BHGE Energy Transition Strategy
How to reach net-zero?
Nathan Meehan
Fundamental energy mix evolving, competition intensifying

Macroeconomic environment setting energy agenda
- Population increases by 25%, GDP increases by 120%
- **Productivity** GDP/($/TOE) needs to improve by 80%

Fossil fuels still the largest by 2040 but growth slowing
- Oil and gas demand expected to peak by 2030 but has long plateau
- Gas demand = 2X oil. Key transition fuel for the future and most competitive with renewables
- Global greenhouse gas emissions estimated at almost 50 GT CO$_2$ eq. on an annual basis. Oil and gas sector represents about 10% or 5 GT CO$_2$ eq (60% upstream, 30% downstream, and 10% midstream).
- World needs to cut emissions in half by 2030 and reach zero net emissions by 2050 to limit global warming to 1.5°C

Electricity growing 4X faster than any other fuel source
- >70% of the new spend on power generation will go to renewables
- Costs of renewables down 80% over a decade

Industrial and consumer behavior play a key role
- Further shift from manufacturing to services
- EVs and the future of transportation
- Petrochem and non-metallic
- Climate and decarbonization

Source: BHGE modeling based upon BP Even Faster EV Adoption scenario for 2040
BHGE 2050: ENERGY FORWARD, CARBON NEUTRAL.
Transforming what we do and how we do it for the new energy future

**ELIMINATE**
OUR CARBON FOOTPRINT

Net-zero BHGE emissions by 2050

Achieve a 50% reduction by 2030 and net-zero carbon emissions from BHGE operations by 2050

**REDUCE**
CUSTOMERS' CARBON FOOTPRINTS

Net-zero emissions partner by 2050

Provide products and services with net-zero emissions to reduce our customers' carbon footprints for their operations, projects, and products.

**GROW**
OUR NEW ENERGY PORTFOLIO

Explore energy transition frontiers

Innovate and develop physical and digital technologies and business models to capitalize on energy transition

---

Copyright 2018 Baker Hughes, a GE company, LLC ("BHGE"). All rights reserved.
Three main ways to achieve net-zero emissions


- **Avoid Emissions and Reduce Energy Consumption**
  - Eliminate flaring, venting & fugitives through produced gas re-injection/conversion, alternative valve actuators, surveillance, etc
  - Increase energy efficiency of pumps/compressors/heaters, cogeneration of power and heat, improve flare combustion, increase electrification

- **Replace Energy Sources**
  - Integrate low carbon options such as biomass, hydro, geothermal, wind, solar and decarbonized hydrogen

- **Offset and Sequester**
  - Offset via reforestation, land-use protection, farming practices, renewable energy
  - Sequester captured CO₂

Sequencing and relative emphasis on each will vary based on economics
4 Examples of BHGE’s Low Carbon Technologies

Notes:
1. "Deployment" units are defined at unit or modular level so they can be scaled across activity base
2. Assumes all identified emissions are eliminated
Gaffney, Cline & Associates: Carbon Management practice

Vision: The oil and gas industry leader in providing carbon management advice and consultancy

Mission: Helping governments, energy companies, and the financial community understand and solve energy transition issues related to oil and gas resources, assets and investments.

Technical, commercial and strategic assessment of carbon & climate risks and opportunities

Practice:
- Quantification carbon intensity
- Evaluation of policies and regs
- Assessment of carbon solutions
- Accreditation of emissions reduced

Foundation: Gaffney, Cline & Associates expertise and experience of providing impartial and confidential advice in oil and gas resource/reserves reporting, field development and fiscal negotiations
Global oil and gas industry directly emits ~4,419 MMT CO$_2$ eq. (~13% of global total) across supply chain

Global Greenhouse Gas Emissions by Oil and Gas Supply Chain Element, 2016, Millions of Metric Tons of CO$_2$ Equivalent (1)

~60% of emissions comes from upstream, with processing (e.g. associated gas venting and flaring) the largest component; downstream accounts for ~1/3 of emissions

Within upstream and midstream, combustion is single largest source, followed by venting and flaring; fugitives are relatively low.

Global Greenhouse Gas Emissions, Upstream and Midstream, by Activity and Emissions Source, 2016, Millions of Metric Tons of CO₂ Equivalent (1)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Combustion</th>
<th>Land use</th>
<th>Venting</th>
<th>Flaring</th>
<th>Fugitives</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling &amp; Development</td>
<td>1.9</td>
<td>419.9</td>
<td></td>
<td></td>
<td></td>
<td>421.9</td>
</tr>
<tr>
<td>Production &amp; Extraction</td>
<td>282.6</td>
<td></td>
<td></td>
<td>20.7</td>
<td>95.1</td>
<td>303.3</td>
</tr>
<tr>
<td>Surface Processing</td>
<td>244.3</td>
<td></td>
<td>721.9</td>
<td>694.5</td>
<td></td>
<td>1,755.7</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td>25.6</td>
<td></td>
<td></td>
<td></td>
<td>25.6</td>
</tr>
<tr>
<td>Transport (midstream)</td>
<td>315.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>315.6</td>
</tr>
<tr>
<td>Various</td>
<td>83.7</td>
<td>8.4</td>
<td>25.1</td>
<td>25.1</td>
<td>25.1</td>
<td>167.3</td>
</tr>
<tr>
<td>Other</td>
<td>46.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46.3</td>
</tr>
<tr>
<td><strong>Total Upstream and Midstream</strong></td>
<td><strong>974.4</strong></td>
<td><strong>428.3</strong></td>
<td><strong>772.6</strong></td>
<td><strong>719.5</strong></td>
<td><strong>140.8</strong></td>
<td><strong>3,035.7</strong></td>
</tr>
<tr>
<td>Total Downstream</td>
<td></td>
<td></td>
<td>(Breakdown by Emissions Source Not Available)</td>
<td></td>
<td></td>
<td>1,382.9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,419</td>
</tr>
</tbody>
</table>

