ENABLING LNG

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LNG New Markets – Technology

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Reserves: Our use of the term "reserves" in this presentation means SEC proved oil and gas reserves. **Resources:** Our use of the term "resources" in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions. **Organic:** Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact. **Resources plays:** our use of the term 'resources plays' refers to tight, shale and coal bed methane oil and gas acreage.

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1 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

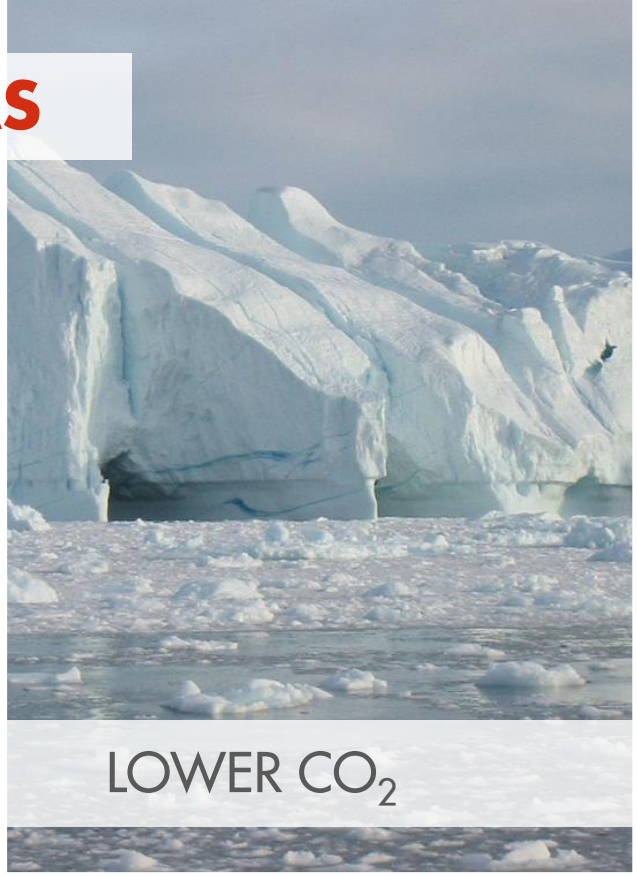
Energy demand could **DOUBLE** from its level in 2000… while CO_2 emissions must be **HALF** today's to avoid serious climate change

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

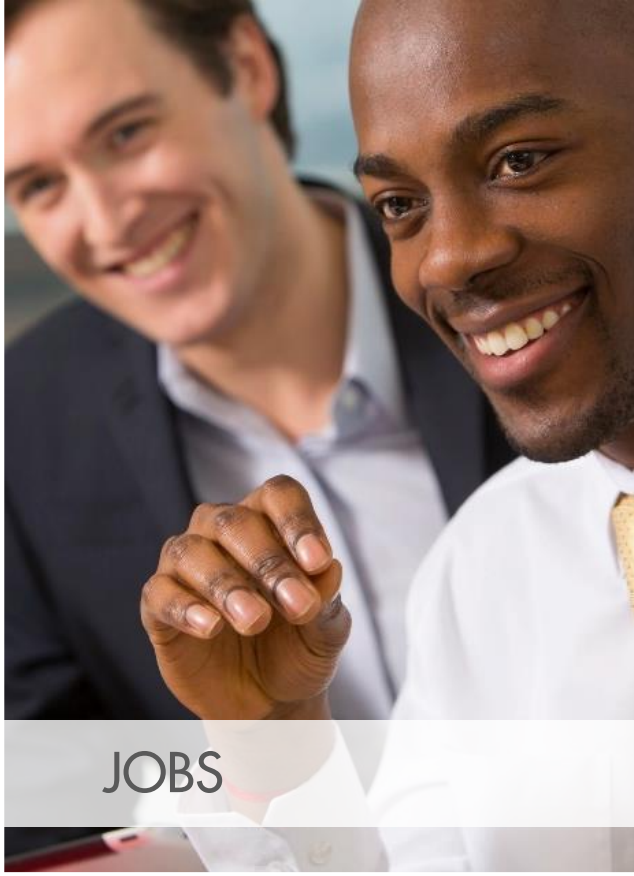
Renewables could supply up to **30%** of the world's energy

