

# CNG OPTIMUM

A VIABLE MARINE CNG TRANSPORT SOLUTION



GAS & LNG MIDDLE EAST SUMMIT | OMAN 2018



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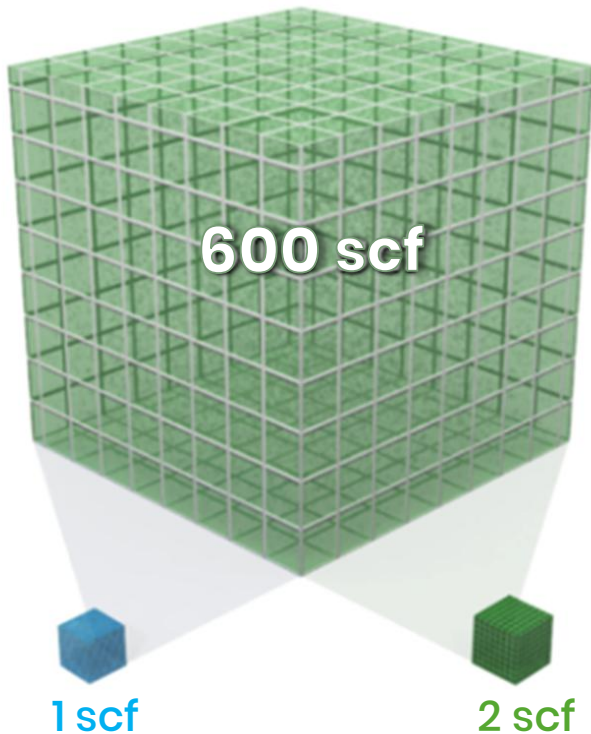


# FREEZE OR SQUEEZE

LIQUEFIED  
**LNG**

-162°C  
1 atm

**600:1**



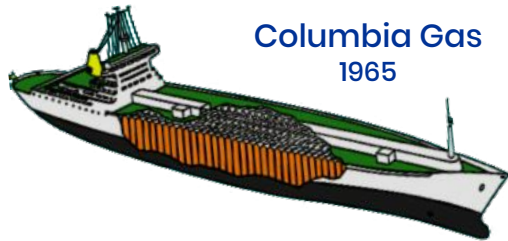
COMPRESSED  
**CNG**

30°C  
3,600psi

**300:1**

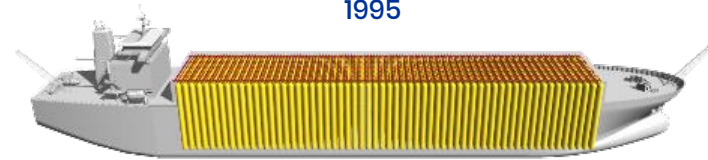
# EVOLUTION OF THE CNG SHIP

## EARLY DESIGNS



Columbia Gas  
1965

Steel and design factors of the 60's  
Too many connections  
**Very limited economic range**



Bottle-Ship  
1995

Increased gas volume to steel ratio  
High-strength steel  
Too many connections  
**Limited economic range**

### Early CNG ship designs were constrained by:

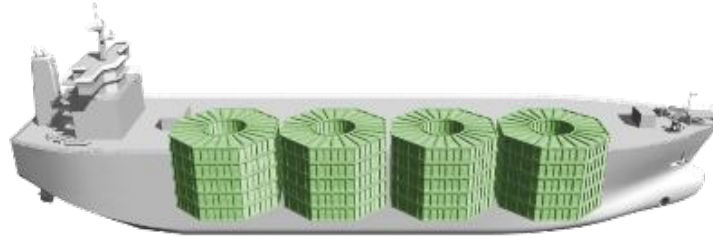
- Stacking long horizontal pipes was not permitted because they would rub together as the ship flexed at sea
- Vertical pressure bottles became the 'standard' for CNG ships
- Vertical bottles had to be supported in a framework and required space between each bottle for inspection

