Nested Liquefied Natural Gas Tank Concept for Maritime Fuel and Transport

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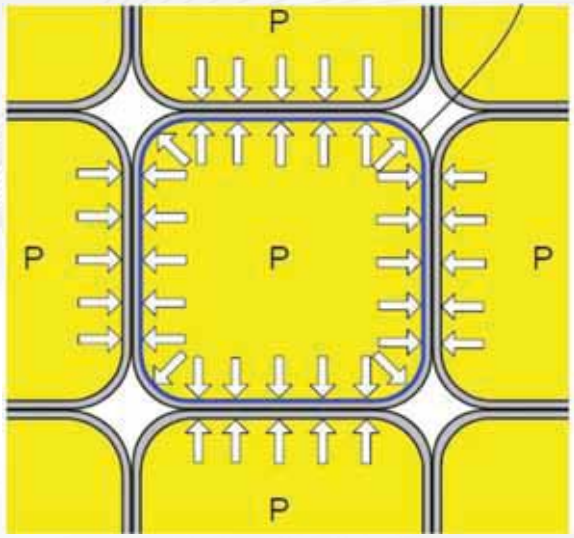
ezNG™ Solutions LLC

OUTLINE –

Getting to know ezNG™ and how the technology enhances the benefits of LNG and CNG, while overcoming their limitations

- The industry & market
- Background
- ezNG™ technology
  - CNG carrier comparison
  - FEA & Heat Gain studies
  - Process comparison studies
- Where does ezNG fit
  - On land
  - Bunkering, Fuel for ships
  - Inland barge case study
- Summary
- Q & A



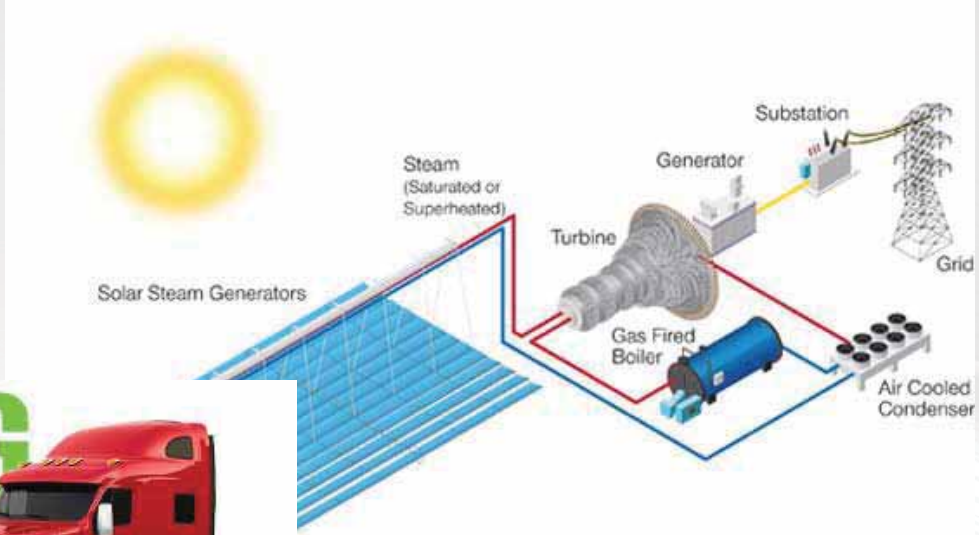
The industry & market

Natural Gas uses and likely targets of ezNG

- Power Generation
- Commercial and residential heating
- Vehicle fuels (fleet operations)

What/who's in the game today

- Gas pipelines
- Gas Storage Facilities (caverns)
- LNG plants, storage & re-gas terminals
- CNG trucking firms
- Small-scale LNG shipping
- CNG shipping