BENEFITS OF GAS

AIR QUALITY



LOWER CO_2



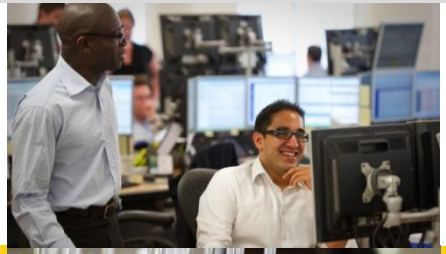
JOBS

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

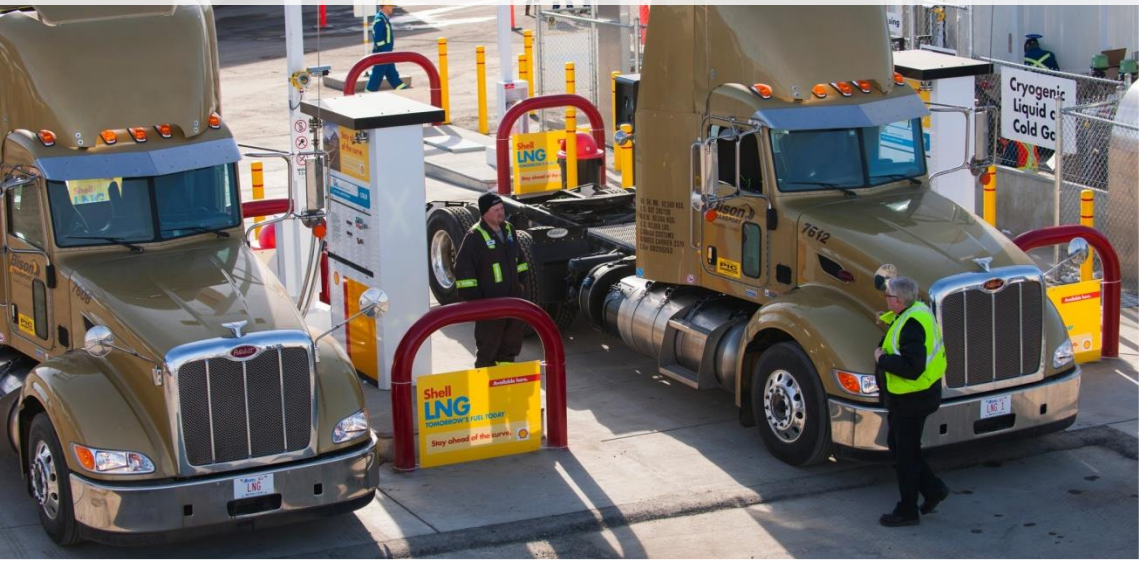
TRANSPORT FUEL
LNG as a liquid in marine, road, industrial applications