Note: (1) Processing includes oil-gas-water separation, associated gas venting and flaring, gas processing, and water treatment and disposal; Other Onsite is small sources from well site; Offsite includes embodied emissions from production and transport of inputs (e.g. wellbore steel, cement, etc.) as well as electricity consumed at well site but produced offsite. While global and U.S. upstream emissions percentages are similar, global downstream percentage is higher than U.S. (~6%), likely due to classification issues.

flare.IQ
Advanced Process Control Software

flare.IQ’s software brings together speed of sound diagnostics with control systems technology to actively manage and optimize flare performance

**Product Overview**

- flare.IQ utilizes speed of sound diagnostics to infer net heating value of flare gas
- Field validation data shows 3-5% algorithm accuracy against GC/MS
- Real time feedback provides significant savings of natural gas and steam consumption, reducing overall emissions
- flare.IQ software is designed to achieve better than 98% destruction efficiency or 96.5% combustion efficiency
- Seamless integration via Modbus TCP/IP with any DCS
Case Study: flare.IQ Combustion Zone Efficiency

- Flare System with typical sweep gas flow of 10 MSCFH
- 20% emission of typical sweep gas flow equals 2 MSCFH or 727,000 pounds of methane per year (operating around 200 BTU/SCF in combustion zone)
- CO2 equivalency of 18,175,000 pounds
- 98% combustion efficiency target results in 16,357,000 pound reduction in CO2 equivalency

US EPA Requirement: NHVcz > 270 BTU/scf

Case Study : Steam Savings

Case Study is refinery data from flare.IQ installation in Ohio, USA. Data trend is comparison to refinery flare control scheme vs. flare.IQ flare control scheme.

Average Steam Savings

<table>
<thead>
<tr>
<th>Hour</th>
<th>Day</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,800 lbs.</td>
<td>165,000 lbs.</td>
<td>60,300,000 lbs.</td>
</tr>
</tbody>
</table>

Resulting Methane Reduction

<table>
<thead>
<tr>
<th>Hour</th>
<th>Day</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 SCF</td>
<td>242,000 SCF</td>
<td>88,580,895 SCF</td>
</tr>
</tbody>
</table>

To generate 1 Lb of steam (300 PSIg) with 75F of water, it requires 1158 Btu. Natural gas heating content of 920 BTU/SCF. With a typical boiler heating/combustion efficiency of 85.7%, it requires:

$$1158 \times \frac{1000}{920} \times \frac{1}{85.7\%} = 1.468 \text{ SCF of Natural gas per pound of steam produced}$$

Multi-day trend of actual steam consumption vs. calculated flare.IQ steam requirement.
Lumen™ consists of both a stationary platform and a drone-based platform

Lumen™ Methane Emissions Detection Systems – Overview, Continued

(A) Stationary Platform

(B) Drone-based

Both identify and quantify emissions across the entire oil and gas supply chain
TPS GT roadmap toward 100% H₂ fuel DLE Combustor

Power generation progressively shifting from fossil fuels to renewables ... green hydrogen ... flexible power generation system ... energy storage

Today - NovaLT16

- **Burn** gas blends up to 50% C₂ or 30% H₂, with expected NOx emissions well below 70 ppm;
- **Start up** with gas blends up to 50% C₂ or 30% H₂;
- Capable to **switch** from NG to gas blends up to 50% C₂ or 30% H₂

By 2020 | Wet combustion 100% H₂

- NOx emission reduction strategy based on current burner

Dry 100% H₂ combustion

- With low Nox emissions
TPS GT H2 fuel strengths

Multiyear Proven record

2006: GRC test on Single cap
Fr52E burner flame holding test with 80% H2

2006: GE Power Single can
14% H2 on Fr52E

2010: First 100% H2 unit GE10, Fusina, Italy
200 ppm NOx with steam injection
GT package 100% H2 proof;

2013: DACRS burner, 100% H2 PMX characterization
25 ppm NOx feasibility;
Enhanced Flame holding and flash back capabilities

2018: Fuel Flex test on NovaLT16 25 ppm standard config.: including up to 30% H2 blend

BHGE Wing to Wing H2 Capabilities

Proprietary Analytical model for computer simulation

Florence Additive Manufacturing lab for burners rapid prototyping

Florence Single Burner (Blue Rig) lab for rapid characterization & development

Full Scale Annular Combustion Chamber in Sesta Combustion lab

LT16 engine unavailable for endurance testing
NextStream CO2, Process Concept

1. Hot Exhaust Gas (Low Pressure) → HEX
2. Hot, High-Pressure Retentate → Turbocharger → Compressor
3. CO2 Product (Permeate) → Membrane
4. Vent

Cool, High-Pressure Retentate
Quantification of Carbon Intensity: Upstream Oil

Not all fields are created equal

• A study of 9000 oilfields across 90 countries derived an average carbon intensity of 10.3 gCO2e/MJ, but a range between 3.3 to 20.3

Light oil does not necessarily correlate to low carbon intensity

• Exploration, production, transportation and refining practices can make-up 40% of the life-cycle (well to wheel) GHG emissions
• Portfolio strategy, and asset design and management practices can significantly control emissions

Sources: Stanford University, Saudi Aramco