Energy 2020: Truck, Trains and Automobiles

Start your natural gas engine

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A combination of factors could push oil demand growth lower.

Source: IEA, Citi Research
Why gas is a threat?

Eroding the 40-m b/d global motor fuel market – natural gas can substitute for oil in the transportation sector, particularly heavy-duty vehicles, as shown below, but also for rail and marine transport.

Crude and US natural gas prices have diverged

Projected gas demand in transportation

Estimated NGVs as % new HDV sales in the US

Diesel’s share of new Class 8 trucks sales in US, 1950-2010

Source: MacKay, Wards Auto, Westport, Ayres-Ayres-Warr, Citi Research
Oil displacement in oil-gas switching could range from 2.6 to 4.5-mb/d by 2030

### Projected Gas Demand for Transportation (Bcf/d)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tr>
<td><strong>On-road vehicles</strong></td>
<td></td>
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<tr>
<td>U.S.</td>
<td></td>
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<tr>
<td>Base</td>
<td>0.1</td>
<td>0.2</td>
<td>1.8</td>
<td>4.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Complete turnover</td>
<td>0.1</td>
<td>0.3</td>
<td>2.2</td>
<td>5.9</td>
<td>9.8</td>
</tr>
<tr>
<td>Slow adoption</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>1.1</td>
<td>2.5</td>
</tr>
<tr>
<td>EU</td>
<td>0.2</td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Asia</td>
<td>2.9</td>
<td>3.8</td>
<td>6.1</td>
<td>8.1</td>
<td>10.1</td>
</tr>
<tr>
<td>South America</td>
<td>1.1</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>International Marine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lloyds Register (High)</td>
<td>0</td>
<td>0.1</td>
<td>0.3</td>
<td>3.2</td>
<td>5.1</td>
</tr>
<tr>
<td>Lloyds Register (Base)</td>
<td>0</td>
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<td>0.1</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Lloyds Register (Low)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>TOTAL*</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
<td>4.4</td>
<td>7.1</td>
</tr>
<tr>
<td><strong>Other U.S. (rail + marine)</strong></td>
<td>0</td>
<td>0.1</td>
<td>0.4</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Total Demand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Base + Lloyds Register (Base)</td>
<td>4.3</td>
<td>5.5</td>
<td>10.2</td>
<td>16.7</td>
<td>22.1</td>
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<tr>
<td>Complete turnover + TOTAL*</td>
<td>4.4</td>
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<td>11.9</td>
<td>21.4</td>
<td>30.6</td>
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<tr>
<td>Slow adoption + Lloyds Register (Low)</td>
<td>4.3</td>
<td>5.4</td>
<td>8.6</td>
<td>12.7</td>
<td>16.9</td>
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</table>

### Projected Oil Demand Displaced (mb/d)

<table>
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<tr>
<th></th>
<th>2013</th>
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<th>2020</th>
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<td></td>
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</tr>
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<td>0.3</td>
<td>0.8</td>
<td>1.2</td>
</tr>
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<td>0.1</td>
<td>0.4</td>
<td>1</td>
<td>1.7</td>
</tr>
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<td>0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>EU</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Asia</td>
<td>0.4</td>
<td>0.6</td>
<td>0.9</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>South America</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
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<tr>
<td><strong>International Marine</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Lloyds Register (High)</td>
<td>-</td>
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<td>0</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Lloyds Register (Base)</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Lloyds Register (Low)</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>TOTAL*</td>
<td>-</td>
<td>0</td>
<td>0.2</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Other U.S. (rail + marine)</strong></td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
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<td><strong>Total Displacement</strong></td>
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<td></td>
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<tr>
<td>Base + Lloyds Register (Base)</td>
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<td>0.8</td>
<td>1.6</td>
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- We look at three scenarios for NG HDV adoption – a base case, complete turnover and slow adoption.
  - In the "base" case, NGVs as a percentage of new heavy-duty truck sales will reach 50% in 10 years;
  - In the "complete turnover" case, NGVs as a percentage of new heavy-duty truck sales will reach nearly 100% in a little more than 15 years; and
  - In the "slow adoption" case, NGVs as a share of new sales would not reach 20% until 25 years later.

Source: IEA, Lloyd’s Register, TOTAL, Citi Research
Global gas-for-oil substitution market in transportation is sizable

- Transportation accounts for 44-mb/d of global oil demand, almost 50% of the total.
- Within transportation, oil demand for light vehicles accounts for over 20-mb/d, trucks for more than 10-mb/d, marine and aviation each uses about 5-mb/d, and the rest is in rail and other transportation.
- Most regions worldwide, other than Africa, already have some presence of NGVs
- The trucking, marine and rail sectors, as well as certain light vehicle markets, should be sizable market opportunities for natural gas.

Source: IEA, Citi Research
North America uses about 16-mb/d of oil for the transportation sector. With low natural gas prices, all but the aviation in the transportation sector provide attractive opportunities for natural gas.

Infrastructure costs could be helped by starting with main corridors in trucking, rail, and marine barge.

Europe consumes more than 8-mb/d of oil in transportation.

Environmental issues, fuel economics, and the push by Russian gas company Gazprom, among others, are also encouraging a partial switch to natural gas as a fuel.

Truckers using natural gas can benefit from cost savings as high diesel prices in Europe and partially mitigating the concern with higher natural gas prices there.
Asia is currently the largest NGV market, led by Pakistan, Iran and India, with China surging ahead. Favorable fuel economics between oil and natural gas, national security and environmental factors, in part or in full, drove the adoption of natural gas vehicles.