REGAS, PIPELINES, STORAGE
Strategic positions, active portfolio management

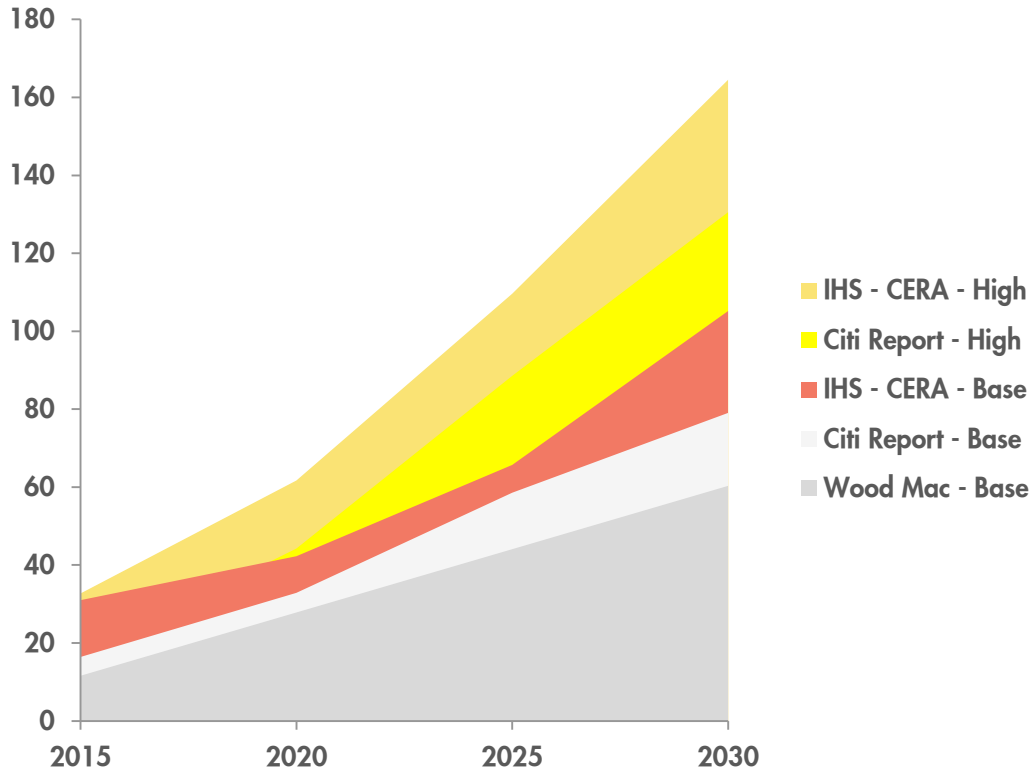
PARTNERSHIP
Strong OEM partnerships and global customer relationships

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

2 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°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

Source: Gas Matters

LNG AS A TRANSPORT FUEL

DRIVERS

SUPPLY

Abundant global gas reserves

ENVIRONMENT

Lower emissions NOx, SOx 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

Bison Transport

Westport Innovations Inc.