### The excessive number and spacing of vertical pressure vessels resulted in:

- An inefficient use of the cargo space
- A highly expensive connection system

# EVOLUTION OF THE CNG SHIP

## COSELLE DESIGN (1998)



Reduced connections using large coils of small diameter pipe  
**Modest economic range**

The Coselle design achieved American Bureau of Shipping “Full Design” Approval. The design:

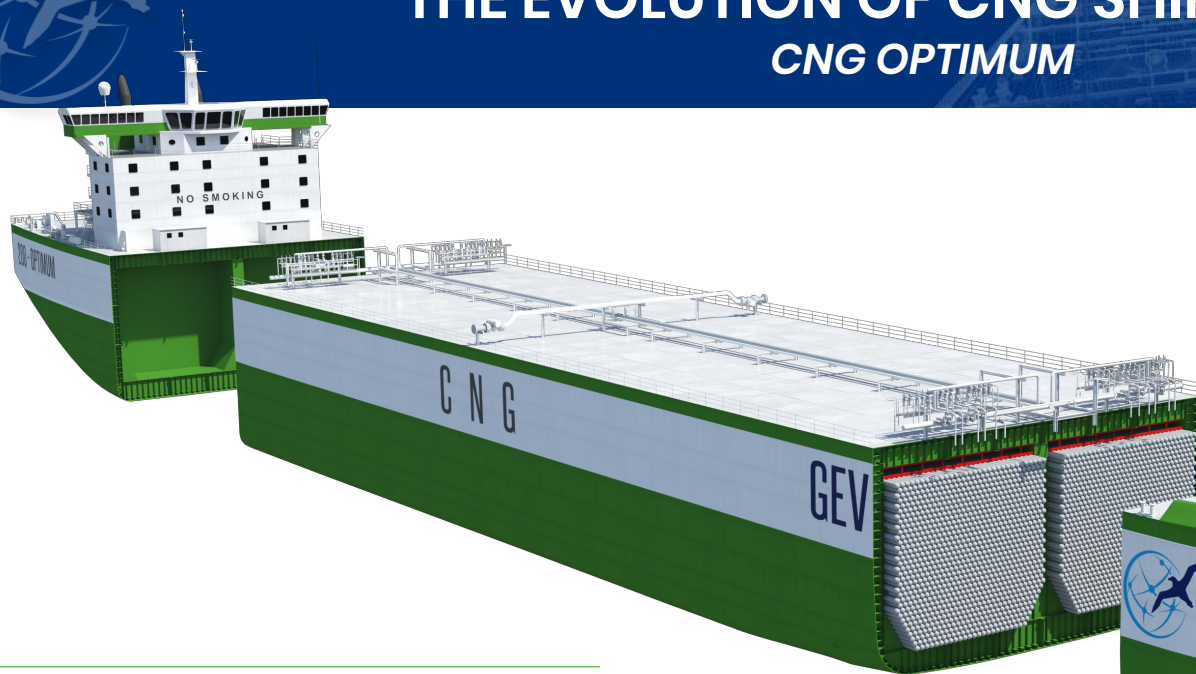
- Showed the merits of long coiled lengths of pipe to minimize the number of connections
- Showed the merits of integrating the containment system into the ship design
- Showed that the CNG storage in the ship was still not optimum because of the wasted space due to geometry
- Overly complex in construction because a specialised facility was needed to fabricate the Coselle's

Therefore, the “light bulb” moment:

- Use **horizontally stacked** straight pipe to optimize the usage of the ship's cargo hold
- **Invent a system to overcome the horizontally stacked straight pipes rubbing together**

# THE EVOLUTION OF CNG SHIP DESIGN

## CNG OPTIMUM



### CNG SHIP

184.7m	Length
16.8m	Moulded Depth
31.3m	Moulded Breadth
9.2m	Full Load Draft
45,600 t	Displacement

### OPTIMUM STORAGE SYSTEM

200 MMscf	Loaded Gas Volume
3,600 psi	Operating Pressure
X80 Steel	Pipe Grade
500mm (20")	Pipe Diameter
108m	Length of Individual Pipes
140km	Total Length of Pipes

