



Lattice Pressure Vessel

Enabling scale and cost reductions in the UK CCS value chain

Technology Leadership Board
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Lattice International AS

Lattice Pressure Vessels for Any Shape, Any Size, and Any Pressure

Company overview

- * Established by Professors Pål G. Bergan and Daejun Chang in 2012 at the Korean Advanced Institute of Science & Technology (KAIST), South Korea
- * Offices in Oslo, Norway (HQ) & Daejeon, South Korea
- * LATTICE is an IP and technology company that designs and engineers LPV containment solutions for clients globally
- * License model structure based on the value addition created by LPV solutions
- * Key problems addressed and solved:
 - How to scale transportation and storage of liquefied gases?
 - How to deliver highest volume at lowest cost per unit?

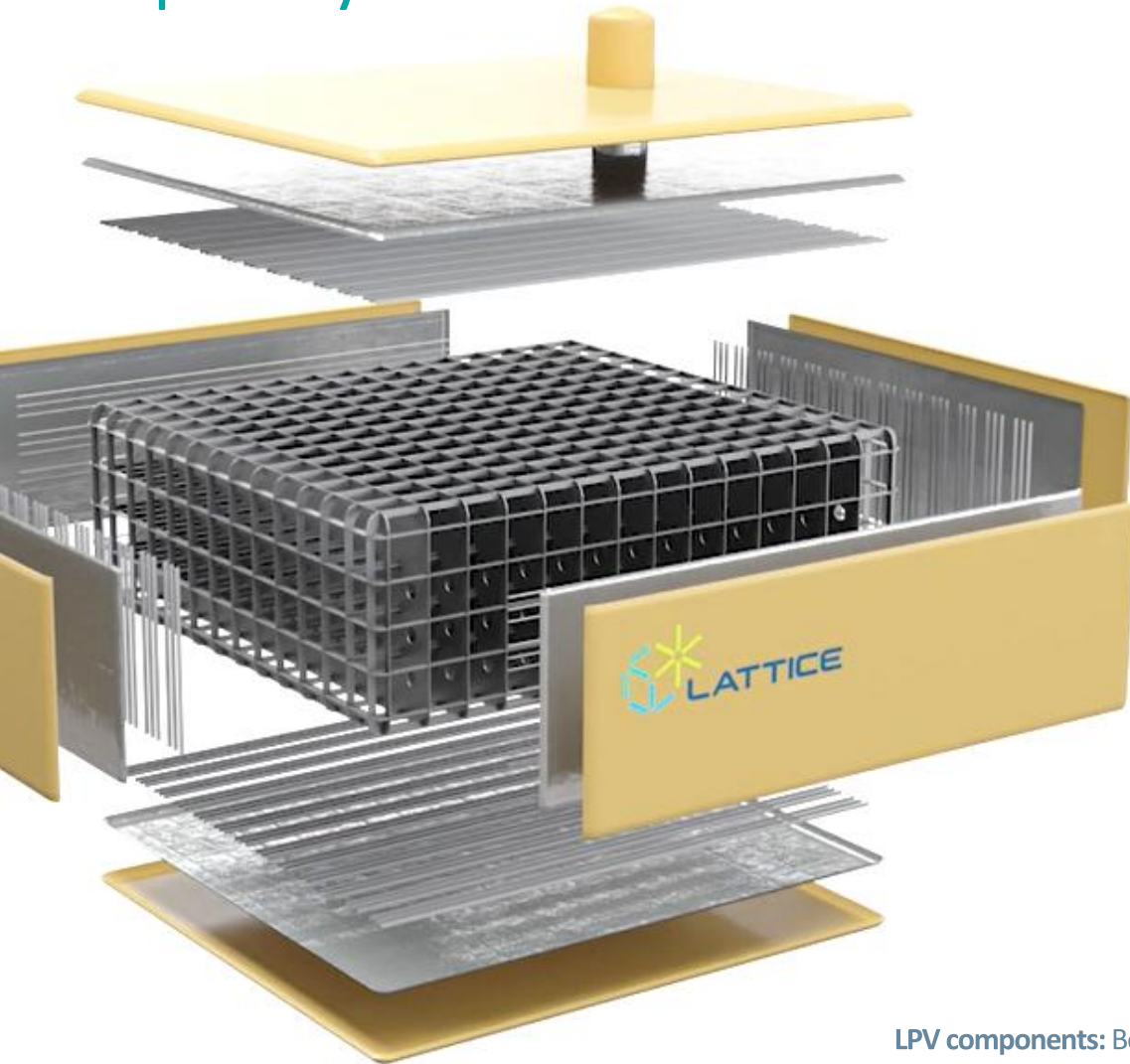


What makes the LPV technology unique

- * Cryogenic containment solutions for liquefied gases & energy carriers
- * Free-shape, free-size, any pressure