TA TravelCenters of America

GE Transportation

Volvo

Wärtsilä

C.R. England

Suez Environnement / SITA

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

3 LNG COMPOSITION - APPLICATIONS

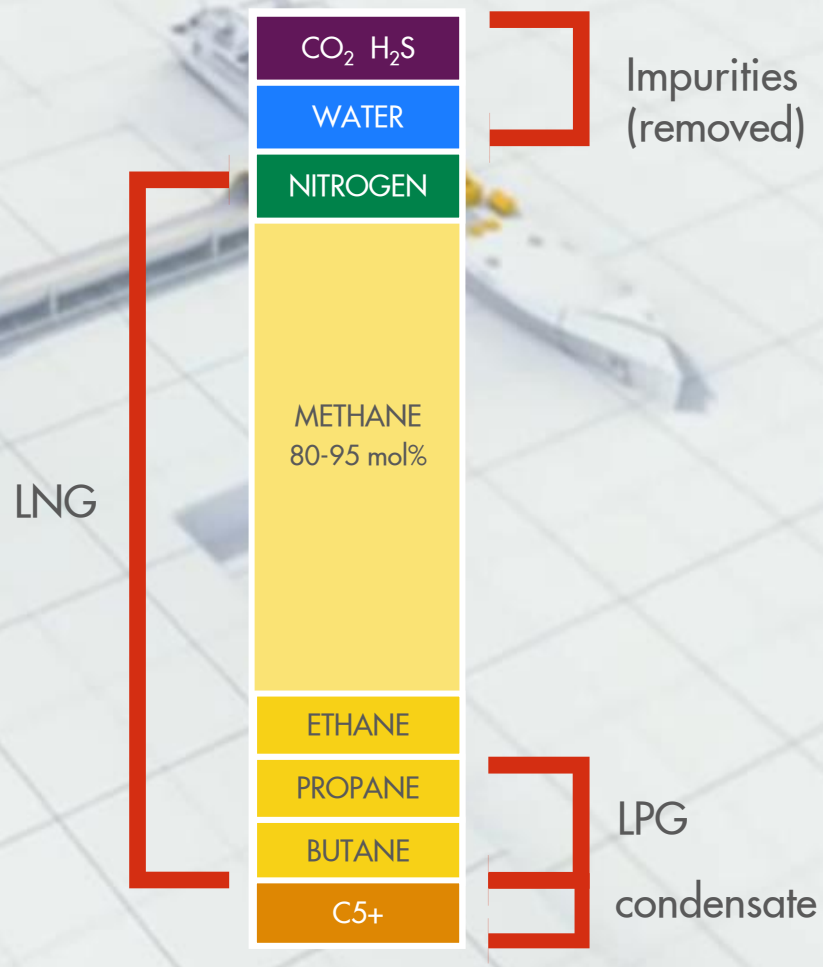
LNG COMPOSITION AND QUALITY

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 CHARACTERISTICS

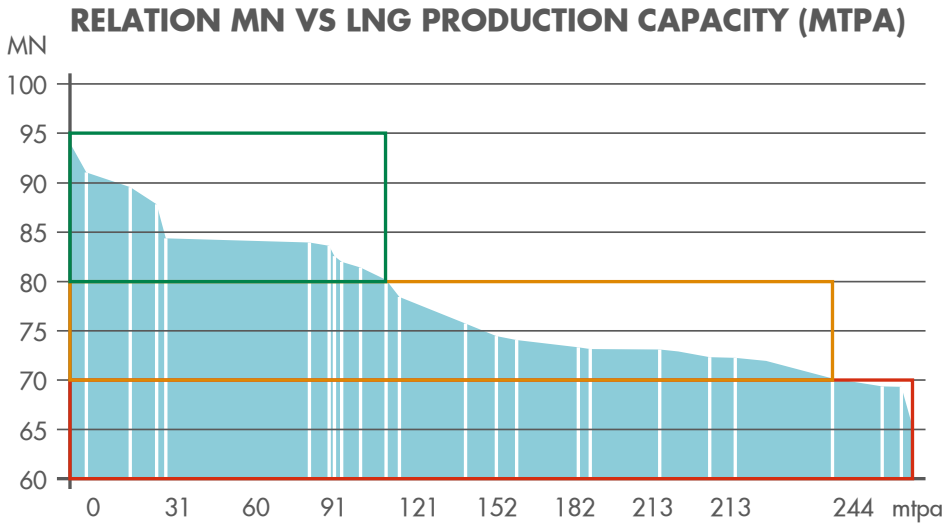
WHAT ARE THE KEY CHARACTERISTICS OF LNG?

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

…AND WHAT ARE THE CONSEQUENCES OF THESE CHARACTERISTICS?

- High energy density, 2.5 times that of CNG
- 0.9kg LNG contains the same energy as 1.0kg 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

3 LNG WELL-TO-WHEELS, EMISSIONS, PERFORMANCE

ANALYSIS OF SUPPLY CHAIN

Well-to-Wheel (WtW)

Overseas LNG production

- **Extraction**
  - CO_2 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

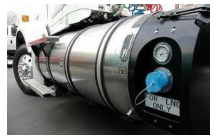
- **Distance from LNG distribution centre to refuelling station**
- Truck GHG emissions
- Boil off

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_2* footprint in heavy duty trucks, compared to regular diesel and B7 used in Euro 5/6 engines**