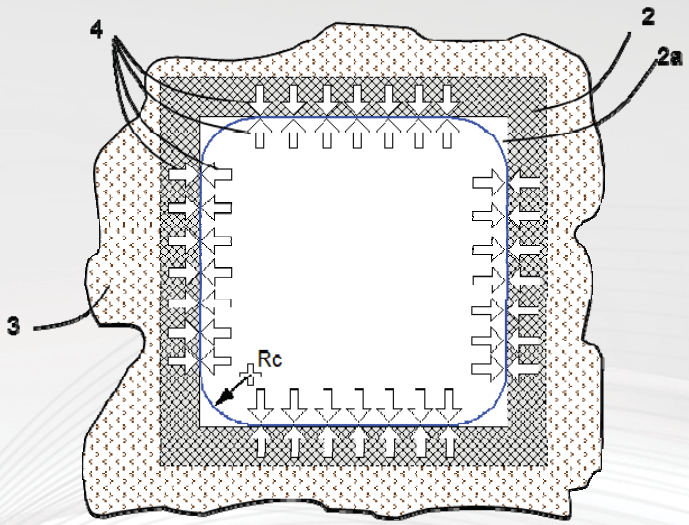


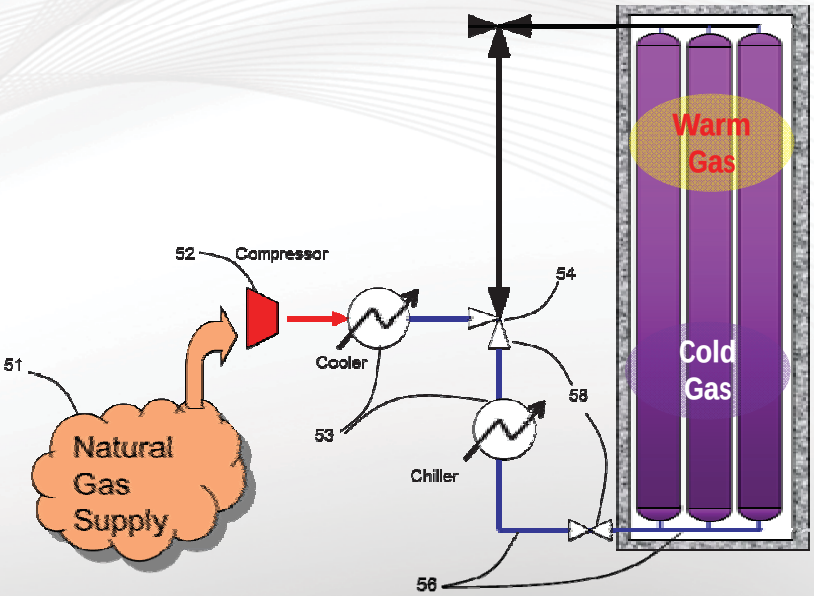
CNG ship for built Indonesian power project 2016

ezNG™ Technology – Origins and Fundamentals

- Secord and Broeker defined optimal conditions for natural gas storage
  - "Sweet Zone" balancing pressure & low temperature
- ExxonMobil evolved Pressurized LNG
  - Wide P-T range, 76bar @ -62C down to 10bar @ -123C

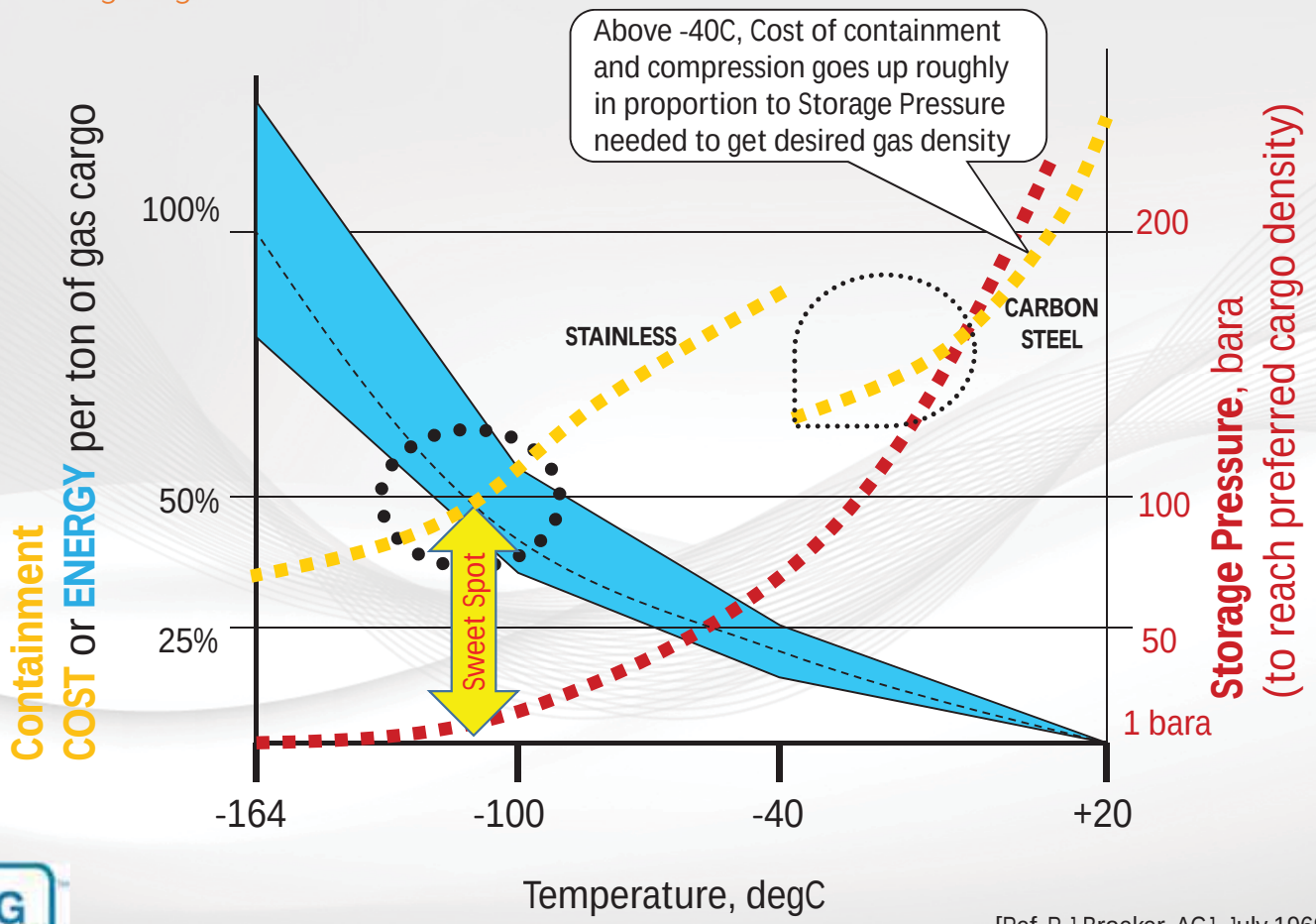
- **ezNG** utilizes Secord storage principles but defined and patented an **optimal "squared" container**
- **ezNG** offers simplified patented **"gas on gas" handling** to load and discharge