- * Adaptable to any space or confinement
- * Unique inhouse competence for tailoring tanks to client's needs
- * Awarded "ASME emerging technology award in pressure vessels" in 2019
- * Approval with all major Classification Societies, ASME, US Coast Guard



Unique pressure-loading capability



- * Smart 3D lattice structure for added safety and performance
 - Stresses, loads distributed effectively within the internal structure
 - Weld crack can only propagate to closest internal members, not to the outer shell
 - Reduces sloshing and free-surface effect
- * Effective BOG handling through adaptive design of pressure vessel
- * Leak-tight primary barrier
 - No secondary barrier needed, no additional handling and safety systems
- * Full flexibility in accommodating all storage conditions
 - From cryogenic temperatures at low pressure to higher temperatures at medium pressure

LPV components: Beams, Plates, Stiffeners, Outer shell, PUF, Supports

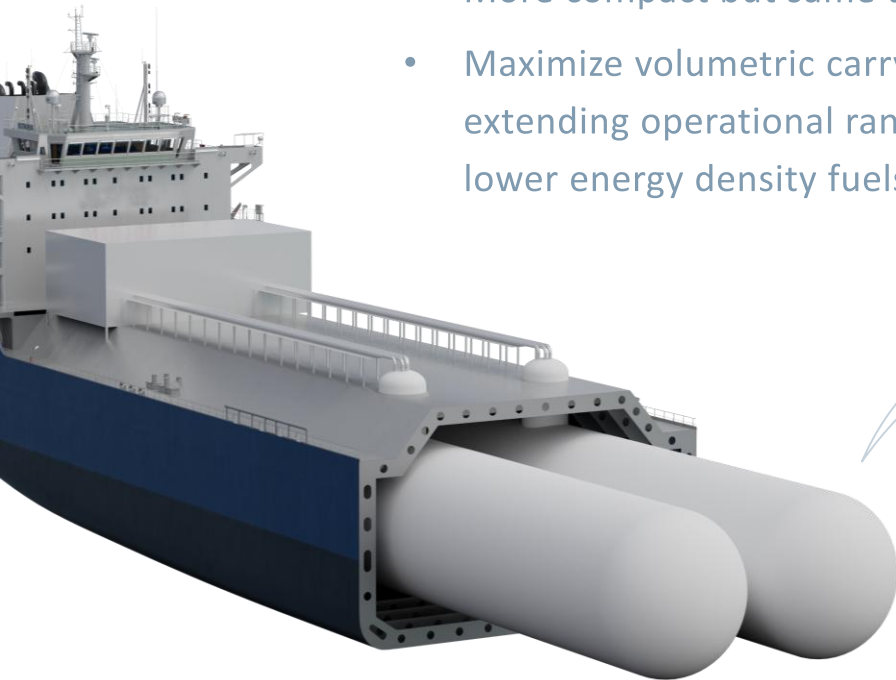
Optimal space efficiency

* Supreme space utilization...