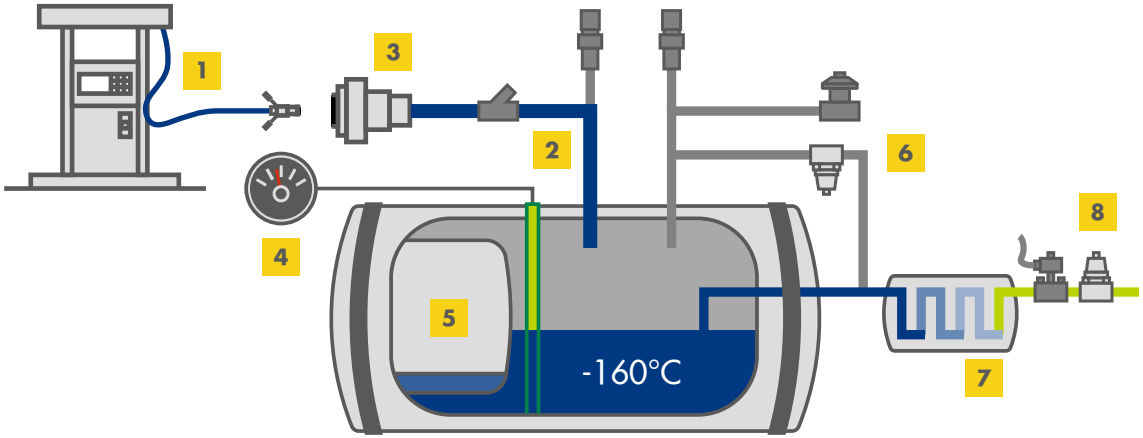
* CO_2 indicates CO_2 equivalents, which includes in the calculation the contribution of the following greenhouse gases: CO_2, methane and N20.

** 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

3 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

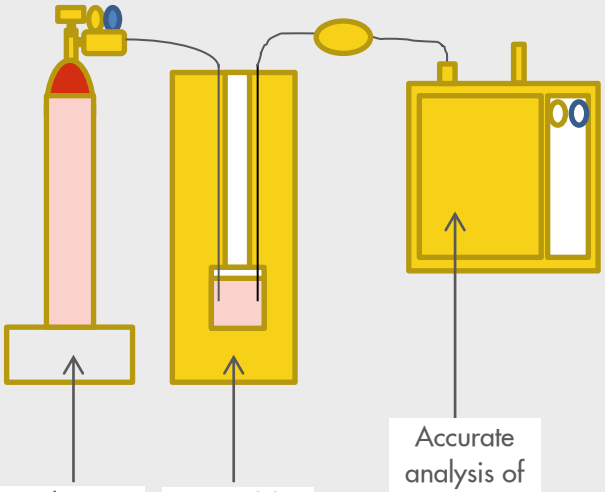
6 Tank: Insulated by double walled stainless steel tank, vacuum space between layers to act as thermal barrier

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

8 Vaporiser: heated with engine coolant to evaporate fuel

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

LNG CRYOSTAT DEVELOPMENT ENABLES RAPID ODORIZER TESTS



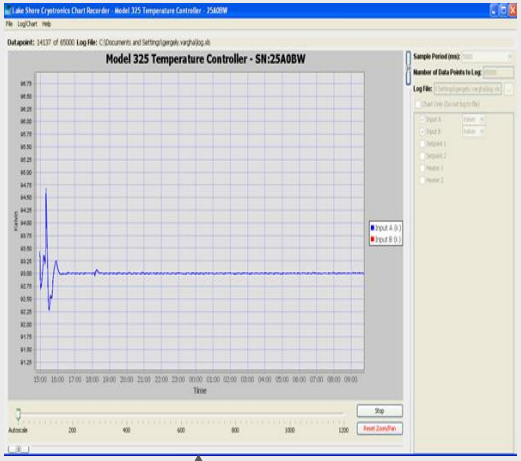
Odorant sampling with high purity gases

Careful liquefaction of odorant gas mixture

Accurate analysis of odorant in liquid, headspace and boil off gas

LNG Cryostat

Flexible design allows multitude of sampling, testing, and analytical possibilities



LNG cryostat enables experiments under highly controlled conditions

EffecTech Shell LNG

- 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...

