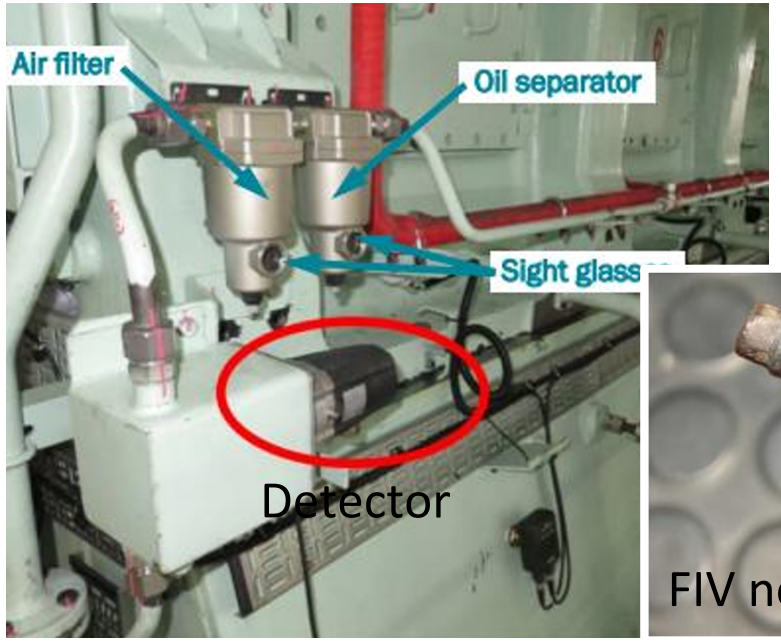
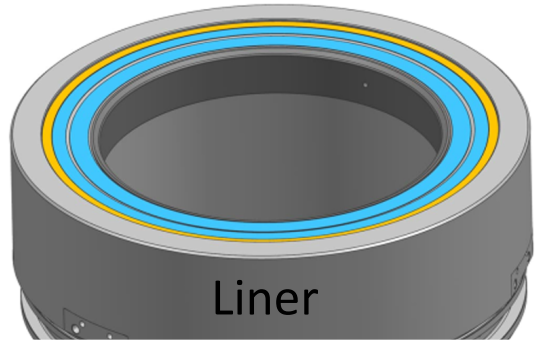
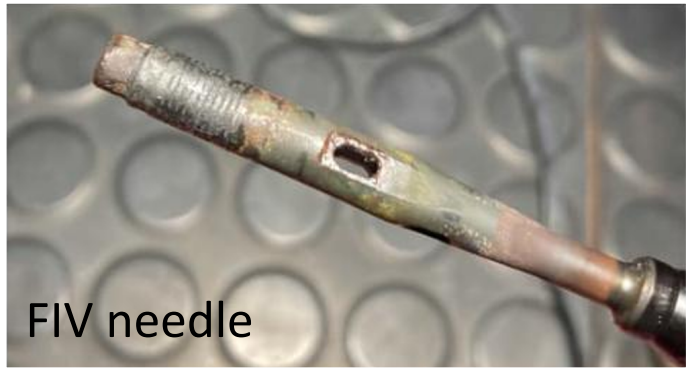
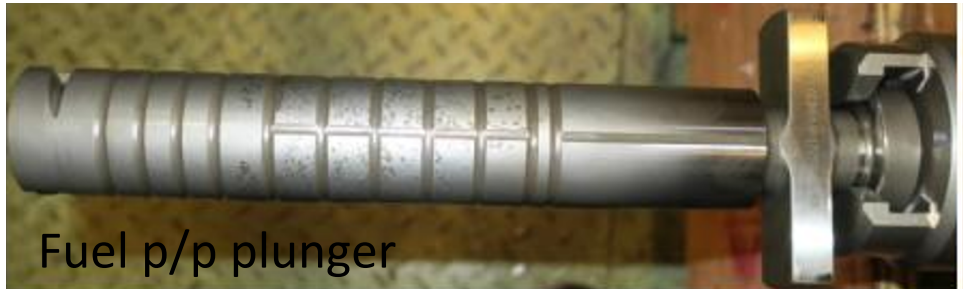
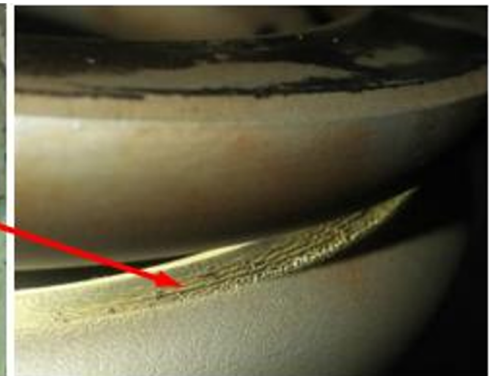
- O-ring failure and internal oil leaks in WVFC → Changed O-ring material and added uncut backup ring installed with expander tool.
- ICER: Methane slip reduction. Challenges with WTS persists.
- Service letters addressing issues such as: T/C dry cleaning, filler gaskets to reduce CH4 slip in non-ICER, addressing issues due to high N2 LNG batches, Piston underside gas detection sensor failures, fuel oil pump corrosion, fuel injectors…