- Design allows tank to be tailored to the vessel, not vice-versa

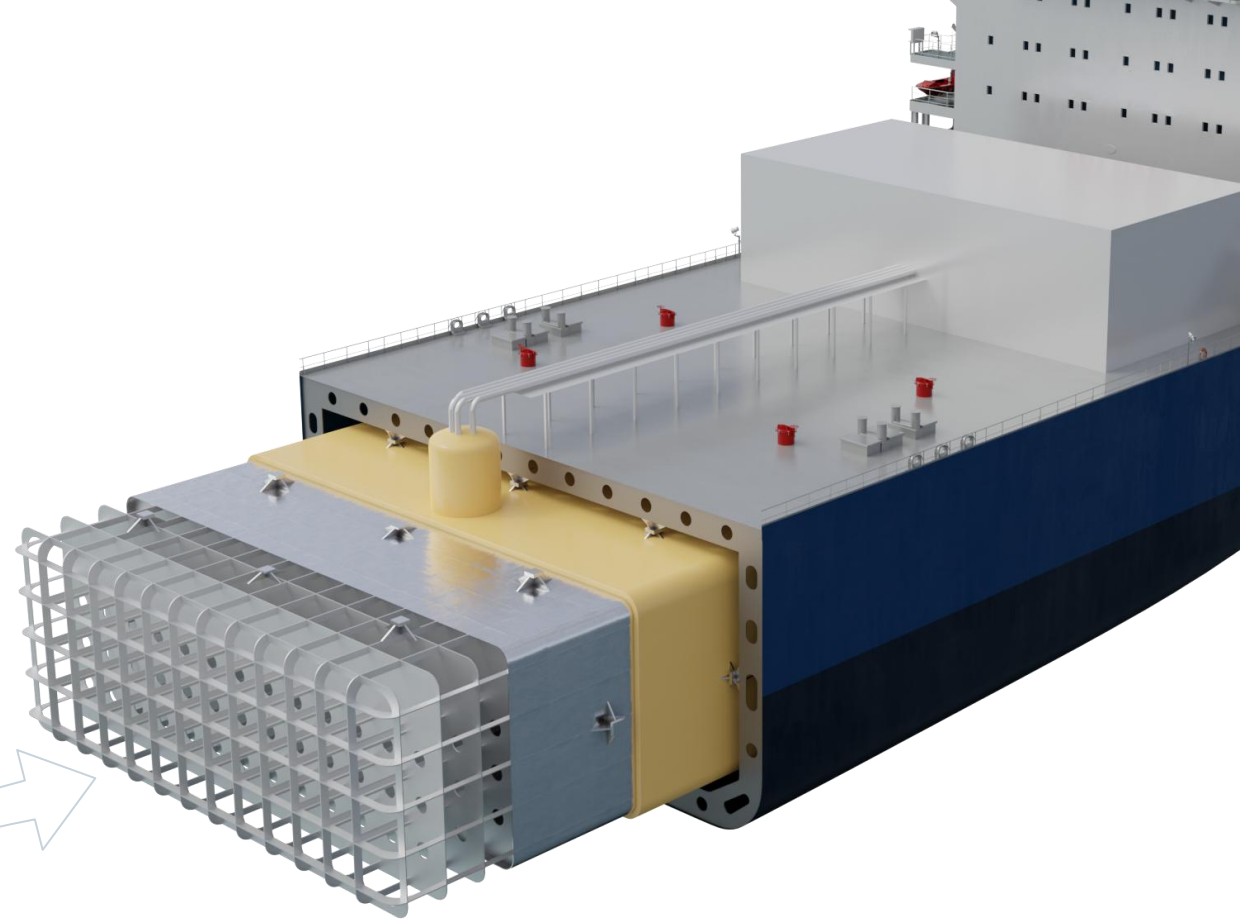
* ...for Fuel tanks

- More compact but same tank capacity, or;
- Maximize volumetric carrying capacity, thereby extending operational range of vessel (even with lower energy density fuels)