Natural Gas Refrigeration & Storage Optima

cost to prepare and refrigerate natural gas for the indicated chilling targets



[Ref. R J Broeker, AGJ, July 1969]

LNG benefits

- Dense form
- Ready markets
- Proven containment and modes of transport

LNG disadvantages

- Energy-intensive refrigeration
- Extensive gas processing required

CNG benefits

- Limited gas processing required
- Ready markets (niche)
- Proven containment and modes of transport

CNG disadvantages

- Low density of stored fluid
- Energy-intensive compression
- Very heavy and/or costly containers

Why XOM invested so much into PLNG

ExxonMobil saw **key advantages** -

- PLNG process much less complex than conventional LNG
- PLNG requires ~50% less energy than LNG
- PLNG liquefaction facility "footprint" is ~1/3 the size of LNG facilities

Why XOM may have missed the boat –

- PLNG team trying to compete directly with extra-large-scale global LNG initiative
- PLNG tanks unsuited for normal LNG

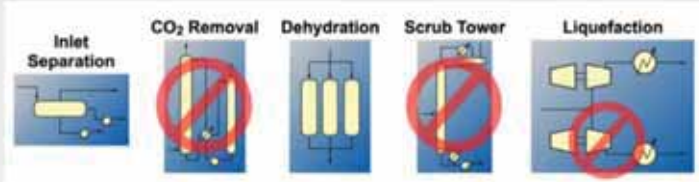
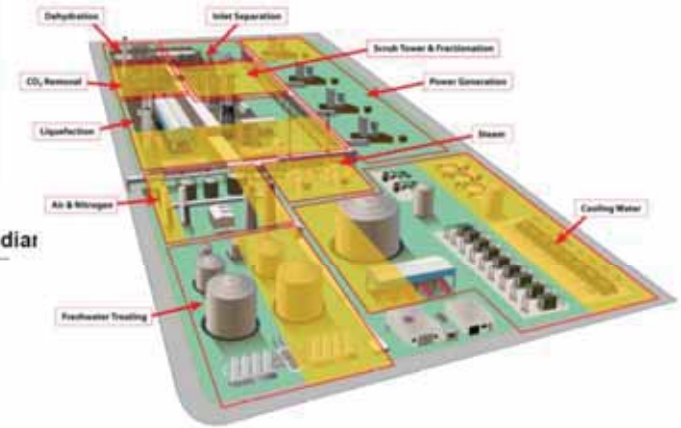


Figure 2.1 Potential reduction and elimination of LNG process steps in a PLNG plant



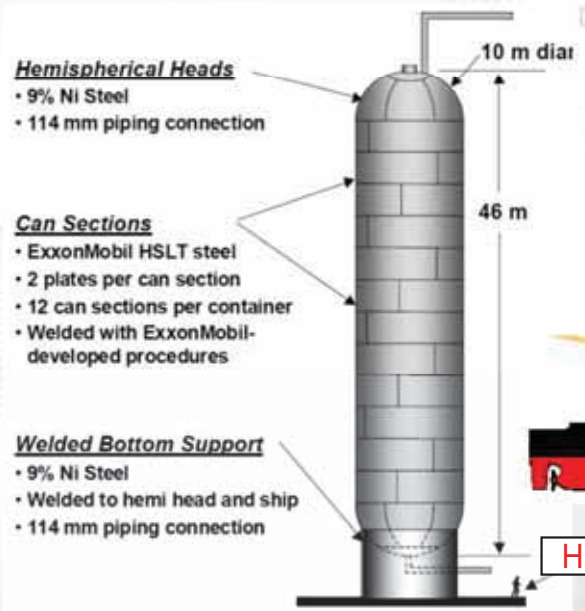
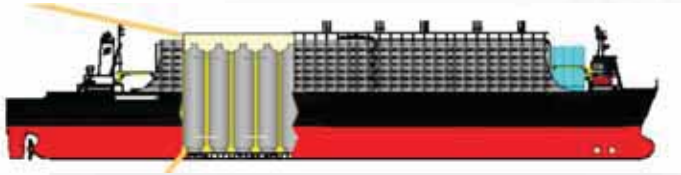