### SAILING PARAMETERS

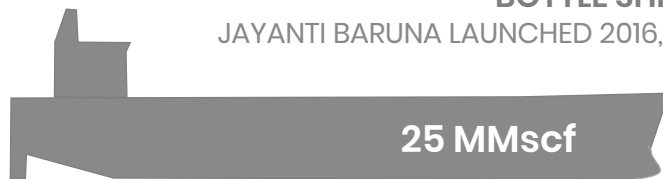
>10.5m	Required Water Depth
14 knots	Average Speed



# A STEP CHANGE IN MARINE CNG ECONOMICS

## BOTTLE SHIP

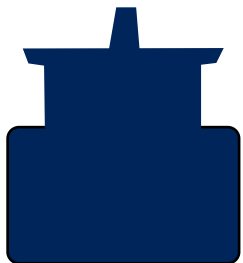
JAYANTI BARUNA LAUNCHED 2016, FOR USE IN INDONESIA



25 MMscf

110m

## COSELLE DESIGN

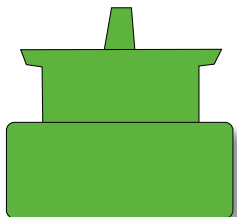


200 MMscf

221m

## CNG OPTIMUM DESIGN

*8 x "Jayanti Baruna" Capacity*



200 MMscf

184m



# ADVANTAGES OF CNG OPTIMUM

## KEY PARAMETERS

- Ideal for regional distances (< 2,500km) – highly competitive marine transport solution
- Flexibility to deliver gas from volumes of 50 to 400 MMscf/d
- Compression requires significantly less capex than liquefaction
- Requires small to medium gas reserves (< 1.0 TCF)
- Rapid CNG project development, less than 3 years

## SCALABLE DEVELOPMENT

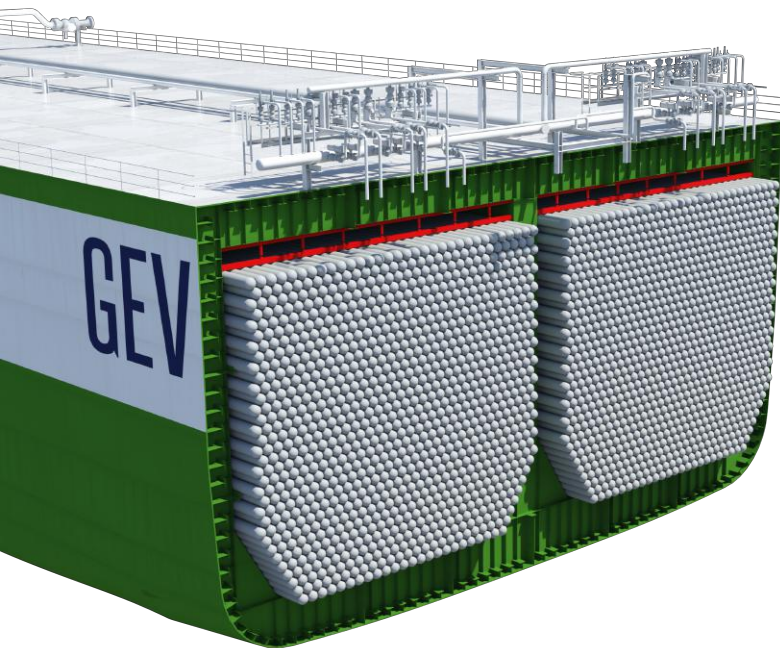
- CNG Optimum is a 'fit for purpose solution' with ships & fleets sized to fit the initial market
- Minimal fixed infrastructure (~ 80% of capex is in the Optimum ships) – no large capex investment in liquefaction and/or regasification facilities
- Scale to current demand, incrementally add ships as the market demand grows
- At the end of field or project life, CNG Ships can be easily re-deployed