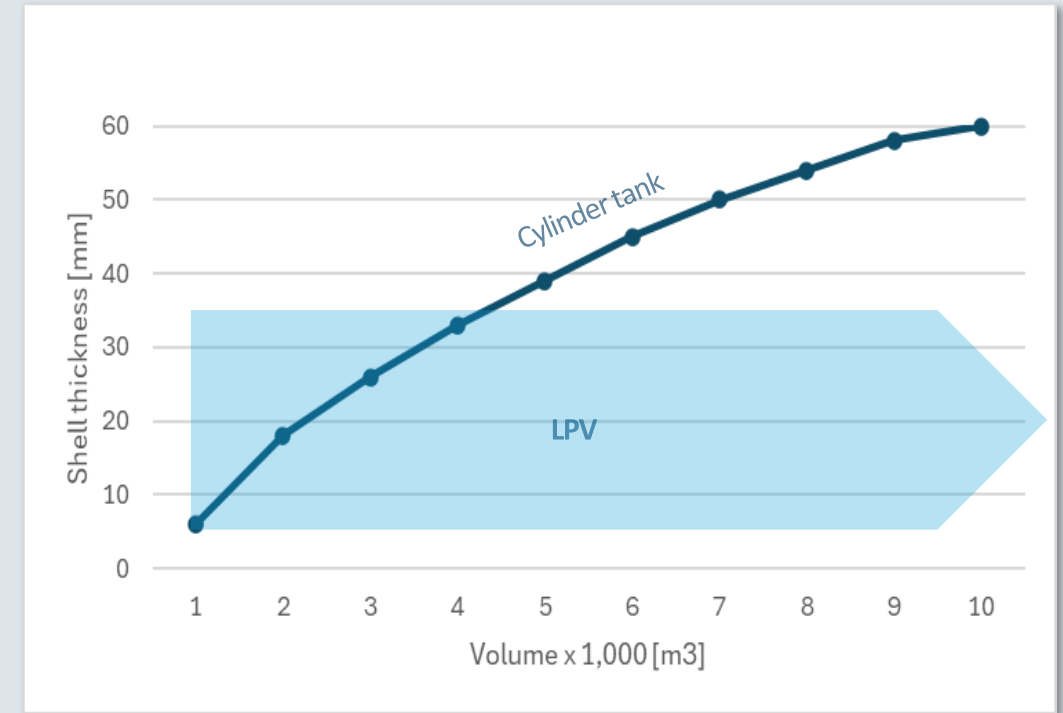
* ... and Cargo tanks

- Increase payload within ship's existing design configuration, or;
- Carry same volume with improved ship design and reduce overall CAPEX and OPEX of vessel
- Transport 1) More m3 for same amount of energy input or 2) Same amount m3 for less energy



Limitless scalability

- * Single LPV tank scaled up to 40k m³, and beyond
- * Minimize number of tanks and hull size
- * Volumetrically most weight efficient solution
 - Achieves lower shell thickness than cylindrical tanks
 - Relative weight of tank per m³ is more advantageous with increasing size
- * Reduced interfacing, complexity and cost
 - Reduce amount of auxiliary equipment (pumps, piping, instrumentation, etc.)
 - Driving down total cost of ownership
- * Lean, repetitive assembly and fabrication process

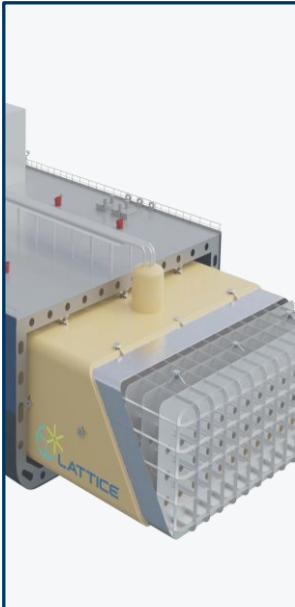


LPV shell thickness is uniform (6-35mm) for all tank sizes
(illustrative purposes only)

