



# ENABLING LNG

**Dr. Stuart Macdonald**

LNG New Markets – Technology

Shell  
**LNG**

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# NATURAL GAS OPPORTUNITY

# ENERGY OUTLOOK BY 2050



**9 BILLION** people, **75%** living in cities  
**(2 BILLION** more than today)



**2 BILLION** vehicles  
**(800 MILLION** at the moment)



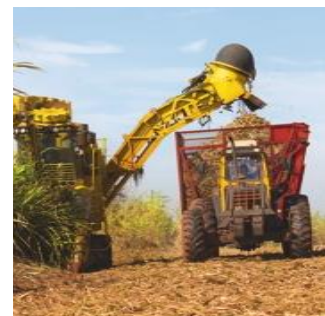
Many **MILLIONS** of people will rise out of energy poverty; with higher living standards energy use rises



Energy demand could **DOUBLE** from its level in 2000... while CO<sub>2</sub> emissions must be **HALF** today's to avoid serious climate change



Twice as efficient, using **HALF** the energy to produce each dollar of wealth



Renewables could supply up to **30%** of the world's energy



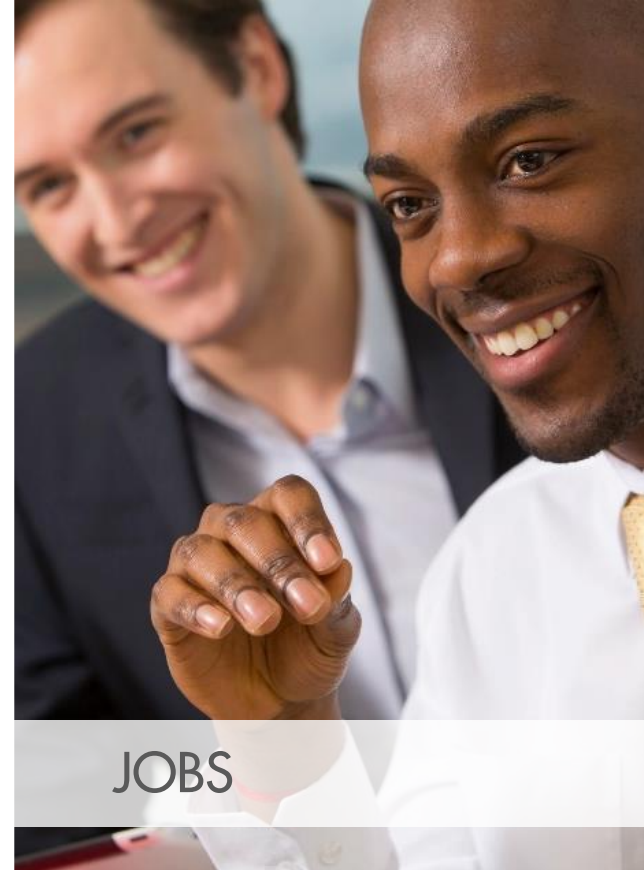
# BENEFITS OF GAS



AIR QUALITY



LOWER CO<sub>2</sub>



JOBS

SMARTER PLANNING



AVAILABLE



# SHELL'S LEADERSHIP ACROSS THE FULL VALUE CHAIN



## EXPLORATION & PRODUCTION

One of the world's largest gas producers



## MARKETING & TRADING

Global positions and capabilities



## LIQUEFACTION

Largest LNG supplier



## TECHNOLOGY

Leader in LNG and gas conversion technologies



## LNG SHIPPING

Largest ship operator



## TRANSPORT FUEL

LNG as a liquid in marine, road, industrial applications



## REGAS, PIPELINES, STORAGE

Strategic positions, active portfolio management



## PARTNERSHIP

Strong OEM partnerships and global customer relationships

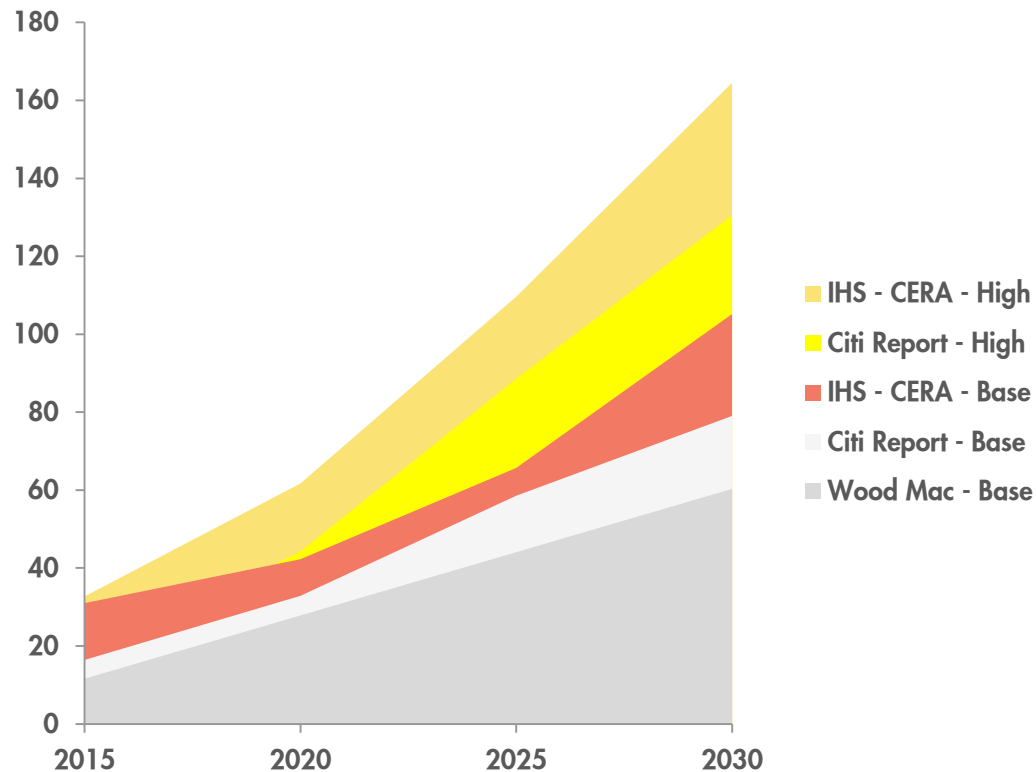
**Shell's leadership across the full Value Chain makes LNG for transport a good fit for shell**



# GAS TO TRANSPORT OPTIONS



# GAS TO TRANSPORT GLOBAL DEMAND OUTLOOK 2015-2020



- Demand likely to be **lower** than external estimates due to:
  - **Lower adoption** by 2015
  - Uncertainty in **date of global sulphur limit application**
- **Potential upside** if new ECAs designated and LNG-HFO/ MDO price differential grows



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# LNG AS A TRANSPORT FUEL



# WHAT IS LNG?

**WORLD LNG PRODUCTION IN 2012 = 236 MTPA**

**COST EFFECTIVE ALTERNATIVE TO PIPELINE FOR DISTANCE > ~3000 KM**



## PRODUCTION

- Natural Gas production and separation from oil and water (when present)



## LIQUEFACTION

- Natural Gas cooled to liquid state at  $-162^{\circ}\text{C}$  at atmospheric pressure
- Volume reduced 600 fold



## SHIPPING

- LNG transported over long distances in purpose built carriers



## REGASIFICATION

- LNG returned to gas state and injected into the transport pipeline network for distribution and sales



## TRANSPORT FUEL

- LNG in marine, road, mining, power, and industrial applications



# LNG AS A TRANSPORT FUEL

## DRIVERS

### SUPPLY

Abundant global gas reserves



### ENVIRONMENT

Lower emissions  
NO<sub>x</sub>, SO<sub>x</sub> and  
particulate matter



### COST

Lower cost  
alternative  
to diesel

## CHALLENGES

### INFRASTRUCTURE

Increasing infrastructure  
development in  
conjunction with  
demand



### VEHICLE TECHNOLOGY

Developing technology



### REGULATORY

Requires framework  
that facilitates  
infrastructure and  
market development

# PARTNERSHIP APPROACH

SHELL HAS ANNOUNCED KEY PARTNERSHIPS  
ACROSS SECTORS



C.R. England



EXAMPLE ACTIVITIES  
WITH PARTNERS

- Regulatory and advocacy collaboration
- Well-to-Wheel/  
Wake, local and  
GHG emissions  
and comparison  
to other fuels
- Gas quality impact  
on engine performance  
and range
- Maintenance and  
Lubricants
- Technology Development
- Technical design,  
HSE, Operations