## CNG IN USE WORLDWIDE

- Millions of CNG vehicles have been in service for over 40 years
- Gas handling at 3,600psi (250 bar) is common place in Oil & Gas Industry
- Similar pressure to a scuba diving tank
- This enormous experience and safety record applies to ambient temperature CNG



# PROPRIETARY CNG OPTIMUM SHIP DESIGN



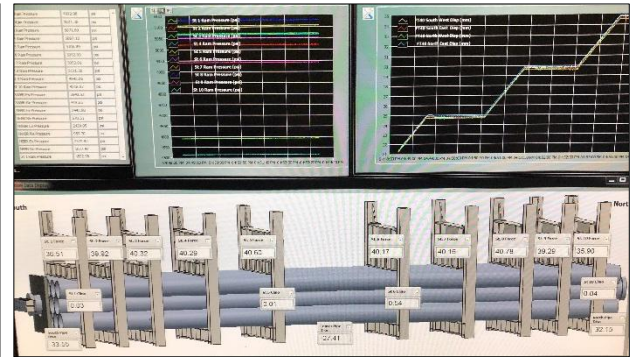
**‘Full ABS Design Approval’  
due shortly**

- Next generation of Marine CNG storage leveraging over two decades of R&D and an expenditure in excess of US\$50M
- CNG containment system is high-strength, hexagonally arranged carbon steel pipes **running the entire length of the ship's cargo hold** (no transverse bulkheads)
- Previous work on this type of system failed because there was no known solution for preventing the pipes from rubbing as the ship flexed in response to sea conditions
- The invention (patents pending) of a mechanism to clamp the pipes so tightly together that they become locked by friction results in a ship that:
  - Meets all American Bureau of Shipping (ABS) class requirements
  - Contains the maximum amount of CNG in the smallest ship envelop hence **“Optimum”**
- Gas is stored at ambient temperatures **avoiding cooling and liquid-push systems**
- In-principle approval from ABS (200MMscf ship) has been obtained. The design has been fully vetted by ABS. Final testing is in progress and at its successful conclusion ABS will Issue **ABS Design Approval**
- The ship and containment system can be fully constructed in a single **conventional shipyard**. Negotiations with four shipyards underway for final capital costs and construction schedules

# ABS FULL CLASS APPROVALS



- Final safety and design approvals by the American Bureau of Shipping (ABS) in progress
- ABS has confirmed **2 out of 3 major tests successfully completed**, with **ABS “Full Class” approvals** to be achieved shortly
- Test 1: **High pressure testing** of the CNG Optimum pipe successfully completed on 10 August 2018 at C-FER. Whilst the operating pressure of the CNG-O-200 design is 3,600 psi, the pipe passed the test by demonstrating that it could withstand pressures up to 7,548 psi
- Test 2: **Proof of concept successfully completed** on 2 October 2018. The ‘Bend & Friction Test’ was to verify that the CNG pipes in the hold of the ship can be forced together in such a way that the pipes will not move relative to each other, or relative to the ship, even in extreme seas
- Test 3: **The 20,000 cycle-fatigue** is ~50% complete, with **two 6,000 cycle tests** to take place concurrently. The fatigue test requires cycling a pressure vessel for ten times it’s design life, from minimum pressure to operating pressure. For our 30 year ship life this means that our cycle test must recreate 300 years (20,000 cycles). **This is an extremely rigorous test**
- Ship design and engineering are being finalised ready for construction by the shipyards in the first half of 2019





# SCOPE OF WORK

## A “PIPELINE TO PIPELINE” SOLUTION

### CNG Export Terminal

Gas Metering, Compression Facilities &  
Pipeline to CNG Loading Jetty

### CNG Import Terminal

CNG Unloading Jetty, Scavenging Facilities  
& Pipeline to Customer

Gas  
Supply

Gas  
Sales

>10.5m



# CNG VALUE CHAIN

## PIPE TO PIPE



A single tariff to transport natural gas from “Pipe to Pipe”