LPV sector applications



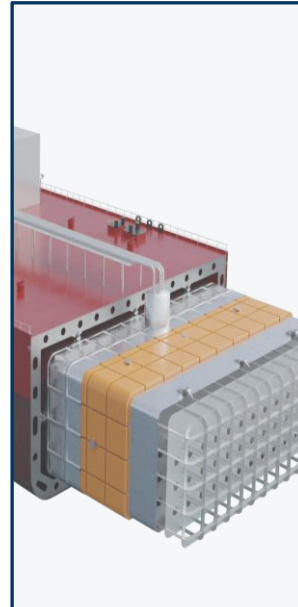
**LNG fuel
solutions**



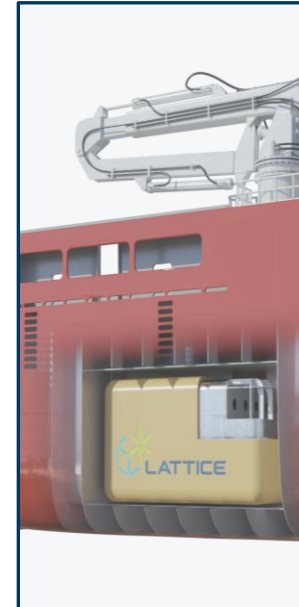
**LCO2 cargo
solutions**



**OCCS
(Onboard Carbon
Capture & Storage)**



**LH2 cargo
solutions**



**LNH3 fuel
solutions**



**Solutions for
Floating unit**



**Onshore
storage**

APPLICATION – LNG FUEL SOLUTIONS

- * 6 LNG fuel tanks in operation!
- * Maximize volume for increased range, or;