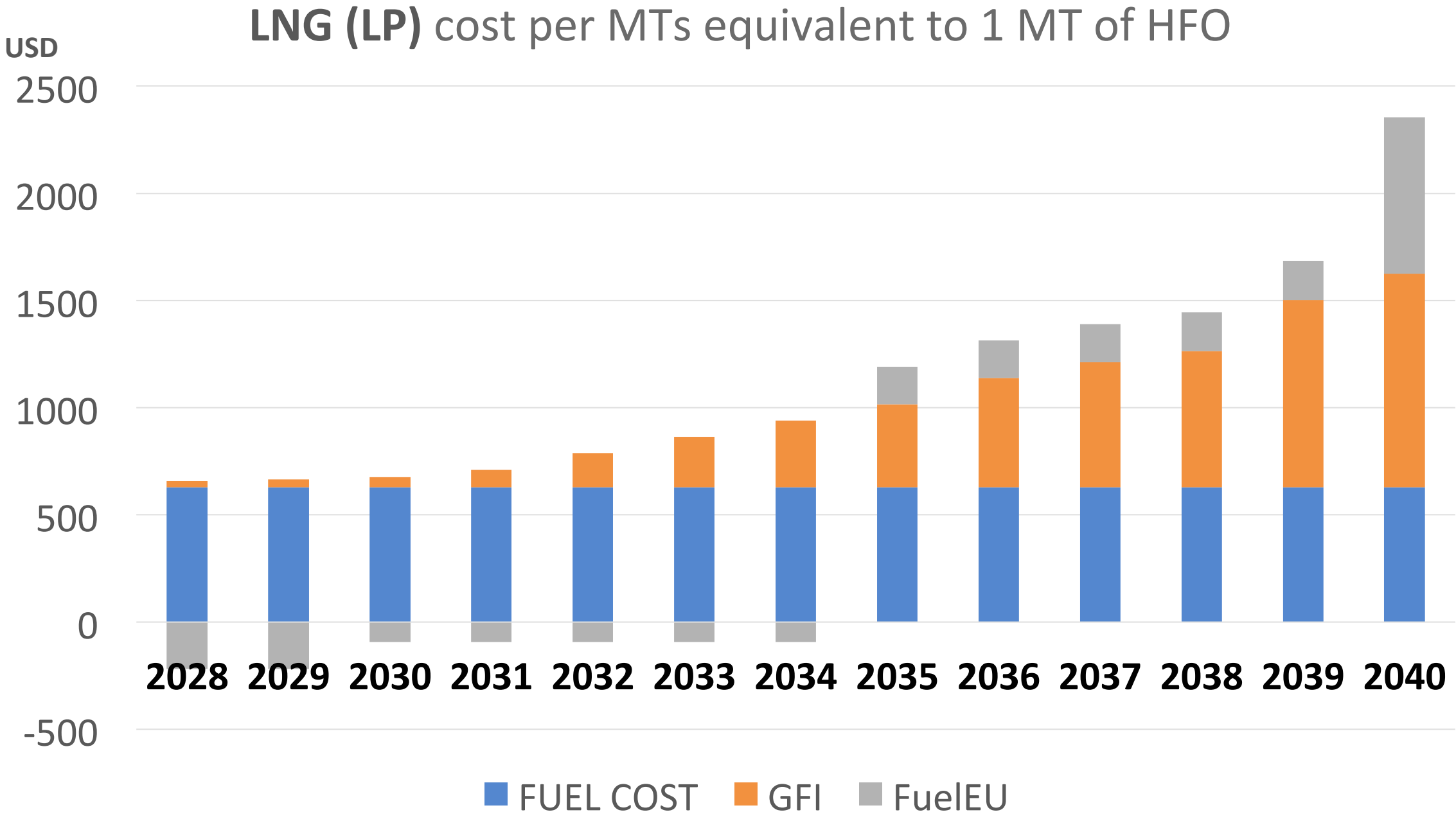











LNG (LP) cost per MTs equivalent to 1 MT of HFO
USD
2500