Figure 3.4 Schematic of 10m PLNG container



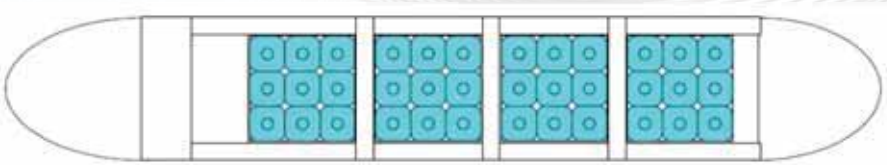
Human

Ref. Bowen et al, GasTech 2005

ezNG Gas Carrier Comparison to World's 1st CNG ship

ezNG Gas Carrier

- **36 tanks at 15bar, -115C**
  - 3m per side w/ 0.800m radius
  - 6.5m tall, weighing 7mt/cell
  - **500mt** containment & direct support
- LOA 100m
- Breadth 17m
- Depth 9m
- Draft 5m
- **50% more cargo** capacity (30mmscf)

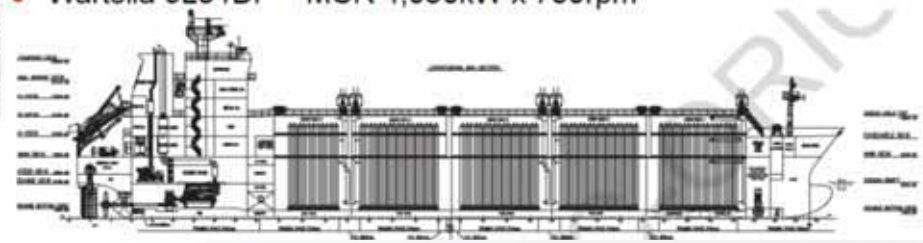


500mt for 36 tanks and 30mmscf

VERSUS➔

Existing CNG Ship

- Designer – CIMC ORIC
- Yard – Jiangsu Hantong
- Indonesian Owner – PT PLN
- Cargo containment system – 832 cylinders 12,040 x 615 x 19mm (250 Bar) – design and fabricate by CIMC ENRIC
- 110.92(Loa)/104.12(Lpp) x 17.60 x 9.00 x 5.20m(dd) – Speed 13.90kN / Complement 18P / Endurance 8 Days
- Wartsila 9L34DF – MCR 4,050kW x 750rpm



3,140mt for 832 cylinders and ~20mmscf

Prismatic tanks use hull volume more efficiently than large diameter LNG bullet tanks

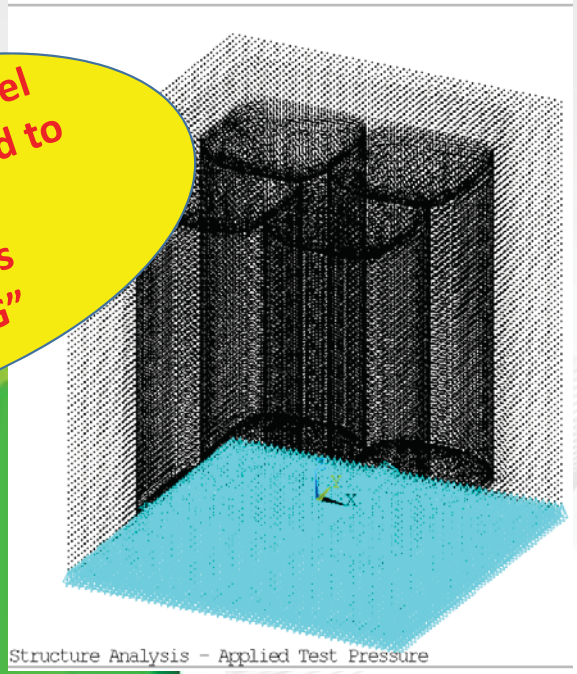
Large diameter LNG bullet tanks usually require low internal pressures (typ. <5bar)