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# **LNG COMPOSITION - APPLICATIONS**



# LNG COMPOSITION AND QUALITY

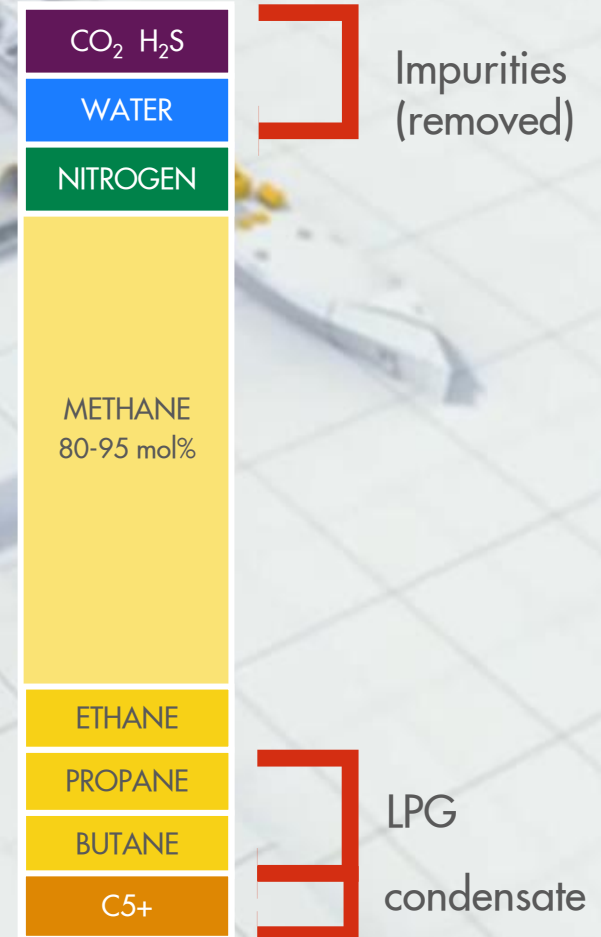
## WHAT DOES LNG CONSIST OF?

- Although LNG consists mainly of methane, the composition can vary based on:
  - Gas source;
  - Contaminants;
  - LPG extraction/injection and
  - Boil-off gas ("aging").

## AND HOW IS ITS VALUE MEASURED?

- Key parameters for combustion:
  - LHV / HHV – energy content;
  - Wobbe Index – gas interchangeability and
  - Methane Number (for LNG in transport).

LNG





# LNG CHARACTERISTICS

## WHAT ARE THE KEY CHARACTERISTICS OF LNG?

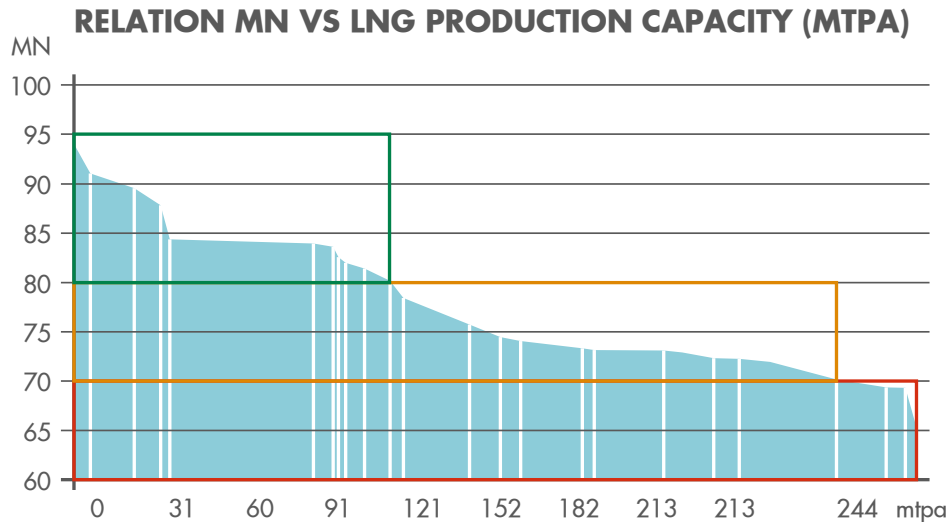
- Comprises mainly methane (C1), colourless, cryogenic liquid
- Atmospheric boiling point of  $-163^{\circ}\text{C}$  to  $-160^{\circ}\text{C}$
- Density of  $458 - 463 \text{ kg/m}^3$  (Depending on composition)
- $1 \text{ m}^3$  of LNG at atmospheric pressure equals  $600 \text{ Sm}^3$  of natural gas