Shell
LNG
TOMORROW'S FUEL TODAY

5 SHELL INITIATIVES

CONCRETE STEPS TAKEN TO DATE

2012

Gasnor, 100% Shell subsidiary.

2013

Shell time charters Greenstream World's 1st 100% LNG propelled barge.

2014

US TA site opened in May.

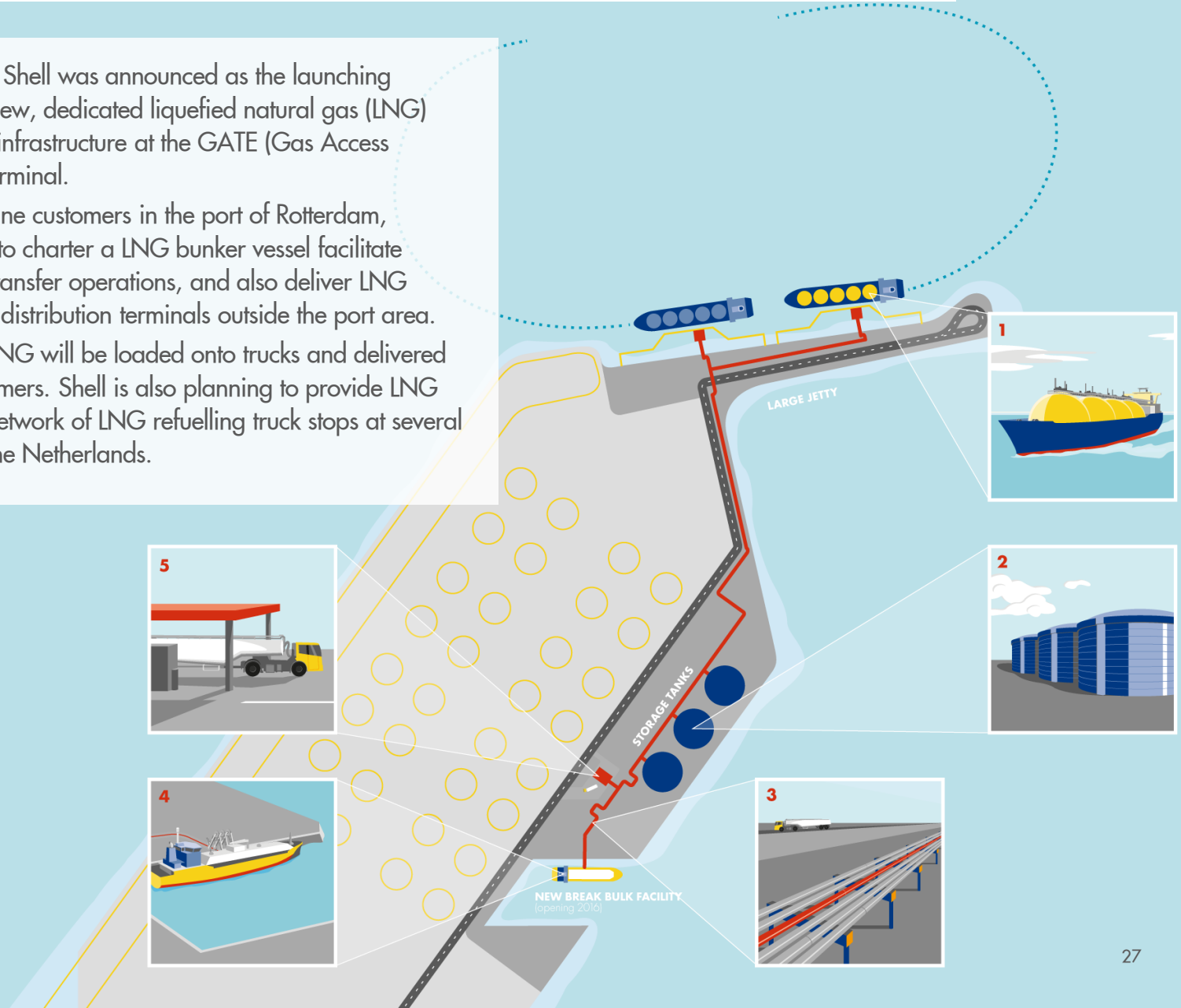
Shell orders 6,500cu.m bunker vessel to deliver LNG to marine customers in North West Europe. The vessel will load at the new break bulk facilities at the GATE terminal.