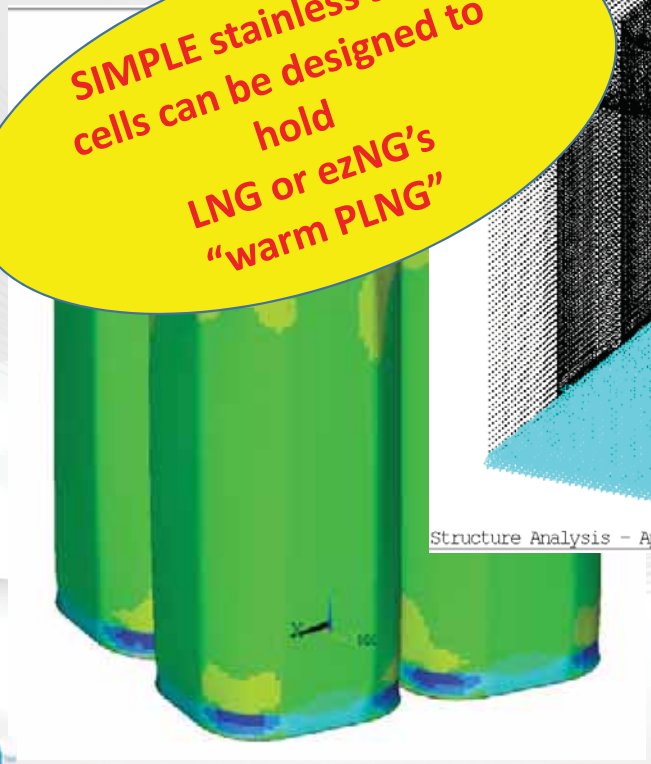
Posco-KAIST, Korea

Prismatic tanks take less space than large diameter LNG bullet tanks

FEA & Heat Gain studies show viability of nested ezNG cell arrays

SIMPLE stainless steel cells can be designed to hold LNG or ezNG's "warm PLNG"





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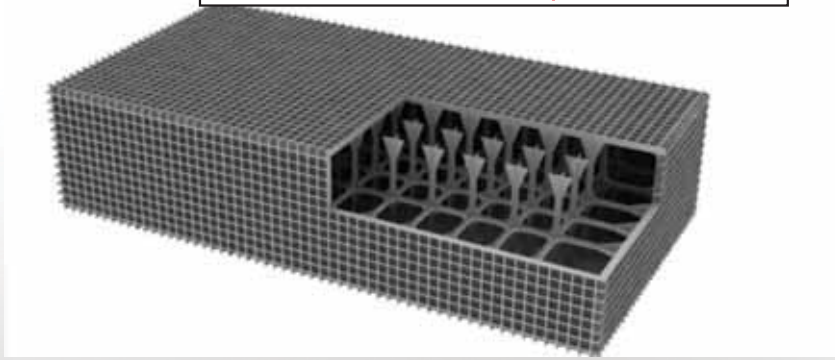
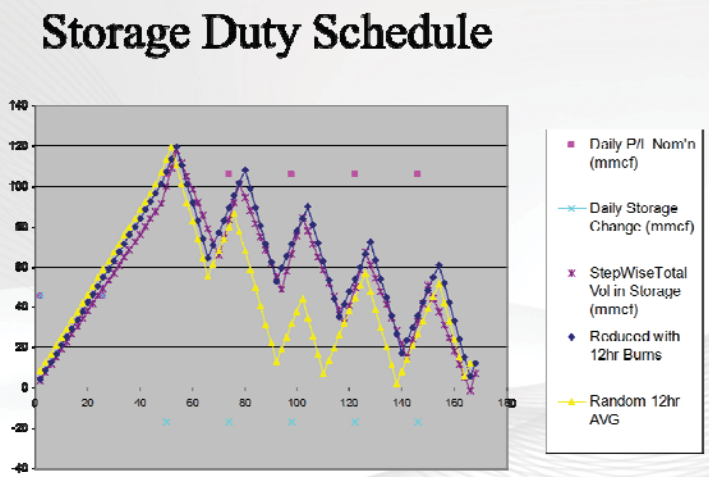
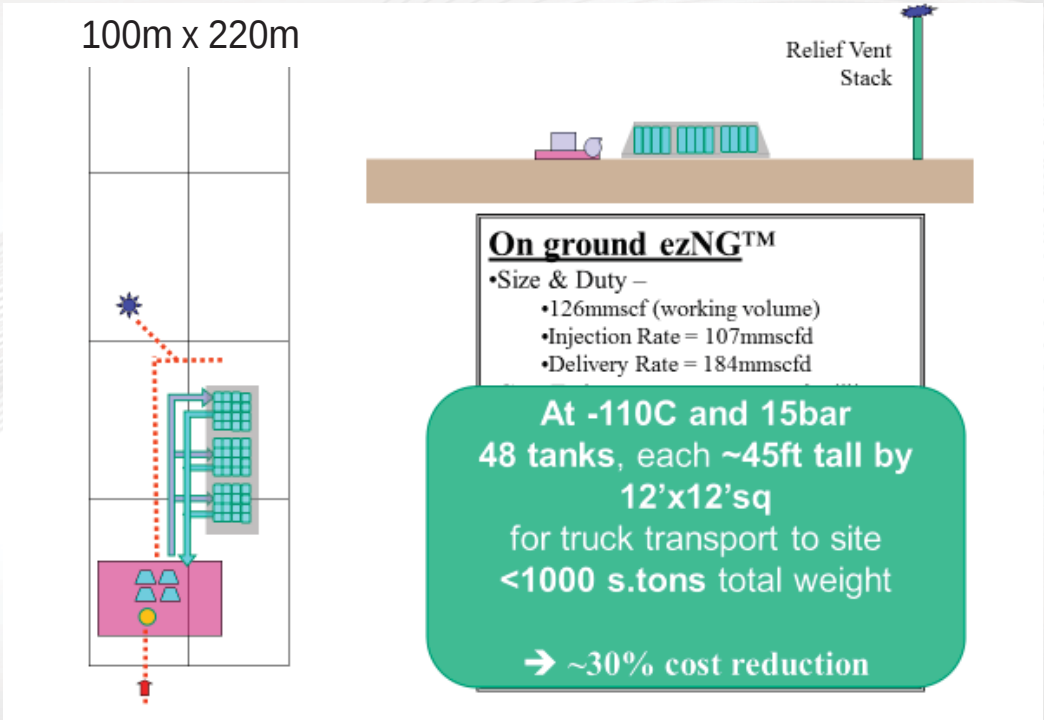
10 bar LNG tank
Posco-KAIST, Korea