## ...AND WHAT ARE THE CONSEQUENCES OF THESE CHARACTERISTICS?

- High energy density, 2.5 times that of CNG
- $0.9 \text{ kg}$  LNG contains the same energy as  $1.0 \text{ kg}$  diesel (however LNG has a lower volumetric energy content due to lower density)
- LNG can cause cold burns if contacts skin
- LNG vaporises quickly in ambient conditions
  - Normally kept in cryogenic insulated storage
- Even when stored in a cryogenic tank, some LNG will vaporise – ‘boil off’
  - Should be addressed in tank design, boil-off impacts upon gas quality (drop in MN)

# PRODUCTION COMPOSITION – VARIATION IN MN VS PRODUCTION CAPACITY



MN Range (AVL)	Global LNG Production (mtpa)	% of Total LNG produced
0 - 70	26	10 %
70 - 75	118.3	43 %
75 - 80	26.1	9 %
80 - 100	102.8	38 %
0 -100	273.15	100 %

- The greatest overall production levels are seen at lower Methane Numbers
- A wider tolerance to gas quality by engines across different sectors promotes market growth through greater supply availability:
  - An engine with a min MN spec (AVL) of 80 can use just 38% of global supply
  - An engine with a min MN spec (AVL) of 70 can use 90% of global supply
- OEMs have widened tolerance to LNG MN so that their engines can use more sources of supply gas





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## **LNG WELL-TO-WHEELS, EMISSIONS, PERFORMANCE**

# ANALYSIS OF SUPPLY CHAIN

## Well-to-Wheel (WtW)



### Overseas LNG production

- **Extraction**
  - CO<sub>2</sub> in raw gas
  - CCS
  - Climate conditions
- **Liquefaction**
  - Plant efficiency



### Shipment to The Netherlands

- Distance from LNG source to distribution centre
- Ship GHG emissions
- Boil off



### On road distribution by trucks

- Distance from LNG distribution centre to refuelling station
- Truck GHG emissions
- Boil off



### Refuelling at retail stations

- Time kept in storage tanks
- Boil off



### Use in HD trucks (exhaust GHGs)

- **Engine efficiency**
- Methane Slip
- Drive Cycle



## Well-to-Tank (WtT)

## Tank-to-Wheel (TtW)



# LNG AS A ROAD FUEL PROVIDES ENVIRONMENTAL BENEFITS

**UP TO 23% GREENHOUSE GAS SAVINGS**

## ENVIRONMENTAL BENEFITS

Shell LNG fuelled engines can help reduce well-to-wheel GHG emissions, helping to improve CO<sub>2</sub>\* footprint in heavy duty trucks, compared to regular diesel and B7 used in Euro 5/6 engines\*\*

\* CO<sub>2</sub> indicates CO<sub>2</sub> equivalents, which includes in the calculation the contribution of the following greenhouse gases: CO<sub>2</sub>, methane and N<sub>2</sub>O.

\*\* Using Shell LNG can help reduce well-to-wheel GHG emissions in heavy duty Euro 5/6 engines compared to regular diesel and B7. Well to wheel calculations are based on a set of assumptions relating to the local market, the use of LNG lean burn (SI) versus CI engines and choice between LNG, regular diesel & B7 fuels