- * Most compact fuel containment solution for increased payload (see case example)
- * Minimize impact on high-value cargo space



Business case – 7,600 CEU PCTC, LPV vs. cylinder:

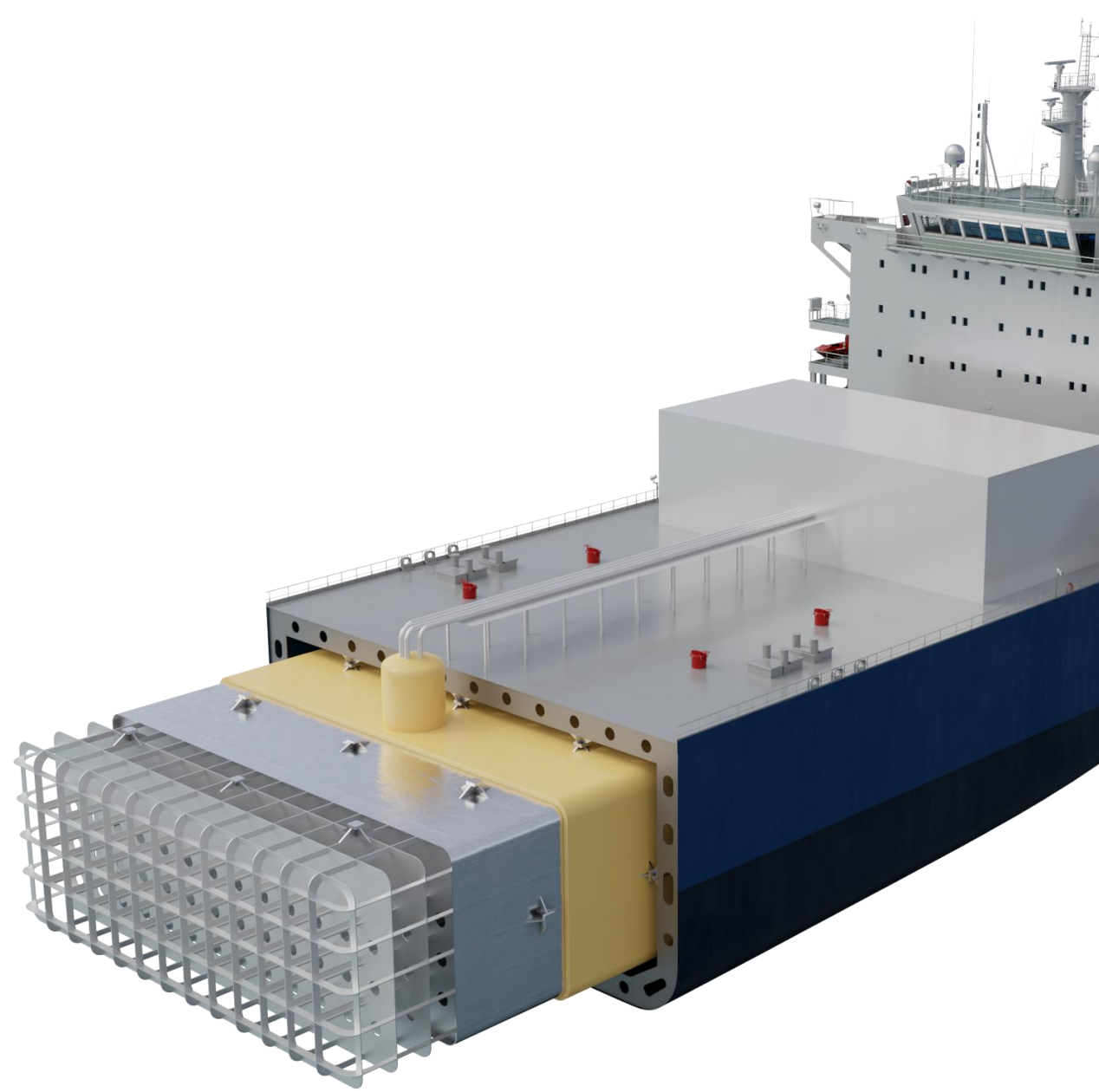
- * Avg. value of deck space: 100m² = 1% of day rate
- * 95 CEUs saved = 600m² = 6% of day rate
- * Roundtrips p.a. = 6
- * Day rate = USD 50,000
- * Annual increased revenue = USD 1,080,000
- * Increased revenue LFT (20y) = USD 21,600,000