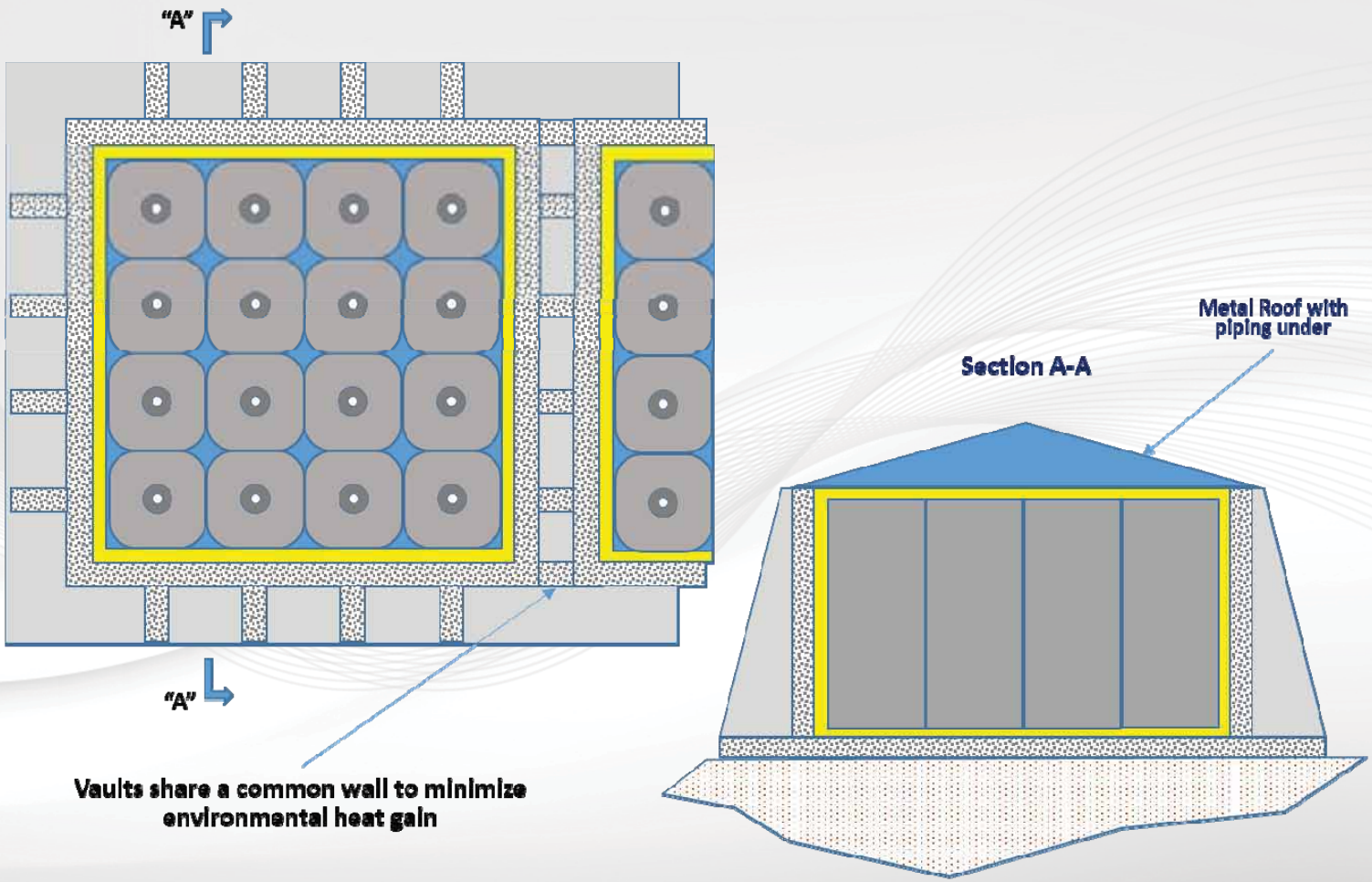


ezNG ground storage can provide gas to power plants





ezNG fluid chambers in concrete "vault"



Process comparison studies - Land Storage

LNG v. CNG v. ezNG

(by River City Engineering)

- **Basis of Study**
  - Pipeline gas supply - 100mmscfd
  - Store at 12, 16, & 20 barg
  - Temperature as needed to liquefy at given Pressure