# LNG CENTRE OF EXCELLENCE



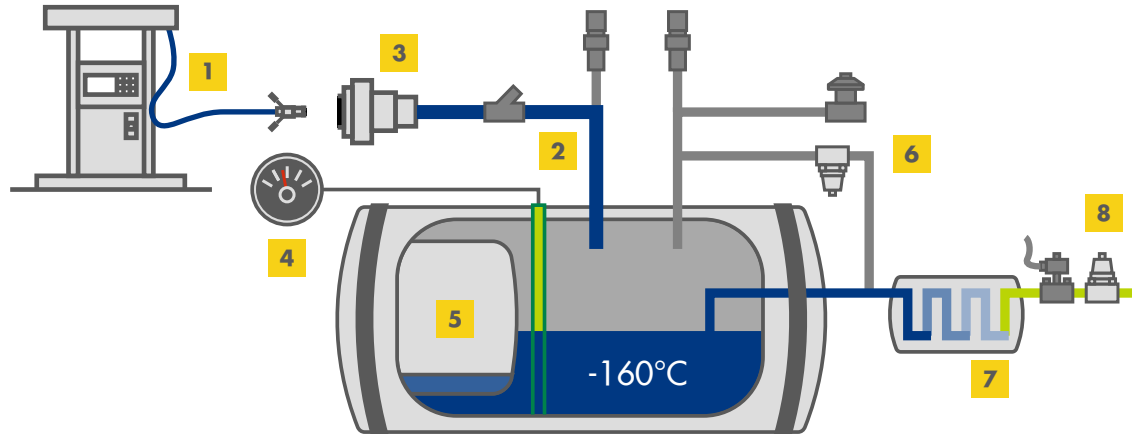


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## **HSSE AND OPERATIONAL STANDARDS**



# LNG TANKS



**1 Liquid dispenser unit:** Fuel stored as cryogenic liquid at fuelling depot

**2 Top fill:** Spray of liquid allows faster filling

**3 Relief valve (PRD):** allows escape of boil-off gas to prevent pressure build up

**4 Fuel gauge:** can be mounted in cab or by fuel receptacle

**5 Vapour space:** small hole near top of tank absorbs excess pressure, extends tank hold time

**9 Fuel:** enters engine as a gas (pressure depends on engine type)

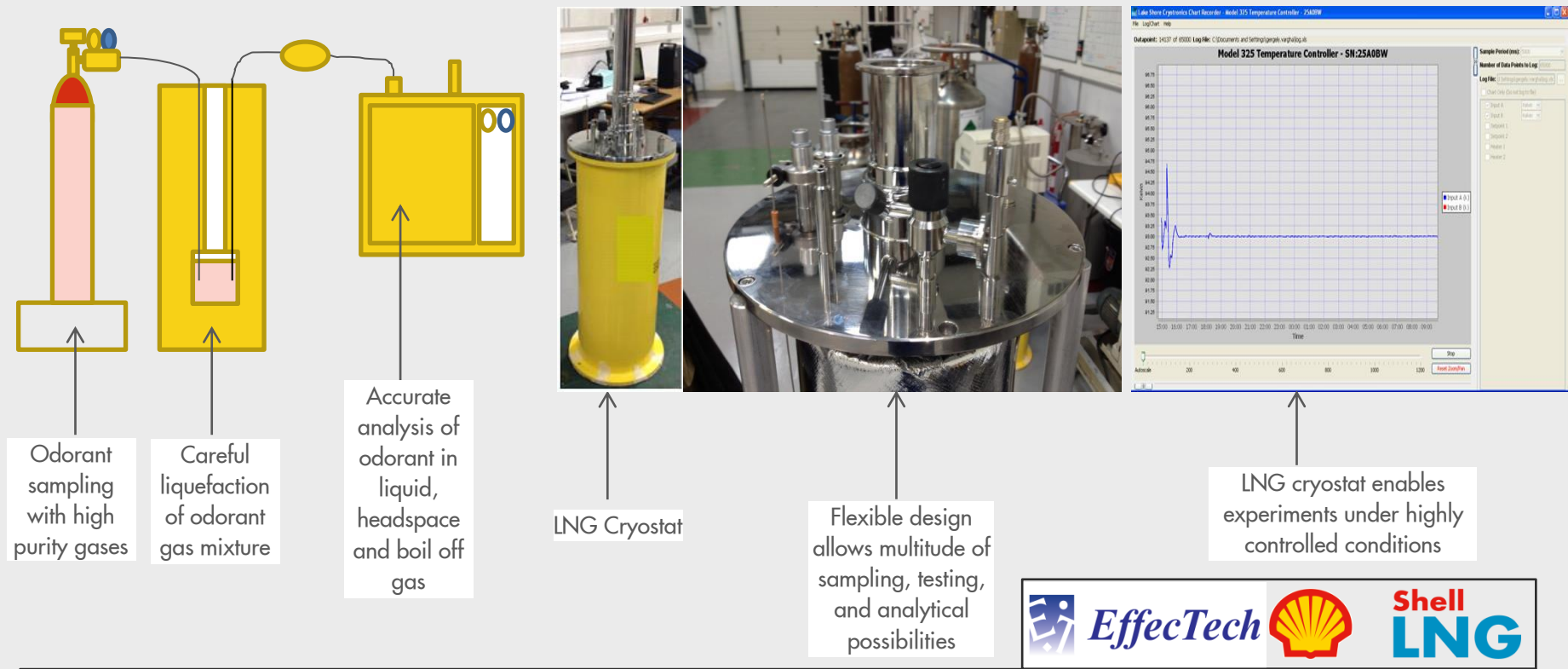
**8 Vaporiser:** heated with engine coolant to evaporate fuel

