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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NATURAL GAS OPPORTUNITY
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 CO₂ 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 CO₂

JOBS

SMARTER PLANNING

AVAILABLE
Shell’s leadership across the full Value Chain makes LNG for transport a good fit for Shell.
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
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.

#### 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
LNG COMPOSITION - APPLICATIONS
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).
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/m³ (Depending on composition)
- 1 m³ of LNG at atmospheric pressure equals 600 Sm³ 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)
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)
- Extraction
- CO₂ 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

ENVIRONMENTAL BENEFITS

Shell LNG fuelled engines can help reduce well-to-wheel GHG emissions, helping to improve CO₂ footprint in heavy duty trucks, compared to regular diesel and B7 used in Euro 5/6 engines**

* CO₂ indicates CO₂ equivalents, which includes in the calculation the contribution of the following greenhouse gases: CO₂, 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.
HSSE AND OPERATIONAL STANDARDS
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)
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...

1. Cost competitive fuel
2. Cleaner burning fuel
   Can contribute to lower local exhaust emissions and global greenhouse gas emissions
3. Proven and reliable LNG engine technology availability
4. Reduced engine noise
   Limited to SI engines with sound intensity measured in watts/m² at peak load and idle conditions
5. LNG Availability, Safe and reliable supply chain

Shell LNG
TOMORROW'S FUEL TODAY
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.
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.
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.