The LNG value chain consists of “Liquefaction + Transport + Regas” as a “Pipe to Pipe” comparison



# DEVELOPING A GLOBAL CNG PROJECT PORTFOLIO

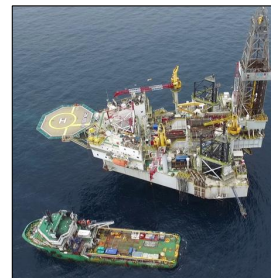


**CNG OPTIMUM SHIP** DESIGN ONE | BUILD MANY | OPERATE GLOBALLY

# HEADS OF AGREEMENT WITH TWINZA OIL TO EXPORT CNG

## HOA EXECUTED WITH TWINZA OIL TO EVALUATE THE CNG TRANSPORT OF PNG OFFSHORE GAS TO THE EAST COAST OF AUSTRALIA, SUPPLY OF 100MMSCF/DAY OF CNG (EQUIVALENT TO 0.7MTPA OF LNG)

- HOA signed with Twinza Oil Limited in August 2018 to undertake a joint study on the commerciality of exporting offshore gas from the PNG Pasca A field via CNG Optimum ships
- Twinza is 100% owner & operator of the Pasca A field, located in the Gulf of Papua
- Final project plan approvals for the development of the liquids rich offshore field imminent, with Twinza targeting **FID mid-2019** (project valuation USD\$1B)
- The Pasca A field facilities are designed for the **production of 125 MMscf/d** and first liquids production is currently **scheduled in Q1 2021**
- GEV and Twinza are focused on key gas markets in Queensland, Australia & PNG mining projects using high cost fuels for power generation



# PASCA A CNG PROJECT

<b>GAS SOURCE:</b>	Pasca A field, Gulf of Papua, PNG
<b>GAS VOLUMES:</b>	100 MMscf/day (~0.7 Mtpa LNG equivalent)
<b>TERM:</b>	10 years
<b>CONTRACT PRICE:</b>	Dependent on delivery location
<b>OPTIMUM 200 SHIPS:</b>	Up to 4
<b>SHIPPING DISTANCE:</b>	Up to 2,000 km
<b>FRONT END ENG. &amp; DESIGN:</b>	Q4 2018
<b>TARGET FID:</b>	Mid 2019
<b>FIRST GAS:</b>	Early 2022
<b>CNG IMPORT LOCATION(S):</b>	Queensland, Australia & Domestic PNG



**MINIMAL ADDITIONAL INVESTMENT IN PASCA DEVELOPMENT WITH GAS COMPRESSION AND CALM BUOY LOADING  
ALREADY INCLUDED IN THE LIQUID FIELD DEVELOPMENT PLAN**

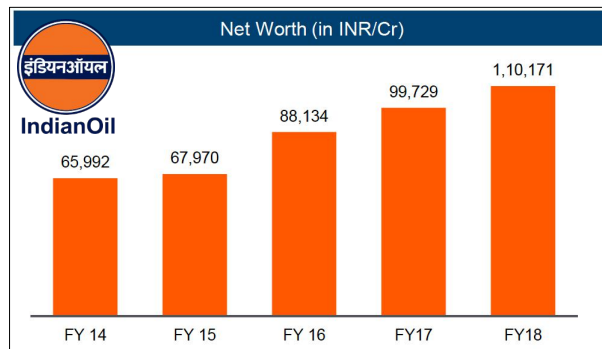
# HOA WITH INDIAN OIL CORP FOR PURCHASE OF CNG

## HEADS OF AGREEMENT WITH INDIA OIL CORPORATION LIMITED FOR THE SUPPLY UP TO 220 MMSCF/D OF IMPORTED CNG FOR 20YRS (EQUIVALENT TO 1.5MTPA OF LNG)