**7 Economizer regulator:** determines and controls tank operating pressure to minimise boil off

**6 Tank:** Insulated by double walled stainless steel tank, vacuum space between layers to act as thermal barrier

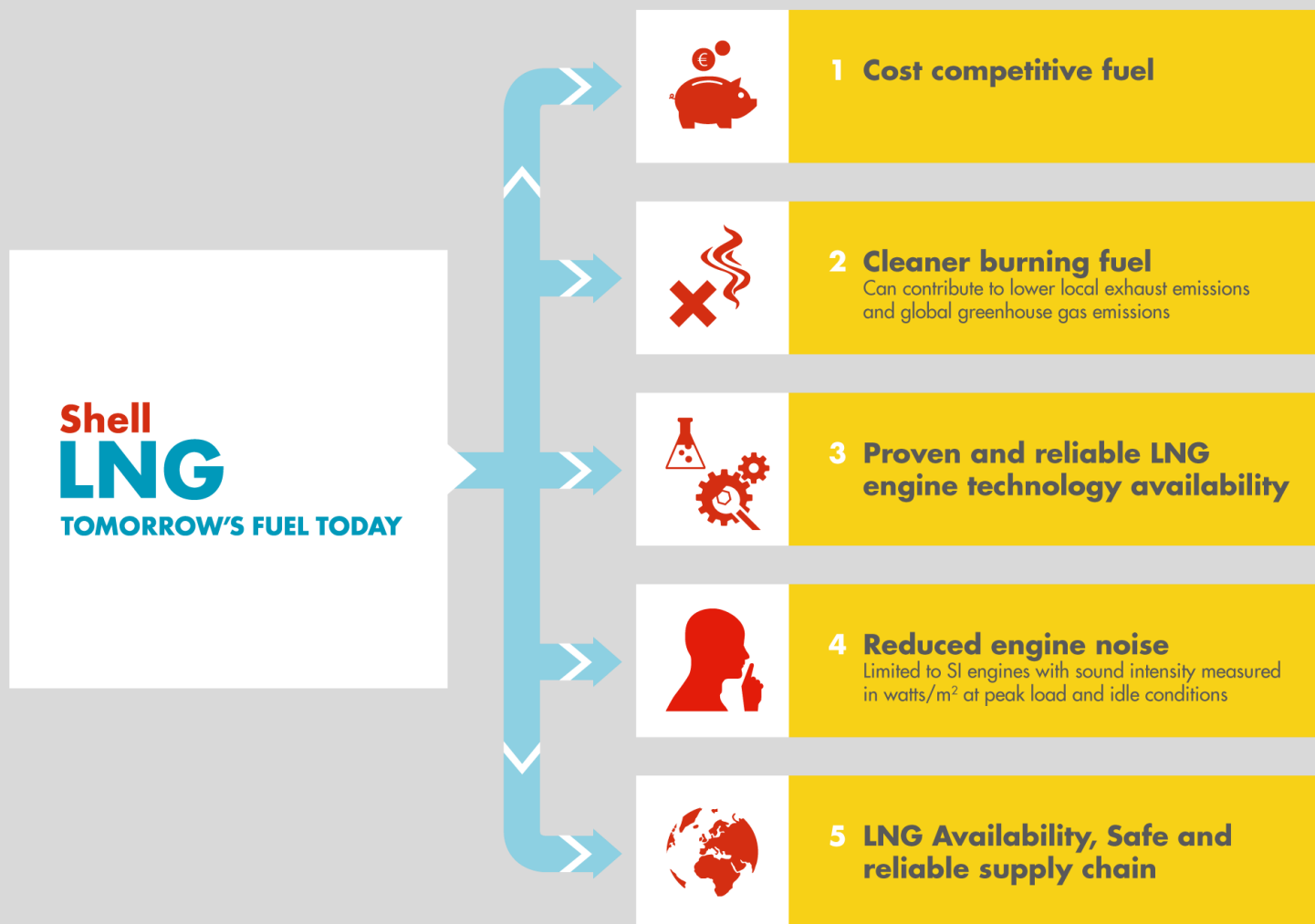


# LNG CRYOSTAT DEVELOPMENT ENABLES RAPID ODORIZER TESTS



- A small-scale LNG cryostat has been developed which enables high purity gas mixtures to be liquefied safely, efficiently, and under very precise conditions.
- The cryostat allows for many time and cost-efficient tests on LNG, which can be carefully analyzed with sophisticated analytical techniques.
- The experimental set-up has allowed for detailed and successful tests on LNG odorizers, understanding behavior in both liquid and gaseous phases under different conditions.