APPLICATION – LCO2 cargo solutions

- * Awarded AiP for 20k and 40k m3 LCO2 carriers
- * Optimized hull significantly reduces CAPEX and OPEX
- * Ongoing development projects with major shipping players
- * Client European gas carrier operator and Korean ship designer

Business case – 40k m3 LCO2 carrier

8 barg (LP) design pressure	LPV	vs.	Cylinder
• Number of tanks (units):	3		7
• Total weight (tons):	5,750		5,800
• Ship length (m):	200		239
• Displacement (tons):	64,450		69,120
+ CAPEX savings:	15.5 - 21.0 MUSD*		
+ Freight cost reduction:	1.5 - 2.5 USD/ton		
→ Total client value:	35-50 MUSD (discounted NPV - 15y)		



*Based on vessel quotations from Chinese shipyard

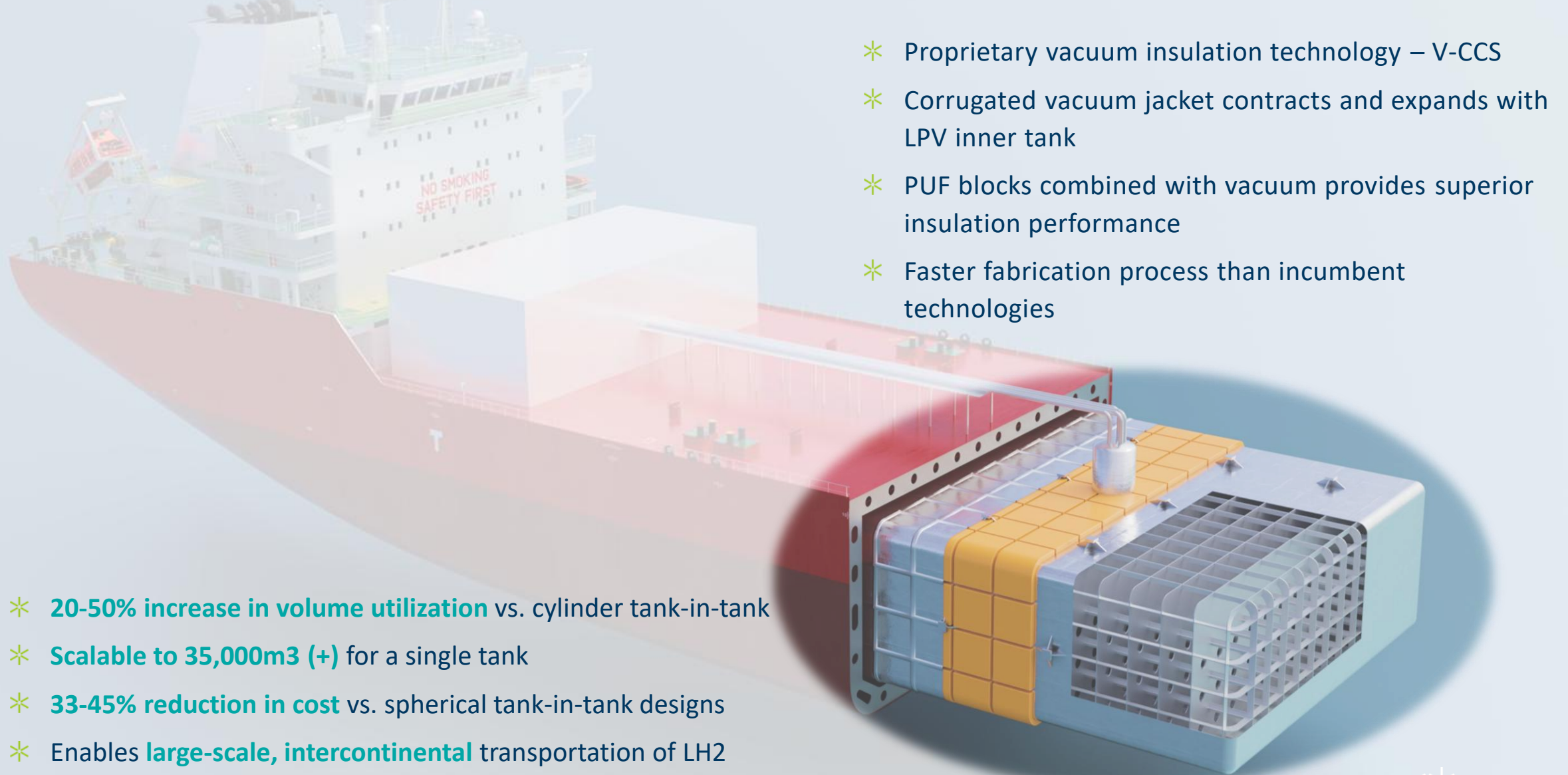
APPLICATION – OCCS

- * Significantly reduces impact of TEUs forfeited as compared to cylinders
- * Easy to install, designed to client's preferred operating requirements
- * One fit-for-purpose tank solution rather than multiple: reduces interfacing, complexity, and total cost
- * Ongoing development projects with major shipping players

Business case – 9400 TEU container ship, LPV vs. cylinder

- * Δ TEU LPV vs. Cylinders: +199
- * Roundtrips p.a. = 12
- * Average revenue per TEU: USD 1500
- * Increased annual revenue = USD 7,164,000
- * Increased revenue LFT (20y) = USD 143,340,000

APPLICATION – LH2 CARGO SOLUTIONS



APPLICATION – LNH3 FUEL SOLUTIONS

- * Maximize volume for increased range (see case example), or;
- * Most compact fuel containment solution for increased payload
- * Ongoing client business case for dual-purpose fuel tanks for ammonia+

Business case – PSV, LPV vs. cylinder:

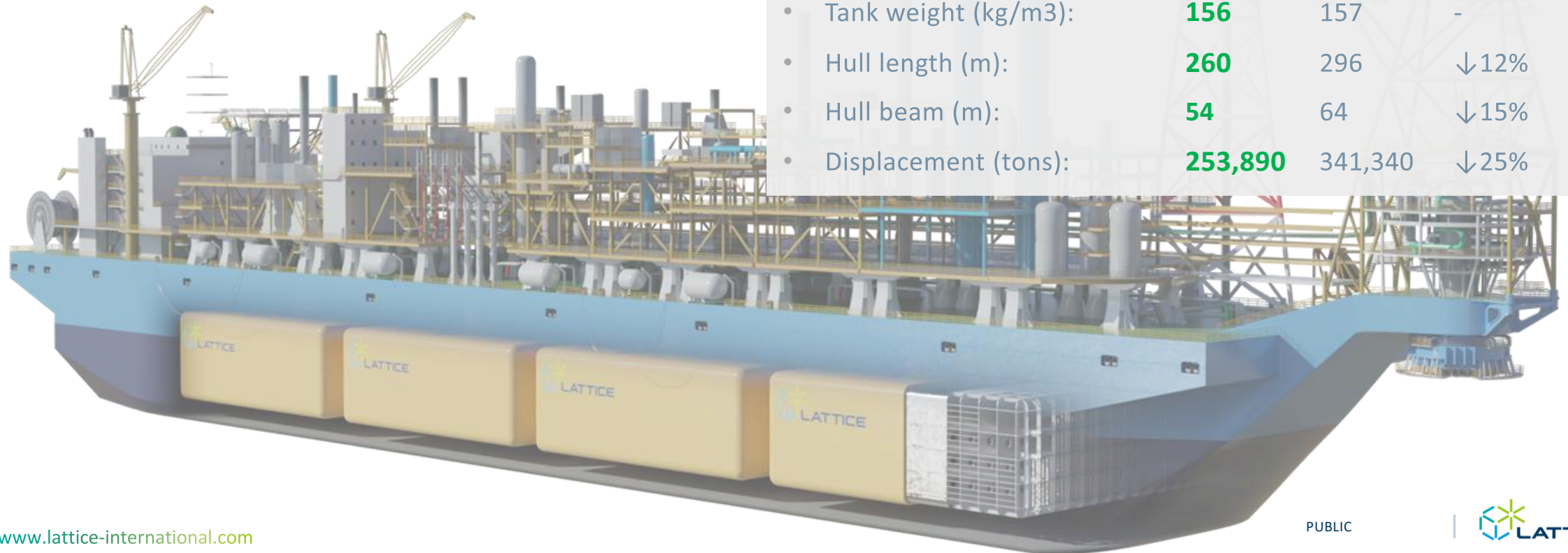
- * Δ m3 LPV vs. Cylinder: +96% capacity increase
- * 4 weeks vs. 2 weeks rotation
- * Port calls saved p.a. = 12 (x3 days)
- * Dayrate = USD 20,000
- * Increased annual revenue = USD 720,000 p.a.
- * **Increased revenue LFT (20y) = USD 14,400,000**

APPLICATION – SOLUTIONS FOR FLOATING STORAGE UNITS

- * Key enabler for large-scale LCO2 FSIUs
- * Scale to 30k+ m3 per tank
- * Accommodate Low- and Medium pressure ratings
- * >20 mUSD CAPEX savings
- * Reduced tank supply chain constraints

Business case – FSIU for LCO2

Details	LPV	Cylinder	Difference
• Design pressure (barg):	12	8	↑50%
• Number of tanks (units):	4	15	↓73%
• Total volume (m3):	108k	105k	↑3%
• Tank weight (kg/m3):	156	157	-
• Hull length (m):	260	296	↓12%
• Hull beam (m):	54	64	↓15%
• Displacement (tons):	253,890	341,340	↓25%



APPLICATION – ONSHORE STORAGE

- * LPV applicable throughout **entire value chain**
- * LPVs for onshore applications where **space constraints and safety** are key for facilitating large-scale storage volumes
 - Intermediate storage at emission sites
 - Offloading/onloading terminals
 - Buffer storages
- * LPV provides strong value-adds:
 - **20-50% increase in volume utilization** compared to cylindrical and spherical tanks
 - **Adaptable tank design** tailored and accommodated to any required dimensions and pressure rating
 - **Reduced civil works** due to optimized ground force distribution
 - **Confirmed reduction in cost**, weight, and size

Business case – storage tanks for LCO2 terminal*

Details	LPV	Spherical	Difference
• Design pressure (barg):	10	10	n/a
• Number of tanks (units):	3	4	↓25%
• Total volume (m3):	60k	60k	n/a
• Tank weight (kg/m3):	105	118	↓12%
• Tank height, incl. sup. (m):	23	36	↓56%
• Total footprint (m2):	2883	4356	↓51%

*Client-verified CAPEX and installation cost reduction for LPV

SUMMARY

SOLUTIONS FOR A GREENER FUTURE

- * LATTICE is redefining the pressure vessel and its **efficacy for storing valuable liquified gases**
- * Strong suite of **value adding advantages** and **economic benefits** that result in the lowest cost of transportation per unit freighted
- * LATTICE Pressure Vessel (LPV) serves as an important catalyst for accelerating **ongoing energy transition** within **Maritime, Energy Infrastructure** and **Manufacturing industry**



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