- Under the Heads of Agreement, parties will commence negotiations for a **binding Gas Sale Agreement for 20yrs, starting late 2021**, priced using a link to Brent crude and delivered to Port of Dahej, an established multi-commodity port that is connected to the India's gas infrastructure network
- Indian Oil Corporation Limited is the largest energy company in India (**137th in Fortune Global 500, 2018**) engaged in the complete supply chain of petrochemical products in India along with a global portfolio of energy assets
- Annual revenues of **USD 63B**; Enterprise Value of **USD 35B** (*Bloomberg*); BBB - rating
- 33% of the country's oil refining capacity; 11 refineries with 80.7MMtpa capacity; 13,200km of pipelines; 44% petroleum market share in FY18; 2<sup>nd</sup> largest in domestic petrochemicals



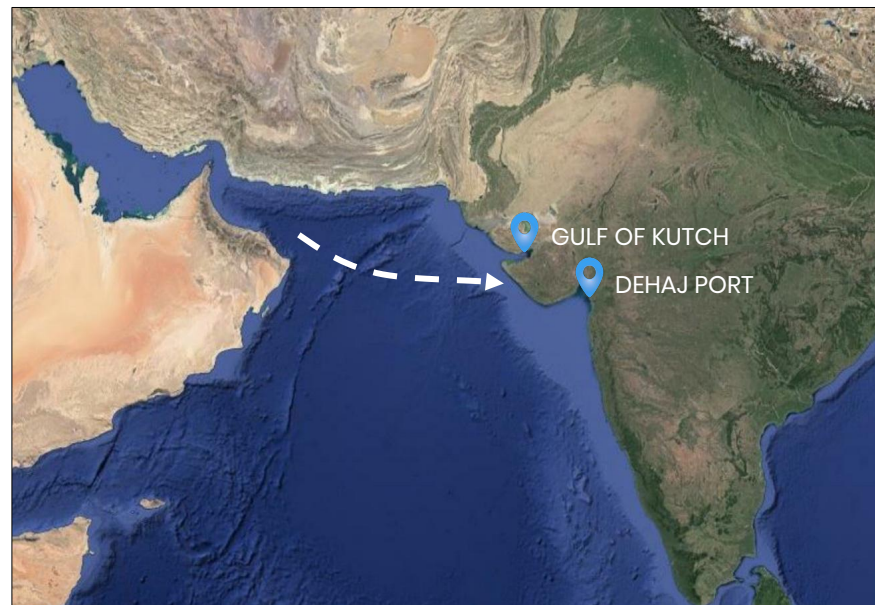
IOCL Executive Director Shailesh Kumar Sharma & GEV CEO Maurice Brand





# MIDDLE EAST GAS SUPPLY TO INDIA

<b>GAS SOURCE:</b>	Middle East Region
<b>GAS VOLUMES:</b>	Up to 220 MMscf/d (1.5Mtpa LNG equivalent) 75 MMscf/d (Start up phase)
<b>TERM:</b>	20 years
<b>CONTRACT PRICE:</b>	Linked to Brent Crude
<b>OPTIMUM 200 SHIPS:</b>	Up to 6 ships
<b>TARGET FID:</b>	Mid 2019
<b>FIRST GAS:</b>	Early 2022
<b>CNG IMPORT LOCATION:</b>	Dehaj Port or Gulf of Kutch, India



# OMAN TO INDIA



# FUTURE OUTLOOK FOR CNG

## CNG OPTIMUM 200 SHIP

- Obtain ABS “Full Design” Approval
- Select Preferred Shipyards

## FIRST PROJECT TO COMMERCIALISE CNG

- Commence CNG Optimum ship construction in 2019
- First CNG Optimum ship in service by early 2022

## EXPANDING CNG APPLICATIONS

- Global implementation of CNG as a viable, competitive marine transport solution
- Implement GEV’s key business objective of integrating the upstream asset ownership with the marine CNG transport – turn stranded gas resources into producing gas reserves
- Implement the development of multiple gas sources to supply multiple gas markets – “fleet of CNG ships” for flexibility



**CNG OPTIMUM SHIP** DESIGN ONE | BUILD MANY | OPERATE GLOBALLY



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