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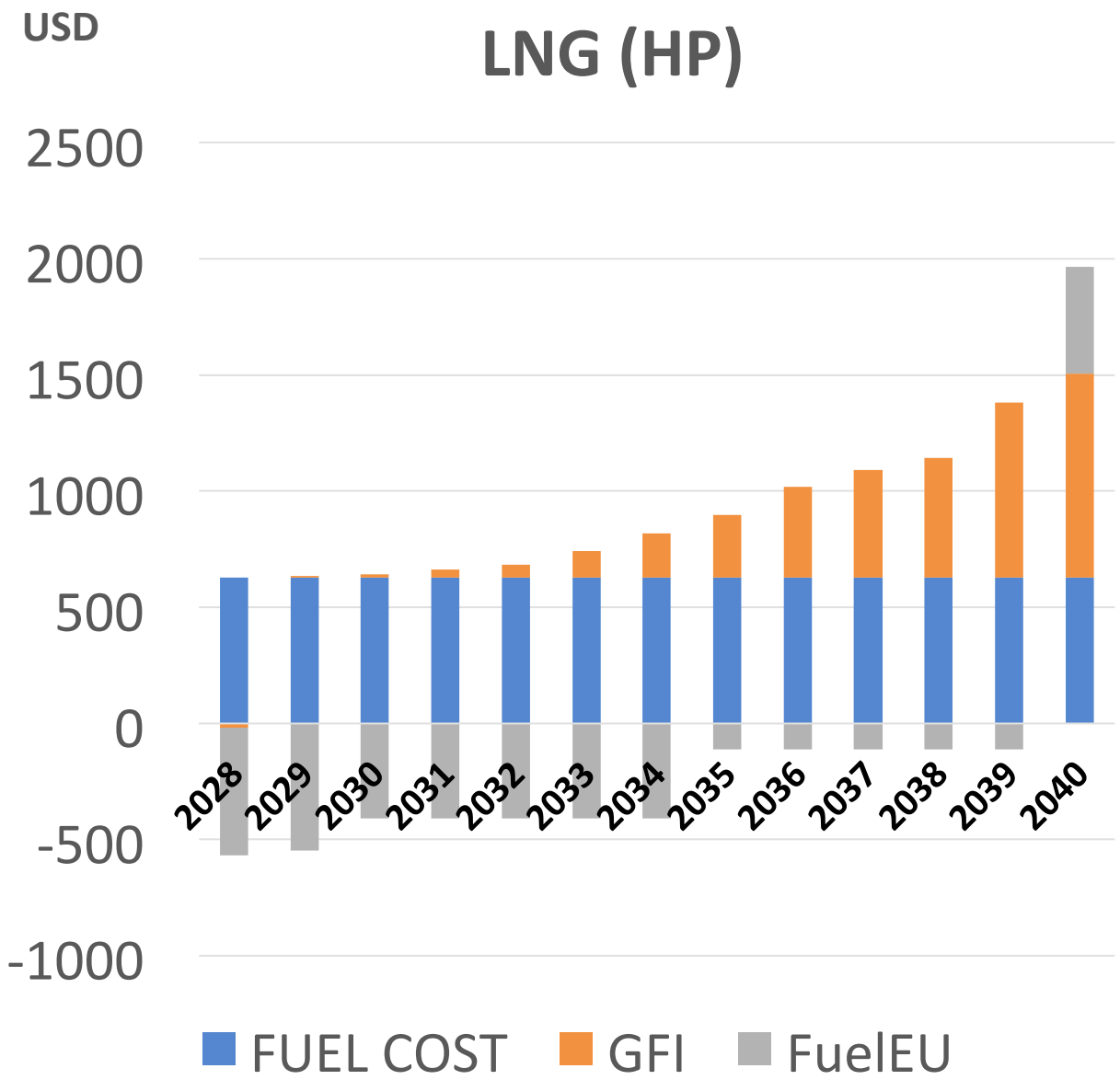
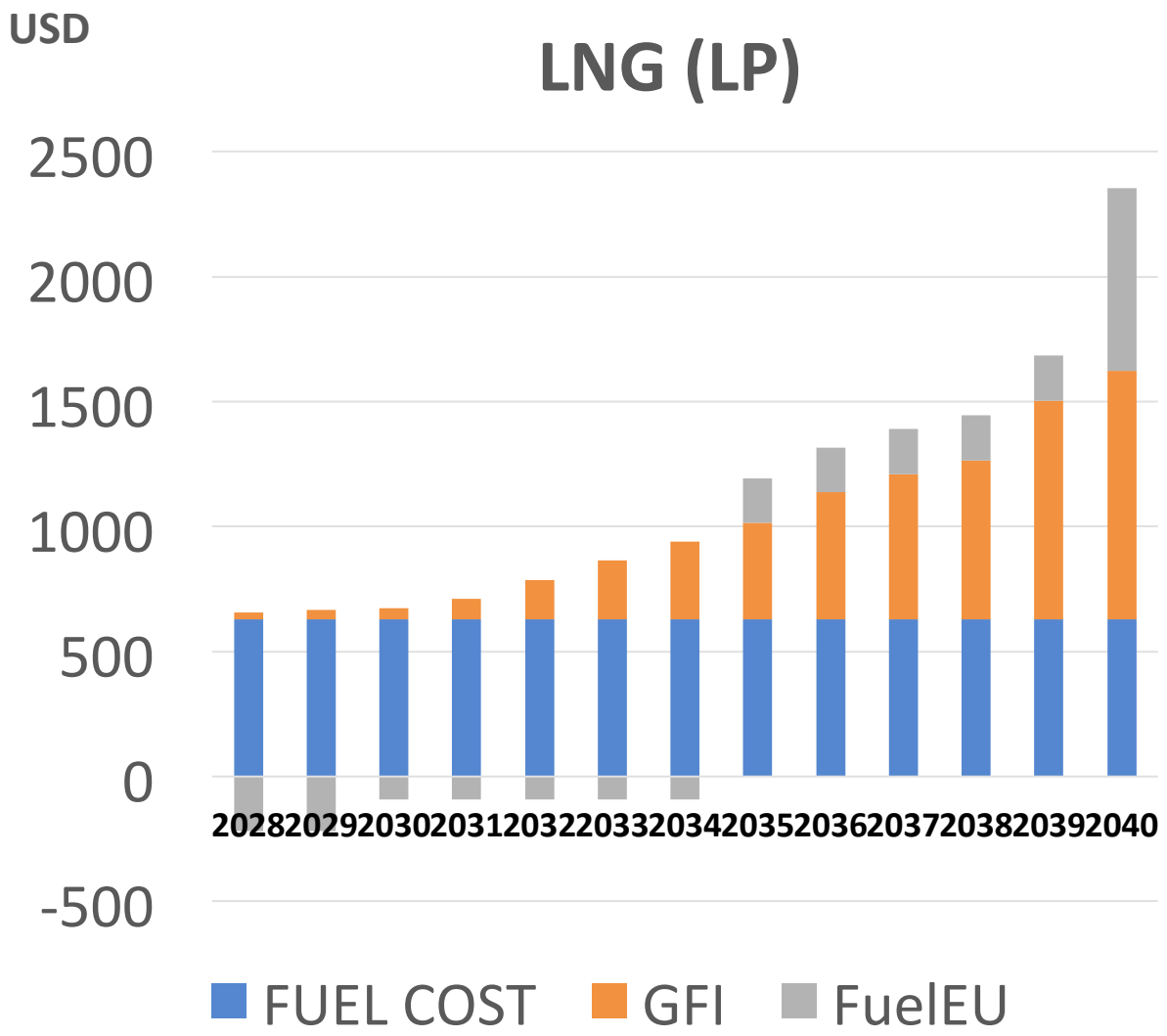
FUEL COST
GFI
FuelEU