- This facility will also support future technology development e.g. LNG sensors

# LNG CAN OFFER A COMPELLING VALUE PROPOSITION...





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# SHELL INITIATIVES



# CONCRETE STEPS TAKEN TO DATE

**2012**



Gasnor, 100% Shell subsidiary.

**2013**



Shell time charters Greenstream World's 1<sup>st</sup> 100% LNG propelled barge.

**2014**



US TA site opened in May.



Shell orders 6,500cu.m bunker vessel to deliver LNG to marine customers in North West Europe. The vessel will load at the new break bulk facilities at the GATE terminal.

**2015**

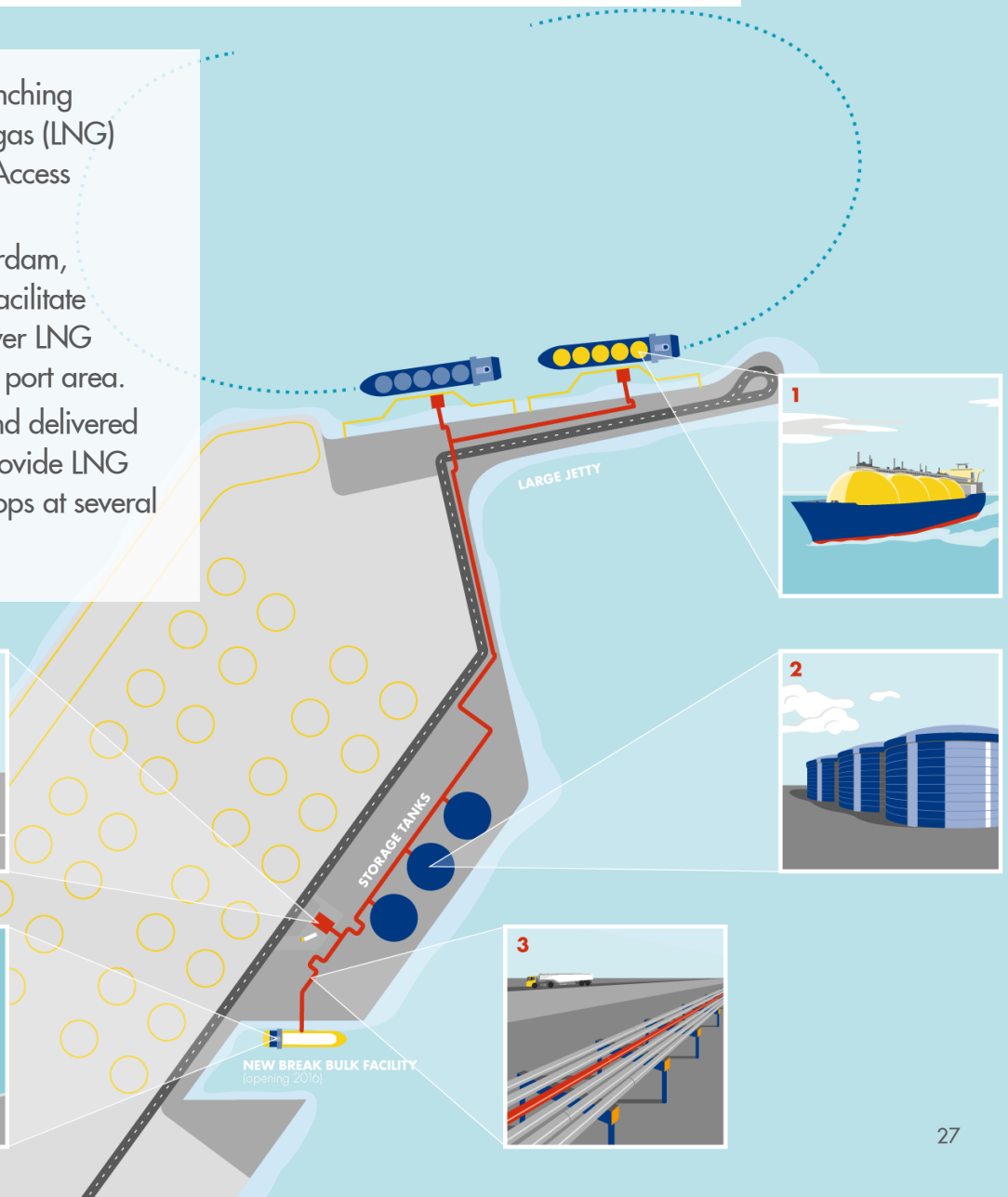
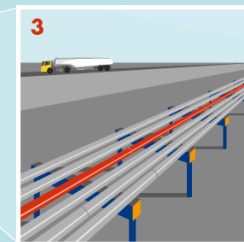
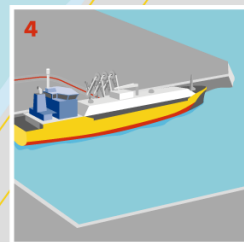
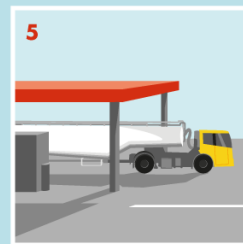