Results

➔LNG requires 50% more energy than ezNG

➔ezNG does not require N2 or CO2 removal

➔ezNG is ~80% as dense as LNG

Figure 1 – Conventional LNG Facility

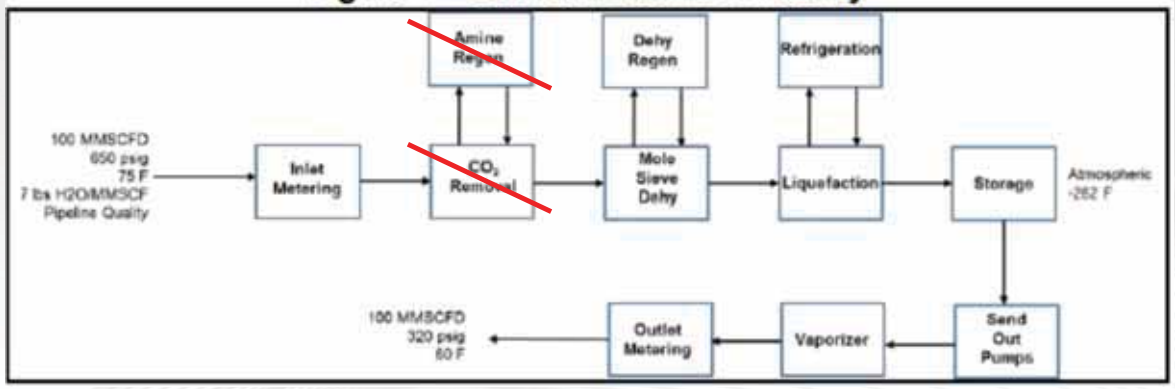
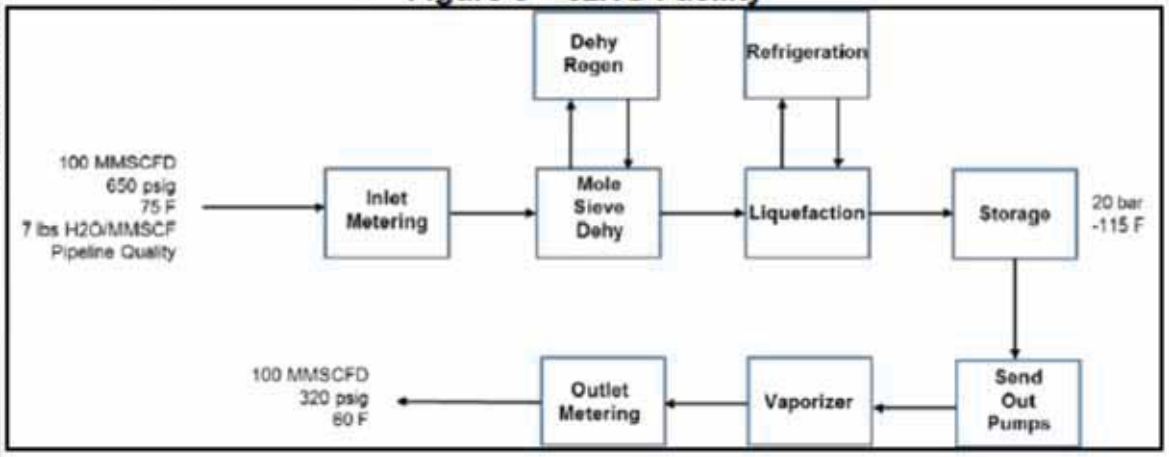


Figure 3 – ezNG Facility



Power Requirement vs Density

LNG v. CNG v. PLNG (ezNG)

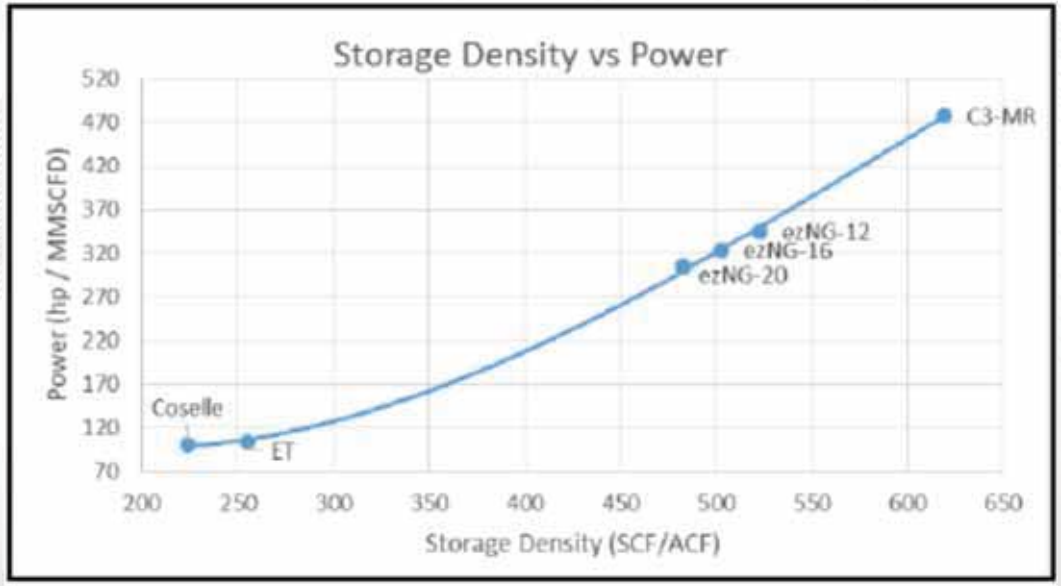
(by River City Engineering)