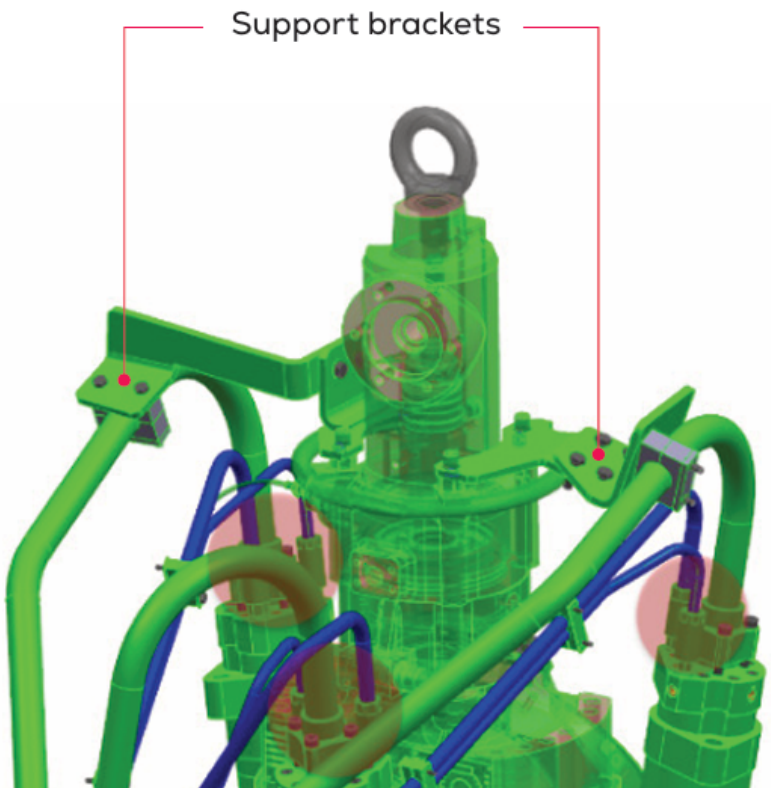
LP vs HP LNG Fuel Costs

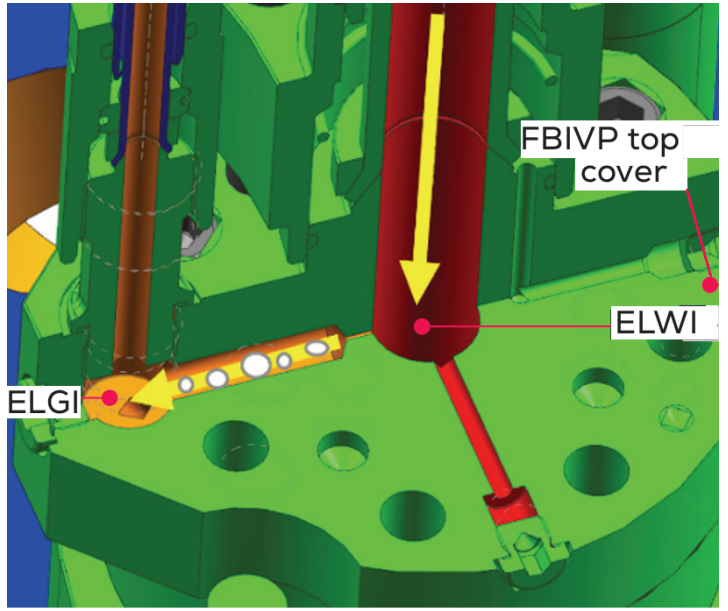




LPG Engines

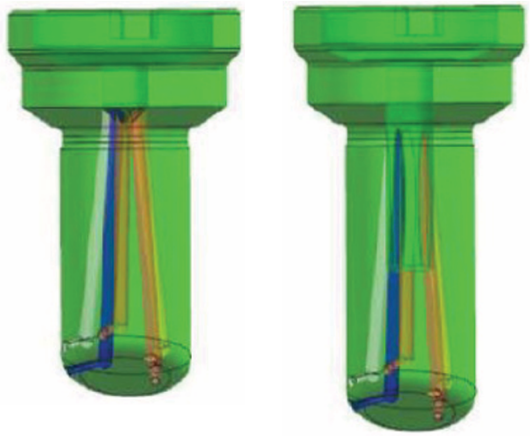
- Hydraulic pipe vibration → Improved double-walled couplings and stronger support brackets reduced leaks and shutdowns.
- Pipe leakage from weak cone design → New 45° cone design with smoother transition lowered stress and prevented breakage.
- Air trapped in ELGI hydraulic lines → Added sandwich plate with non-return valve to prevent air intrusion.
- Air intrusion during venting → Introduced separate venting of ELWI pipe with redesigned top cover and drainage.