Shell launches plans for initial network of up to seven LNG truck refuelling stations in the Netherlands. First site under construction in Port of Rotterdam.



# GATE: LONG-TERM LNG FOR TRANSPORT

- In July 2014, Shell was announced as the launching customer of new, dedicated liquefied natural gas (LNG) for transport infrastructure at the GATE (Gas Access To Europe) terminal.
- To serve marine customers in the port of Rotterdam, Shell intends to charter a LNG bunker vessel facilitate ship to ship transfer operations, and also deliver LNG to secondary distribution terminals outside the port area.
- In addition, LNG will be loaded onto trucks and delivered to road customers. Shell is also planning to provide LNG to an initial network of LNG refuelling truck stops at several locations in the Netherlands.



# CONSTRUCTION OF INNOVATIVE NEW LNG BUNKER VESSEL

Potential customers include container ships, coastal vessels, and ferries.

**FEATURES:** Cutting-edge shipping design and technology with a special loading arm for ship-to-ship transfers and sub-cooling unit to keep LNG at sub atmospheric pressure.

**CAPACITY:**  
6,500 cubic metres

**LENGTH:** ~120 metres



The new vessel will be built by STX Offshore & Shipbuilding. It will be based at the port of Rotterdam in the Netherlands, and will load from the new LNG break bulk terminal and jetty to be constructed by the Gas Access to Europe (Gate) terminal. It will also be sea-going and, therefore, able to bunker customers at other locations.



## CONCLUSIONS AND KEY TAKEAWAYS

- ❑ LNG as a transportation fuel offers a compelling proposition for a range of sectors including on-road, marine, and mining.
- ❑ Shell is leveraging its significant experience across the value chain to bring the fuel to the market safely, and strengthening the value drivers such as cost and environmental benefits.
- ❑ Shell have adopted a partnership approach which sees us working with key partners globally, and across different sectors, to work together to understand and develop key enablers.
- ❑ Significant, tangible developments have already been seen which help further enhance the case for LNG as transport fuel.
- ❑ We are focused on combining internal and external technical talent and capabilities to keep developing new technology and accelerating its path to market.