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

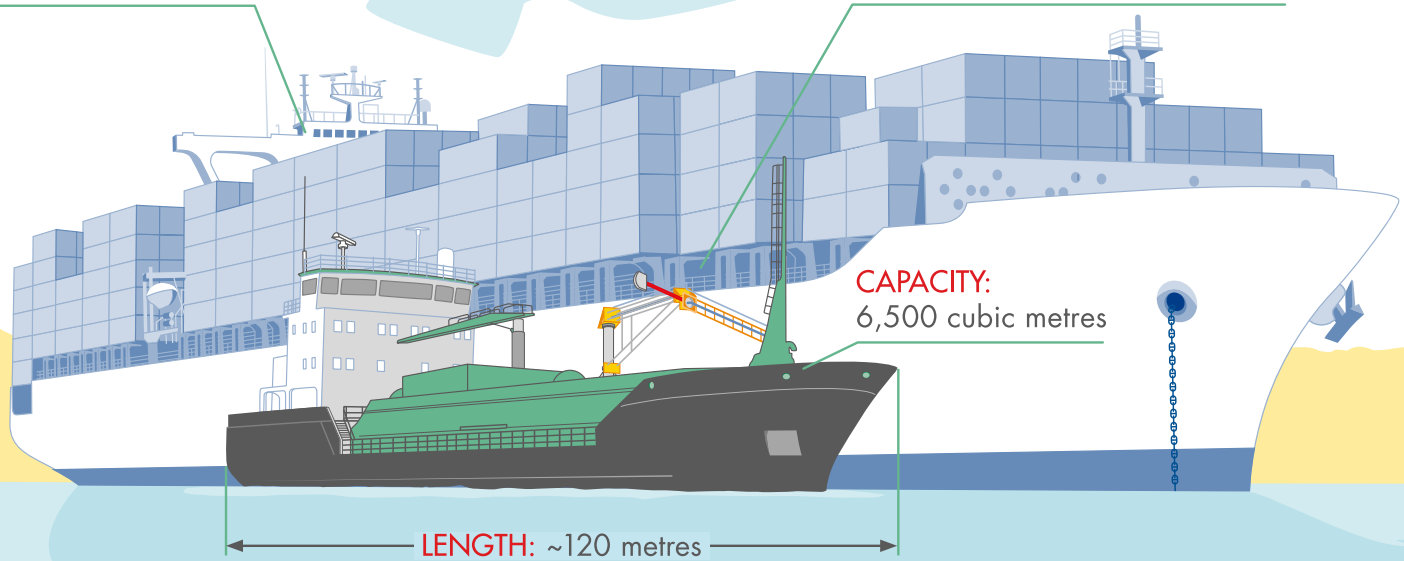
- In July 2014, Shell was announced as the launching customer of new, dedicated liquefied natural gas (LNG) for transport infrastructure at the GATE (Gas Access To Europe) terminal.
- To serve marine customers in the port of Rotterdam, Shell intends to charter a LNG bunker vessel facilitate ship to ship 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.



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.