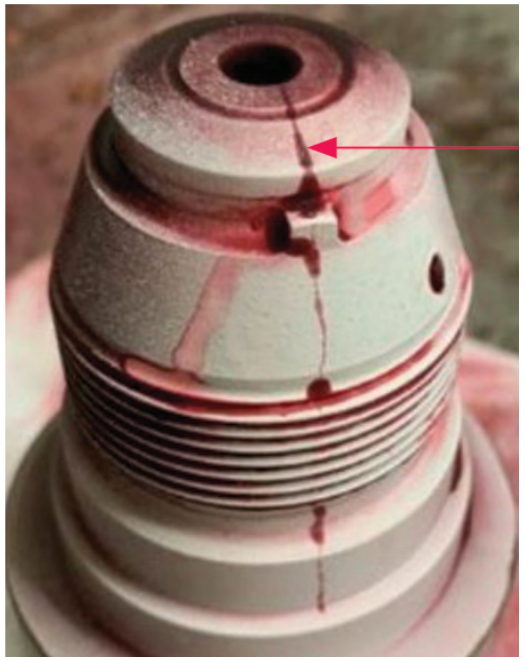




LPG Engines

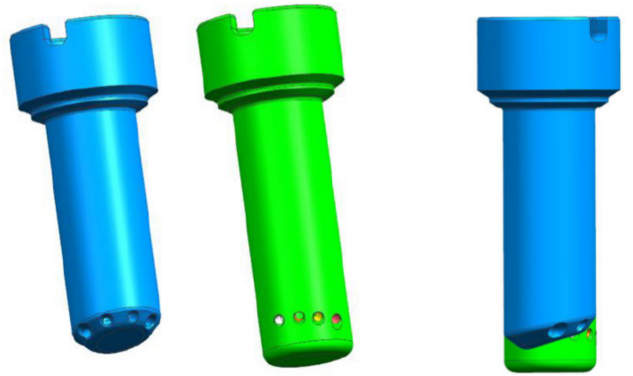
- Cracked spindle guides causing pressure loss → Redesigned with thicker walls, FEM-verified geometry, and leak detection holes.
- LPG phase shift (micro boiling) leading to cavitation → Software and hardware updates: prolonged circulation, orifice plate, and removal of restrictive non-return valve.
- FBIVP plunger seizure and oil leakage → Increased clearances, stronger O-ring materials, and one-part thrust piece.
- Nozzle clogging and hot corrosion → Adopted longer Inconel nozzles, improving durability and reducing failures.

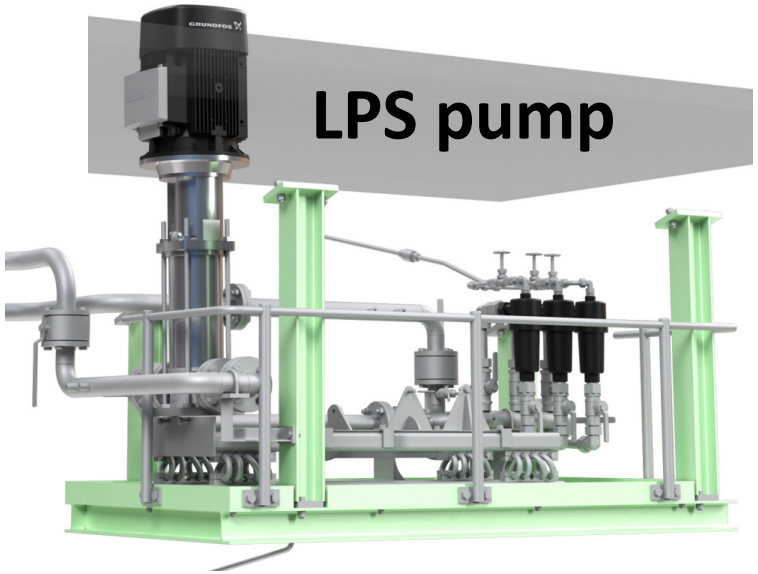




Methanol

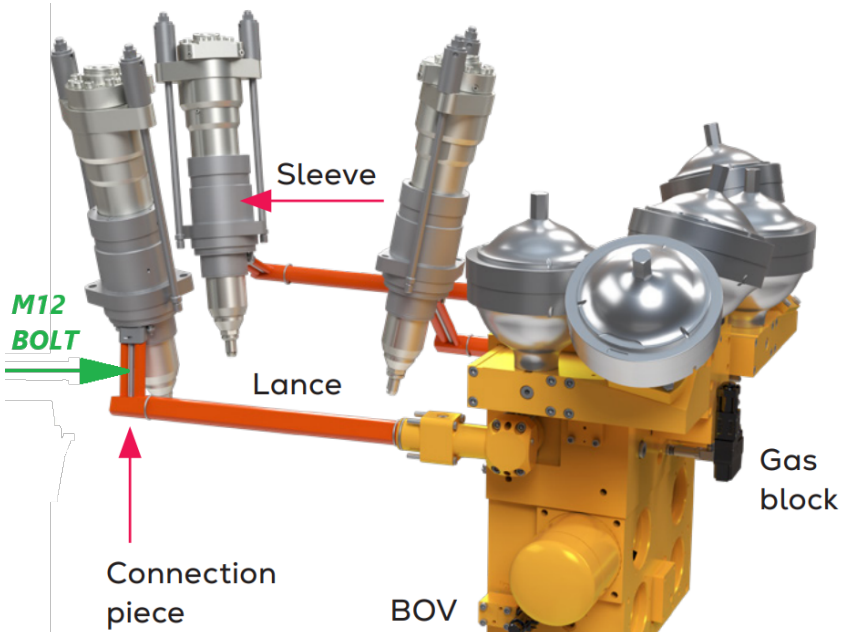
- To comply with Tier III NOX, a methanol-and-water blending / emulsion (**LGIM-W**). Presently, removed from programme. Fatigue damage of nozzles. Solution: working on new nozzle design.
- FBIVM Cut-off shaft material hardness drop within 5hrs. Solution: SUS (X90) → tool steel (S85W6Mo) & M390.
- High-pressure hydraulic pipes pressure peaks. Solution: Deaeration points relocated to the highest point on the high-pressure pipe and the pipe design has been improved.
- A knocking sound during changeover to Methanol because nitrogen accumulated in the FBIVM acting as a gas spring. Solution: each FBIVM chamber is filled with methanol cylinder by cylinder. A high-capacity low-pressure supply (LPS) pump ensures that the FBIVM plunger is positioned at the bottom during methanol filling, preventing the remaining N2 from acting as a gas spring.