China is way ahead of the U.S. in the deployment of NGVs and related infrastructure.

South America, especially Argentina and Brazil, have benefit from high gasoline taxes, rich natural gas resources and a well-established pipeline system fostered the adoption of NGVs.
Historically, fuel substitution could happen rather quickly despite constraints.

Transitions driven by fuel economics over policy changes typically follow an “S” curve, which features a rapid transition period once some critical mass has been reached.

A prime example of classic “S”-curve adoption is the diesel-for-gasoline substitution that began in the late 1950s through to the 1970s in trucking sector, taking up a majority of new sales in merely 20 years.

A similar example is the transition of locomotives in rail transport. In the early mid-20th century, higher efficiency and lower requirement for manual labor drove locomotive transition from steam to diesel-electric in merely 20 years.

Source: MacKay, Wards Auto, Westport, Ayres-Ayres-Warr, Citi Research
Railroads may be able to leverage alternative fuels

- Railroads may be able to leverage alternative fuels

- Cost and complexity are hurdles to adoption
  - The length of haul for a train makes the investment in fueling facilities and inefficiencies from refueling along the track lines may be large. However, payback periods can be quick from the test LNG powered locomotives in U.S., Canada, Russia and India.

- Feasibility studies are starting in rails as cost arbitrage appears compelling.
  - While there is limited information, data and studies regarding the potential for railroads to utilize natural gas, there is clearly potential given that Burlington Northern Santa Fe has engaged feasibility studies and preliminary testing on LNG powered locomotives

Source: US Department of Transportation
Natural gas could make inroads in bunker fuel for shipping

- **Natural gas has already captured 6% of the marine fuel market (mostly in LNG tankers),** consuming about 12-mtpa (12-milion tonne per annum) of LNG out of a market potential of 185-mtpa currently dominated by 180-mt of intermediate fuel oil and 55-mt of marine gasoil.

- **A major driver of gas-for-oil substitution in marine transport is the Regulation on SOx and NOx.** The protocol by the International Maritime Organization, adopted in 1997 and implemented in 2005, sets limits ship exhausts of sulfur oxide (SOx) and nitrogen oxide (NOx) emission and creates special SOx Emission Control Areas (SECAs)

- **Intermediate fuel oil use is hindered by the requirement of scrubbers** in light of stringent emission rules in ECAs

- **Marine diesel oil or gasoil is an option but higher fuel prices make it less competitive vs. LNG**

Source: IMO, Poten and Partners, Citi Research
Infrastructure need could be released as several ports dominate marine traffic

- Lack of infrastructure and ship models is an issue
  - Comparative fuel economics and emission rules are powerful drivers for adoption

- The need for infrastructure build at ports may be less than expected
  - Same as NGVs, the infrastructure construction can start with high traffic ports
  - Within the U.S., several ports dominate marine traffic and these could be first ones to have LNG refueling facilities

- Some key liquefaction facilities will help

Source: US Department of Transportation, Citi Research,
Global gas reserve discovery should lead to increased supply globally

A surge in the discovery of gas reserves globally is expected to increase supply in the coming decade and beyond. See below for a highlight of several locations.

- U.S. gas production could rise by more than 20-Bcf/d between 2012 and 2020
- In China, although unconventional gas production remains low, new policies including current gas pricing reform could come into place to boost output.
- East Africa has large gas resources and is well positioned to supply Asia and Europe

Source: BP, EIA, Exxon, IEA, Citi Research
A key part of supply is deliverability of the fuel to local facilities

- A key part of the whole supply-chain is the availability of distribution networks to deliver the fuel to refueling stations or depots and, in the case of LNG, liquefaction facilities to produce the specialty fuel. This is typically the segment in the value chain that is typically not discussed in the market. However, it is the lack of liquefaction facilities in the U.S. that could slow fuel-switching from diesel to LNG in trucking.

- In both the U.S. and Europe, gas pipeline networks are highly developed that the pipeline infrastructure can ensure deliverability to regional local distribution companies (LDCs), liquefaction (LNG) plants or compressed natural gas (CNG) facilities.

Source: EIA, ENTSOG, Citi Research
Small-Scale LNG is important to add to liquefaction capacities

To serve the growing market of LNG in transportation, liquefaction facilities will have to be expanded and updated,

Small-scale LNG may become more popular at places where gas is flared or where pipeline access is limited or restricted

Regions with an abundance of natural gas, could pick-up NGV adoption quicker and drive the building of refueling stations

Current refueling stations could add LNG storage and dispensing to their facilities

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**Infrastructure Cost to Accommodate the Growth of NGVs in the U.S. (US$ Billions)**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Fuel Production</th>
<th>Fuel Dispensing</th>
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<tbody>
<tr>
<td>CNG for light duty vehicles</td>
<td>Possibly nil</td>
<td>100 to 200</td>
</tr>
<tr>
<td>LNG</td>
<td>20 to 40</td>
<td>10 to 20</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>30 to 90</td>
<td>300 to 500</td>
</tr>
<tr>
<td>Biogasoline</td>
<td>100 to 250</td>
<td>20 to 40</td>
</tr>
<tr>
<td>Electricity</td>
<td>N/A</td>
<td>70 to 130</td>
</tr>
</tbody>
</table>

Source: EIA, GTI, NPC, Citi Research
Appendix A-1

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Anthony Yuen

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