Basis of Study

- Pipeline gas supply - 100mmscfd
- Store at 12, 16, & 20 barg
- Temperatures
  - 12 barg ➔ -118C
  - 16 barg ➔ -112C
  - 20 barg ➔ -106C

note – XOM patents specify T ≥ -112C, but 2005 paper recommends 17barg at -115C for PLNG

Figure 4 – Effect of Storage Density on Power Requirements



ezNG storage facility can be built into a barge and moored next to a power generation plant

Barge Dimensions

- 300'x 82' x 35'

Each Cargo Hold

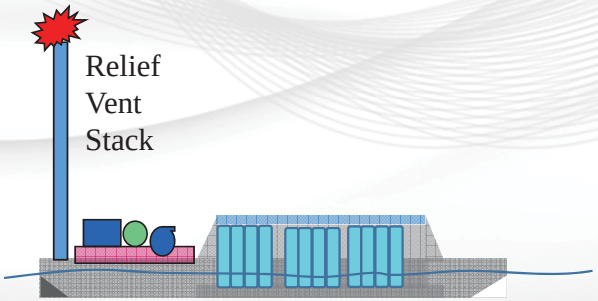
- 53' x 53' by 40' tall
- 16 cells

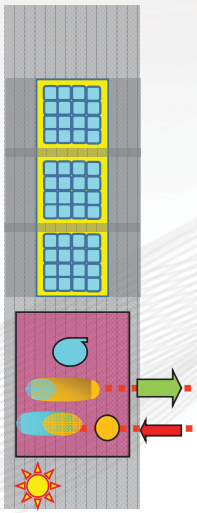
Cargo Block Length

- 160'

Cargo Handling area (double deck)

- 100'x72'





ezNG™ Bunker Barge

- Size & Duty –
  - 100mmscf (working volume)
  - Injection Rate = 50mmscfd
  - Delivery Rate = 100mmscfd
- Storage data
  - –48 cells in 3 holds ("vaults")
  - –Each cell 12ft x 12ft x 36 ft (tall) and weighs 22mt
- Cost Estimate

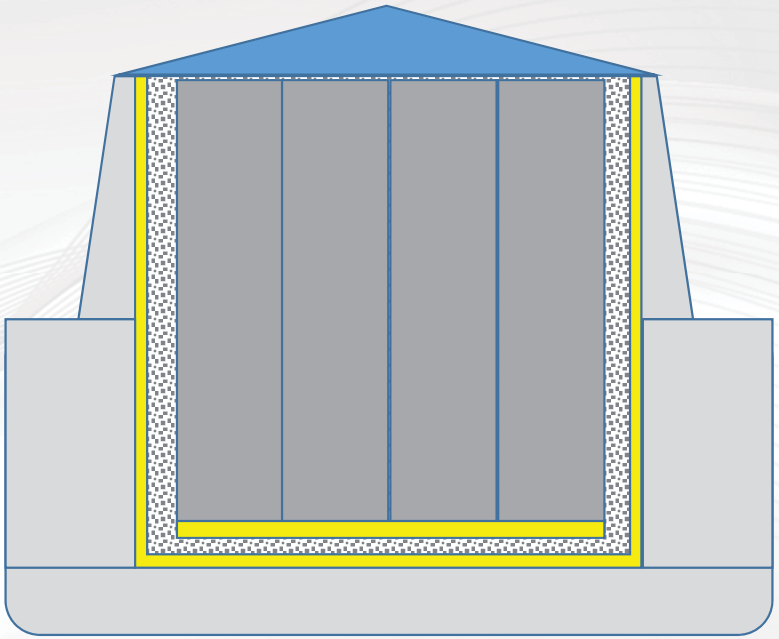
	$million
• Storage	$ 5.0
• Loading	$ 3.0
• Unloading	$ 2.0
• Support Systems	$ 1.0
• Steel Barge	$ 7.0
• **Base Range**	**$18.0**

- 24 months from Sanction to Start-Up

ezNG Pressure Vessel starts with the nested cells

- Stainless steel (SA 240) cells
- Piping
- Liner
- Post-tensioned concrete barrier
- High density insulation
- Hold perimeter steel structure
  - Inner bottom and bulkheads

Alternatively, entire hull/hold can be built of post-tensioned concrete



Questions ?