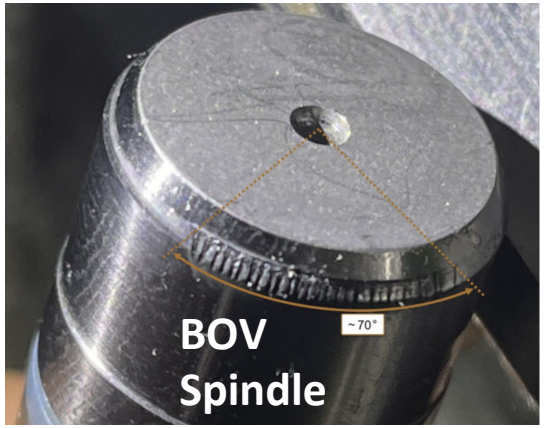


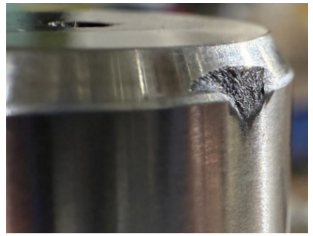


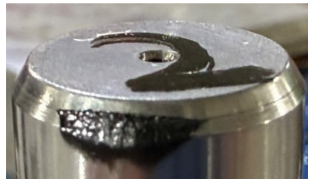
Methanol

- M12 bolts in the connection piece have broken, leading to methanol leakage and dual-fuel shutdown. Solution: The connection piece now includes a distance piece to reduce the bolt dynamic load.
- Blow-off valve (BOV) updated with higher closing pressure: Cavitation and erosion have been observed on the BOV spindle on G95ME-C10.5 LGIM engines. This resulted in methanol leaking to the methanol return pipe and excessive purging with nitrogen, eventually triggering an alarm and dual-fuel shutdown.
- FBIVM nozzle with heat shield (now standard) reduce FBIVM temperature by 100C.
- New mini-sac nozzle designs tested successfully: GI design with separate supply bores to the nozzle holes, which reduces the stress level.

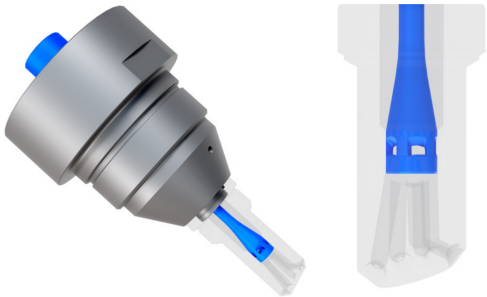








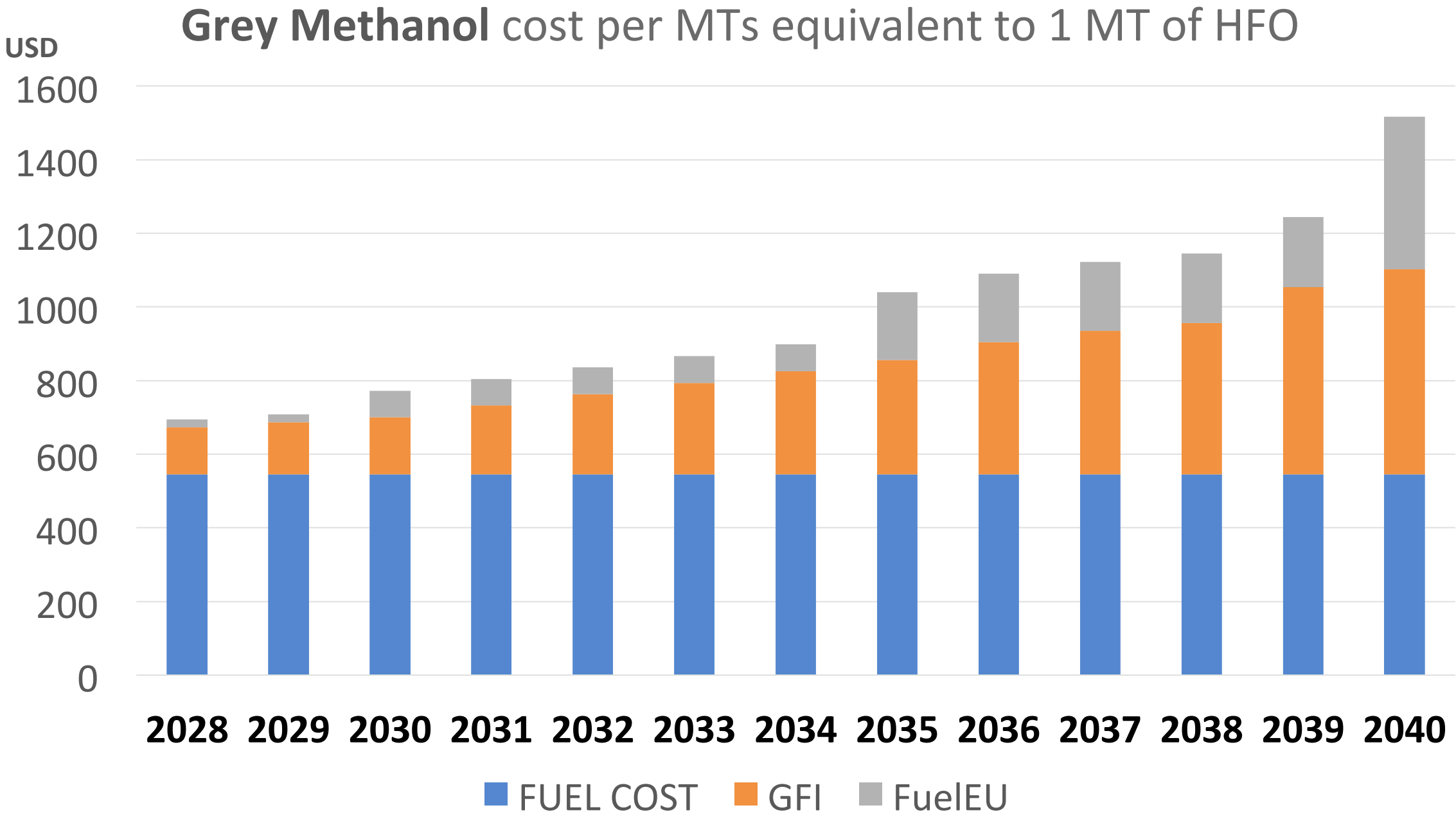
mini-sac nozzle



FBIVM heat shield

Methanol

- Little methanol leakage in the double-wall pipes. A small leakage of few ppm seems not avoidable, but this is not a risk for the crew. Solution: The jumper pipes will be changed to a distribution pipe and a single connection to the cylinder for the next engine.
- Fuel injection valve leaking. This identified from one single maker at the nozzle body seat. Solution: Another material will be tested soon which should solve the issue


Grey Methanol cost per MTs equivalent to 1 MT of HFO
USD
1600
1400
1200
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800
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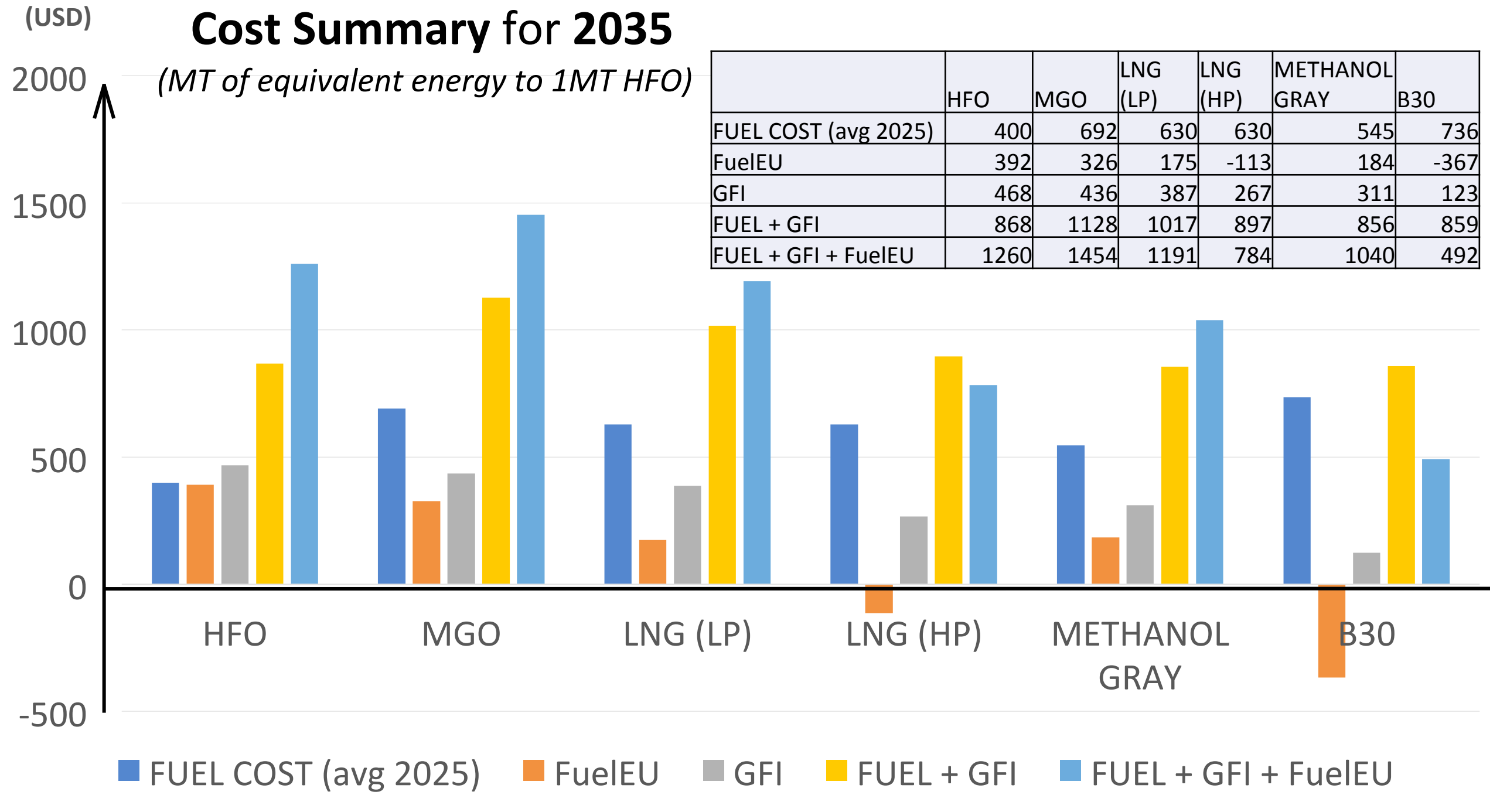
2040
FUEL COST
GFI
FuelEU

Cost Summary for **2035**

(MT of equivalent energy to 1MT HFO)

	HFO	MGO	LNG (LP)	LNG (HP)	METHANOL GRAY	B30
FUEL COST (avg 2025)	400	692	630	630	545	736
FuelEU	392	326	175	-113	184	-367
GFI	468	436	387	267	311	123
FUEL + GFI	868	1128	1017	897	856	859
FUEL + GFI + FuelEU	1260	1454	1191	784	1040	492



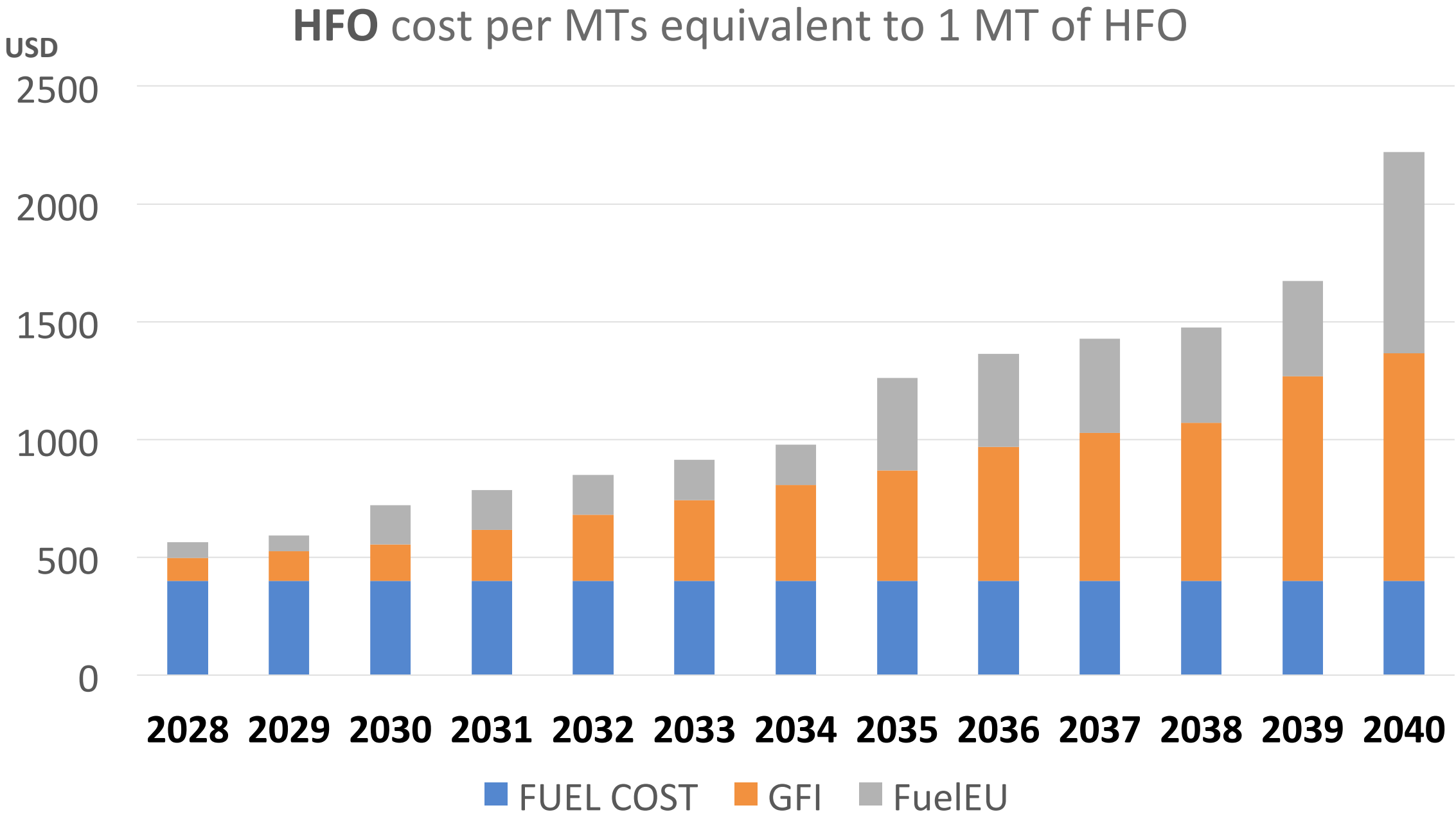
DF engines references per maker

	Everllence	WinGD
HP LNG	**1030** (577 +453)	-
LP LNG	**270** (223 +47)	**924** (598+326)
Methanol	**222** (96 +126)	**76**
LPG	**269** (156 +113)	**0**
Ammonia	**4**	**32**
Total	**1791**	**1032**

No fuel change (HFO)

Penalty paid by
ship operator → charterer → consumer

No	Route	Ship Type	Cargo Type	Cargo Value	Average Speed (knots)	Fuel Cons. (HFO TPD)	Voyage Days	**Freight / Cargo value**	**Fuel cost / Cargo value**	**GFI cost / Cargo value (2035)**
1	MEG → Rotterdam	Suezmax 155,000	Crude Oil	$600/mt	13–14	50	37	**1.88%**	**0.90%**	**0.90%**
2	W. Africa → Rotterdam	Suezmax 155,000	Crude Oil	$600/mt	12–14	50	40	**1.88%**	**0.97%**	**0.97%**
3	MEG → Rotterdam	LR2 112,000	Products	$1,000/mt	13.5–14.5	42	40	**2.67%**	**0.68%**	**0.68%**
4	Med → Rotterdam	MR 50,000	Products	$1,000/mt	12–14	25	15	**2.00%**	**0.34%**	**0.34%**
7	Asia → Europe	8,000 TEU (~95,000 DWT)	Containers	$55,000/TEU	16–18	70	30	**0.16%**	**0.21%**	**0.21%**
8	Asia → Europe	14,000 TEU (~150,000 DWT)	Containers	$55,000/TEU	16–18	95	35	**0.15%**	**0.19%**	**0.19%**
9	US → Europe	Supramax (63,500 DWT)	Grain Cement	$550/mt $100/mt	12-13	23	30	**2.2%** **12%**	**0.9%** **4%**	**0.9%** **4%**
10	Australia → China	Capesize (180,000 DWT)	Iron Ore	$120/mt	13	44	11	**0.8%**	**1%**	**1%**


HFO cost per MTs equivalent to 1 MT of HFO
USD
2500
2000
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2040
FUEL COST
GFI
FuelEU

Conclusions

- All new technologies are coming with teething, design and manufacturing issues.
- No new technology engine should be introduced in the market without previous exhausting test that will warranty minimization of any associated risks.
- The engine technology that will prevail will depend on the fuel cost and the available infrastructure. A priority to green fuel may be given.
- The competition between engine designers and class societies on who will get the lion's share for alternative fuel engines is not "exactly" helping the industry.