Natural Gas Facts & Figures

New Approach & Proposal
1. Production and reserves

Sources: Total G&P, WOC1, IEA, Ihs Cera,

- Resources- Reserves
  - Conventional
  - Unconventional: types and reserves
- Countries, companies
- Costs of production
- New technics and advances (undersalt, high depth, distant offshore)
- Environmental issues (as a specific part)
Natural Gas reserves: plenty & more to come

Proven conventional reserves are growing

In addition:
Unconventional gas has come within technological & economic reach

The total long-term recoverable conventional gas resource base is more than 400 tcm, another 400 tcm is estimated for unconventional: only 66 tcm has already been produced.

- IEA-Golden Age of Gas 2011-
Conventional Reserves: plenty and more to come

Growing proven reserves

Global proven gas reserves have more than doubled since 1980, reaching 190 trillion cubic metres at the beginning of 2010

Source: IEA World Energy Outlook 2011
World gas resources by major region (tcm)
significant unconventional prospects world-wide

Inventorization of unconventional gas is still at an early stage

Source: IEA Golden Age of Gas, 2011
## Proven reserves of Natural Gas by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Proved Reserve (Tcf)</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle East</td>
<td>2,799.98</td>
<td>41%</td>
</tr>
<tr>
<td>Eurasia</td>
<td>2,164.80</td>
<td>32%</td>
</tr>
<tr>
<td>Africa</td>
<td>545.69</td>
<td>8%</td>
</tr>
<tr>
<td>Asia &amp; Oceania</td>
<td>504.75</td>
<td>7%</td>
</tr>
<tr>
<td>North America</td>
<td>412.39</td>
<td>6%</td>
</tr>
<tr>
<td>Central &amp; South America</td>
<td>270.05</td>
<td>4%</td>
</tr>
<tr>
<td>Europe</td>
<td>146.94</td>
<td>2%</td>
</tr>
<tr>
<td><strong>World</strong></td>
<td><strong>6,844.60</strong></td>
<td><strong>--</strong></td>
</tr>
</tbody>
</table>

Source: DOE Energy Information Agency

### Proven reserves of natural gas by region (Tcf) - 2012

- **North America**
- **Central & South America**
- **Europe**
- **Middle East**
- **Asia & Oceania**
- **Eurasia**

Source: DOE Energy Information Agency
Proven reserves of Natural Gas by Country (Tcf) 2012

Source: DOE Energy Information Agency
Evolution of proved reserves (Tcf) 2000-2012

Source: DOE Energy Information Agency
## Production of Natural Gas by Region (Bcf) 2011

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>Natural gas (Bcf)</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD Total</td>
<td>40252.49</td>
<td>35%</td>
</tr>
<tr>
<td>Africa</td>
<td>7003.48</td>
<td>6%</td>
</tr>
<tr>
<td>Asia (excluding China)</td>
<td>10685.19</td>
<td>9%</td>
</tr>
<tr>
<td>China (P.R. of China and Hong Kong)</td>
<td>3530.04</td>
<td>3%</td>
</tr>
<tr>
<td>Non-OECD Americas</td>
<td>5932.32</td>
<td>5%</td>
</tr>
<tr>
<td>Middle East</td>
<td>18114.02</td>
<td>16%</td>
</tr>
<tr>
<td>Non-OECD Europe and Eurasia</td>
<td>29751.24</td>
<td>26%</td>
</tr>
</tbody>
</table>

Source: IEA International Energy Agency
Production of Natural Gas by Country (Bcf) 2011

Source: IEA International Energy Agency

11/19/2014
### Production of Natural Gas by Country (Bcf) 2011

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (Bcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russian Federation</td>
<td>22706.30</td>
</tr>
<tr>
<td>Qatar</td>
<td>5526.10</td>
</tr>
<tr>
<td>Islamic Republic of Iran</td>
<td>5225.08</td>
</tr>
<tr>
<td>People’s Republic of China</td>
<td>3529.32</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2917.89</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2877.13</td>
</tr>
<tr>
<td>Algeria</td>
<td>2808.75</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>2214.67</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>2103.07</td>
</tr>
<tr>
<td>Egypt</td>
<td>2049.51</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1947.23</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>1800.69</td>
</tr>
<tr>
<td>India</td>
<td>1580.68</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>1473.21</td>
</tr>
<tr>
<td>Argentina</td>
<td>1433.48</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1200.01</td>
</tr>
<tr>
<td>Pakistan</td>
<td>1106.62</td>
</tr>
<tr>
<td>Oman</td>
<td>1072.26</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>1039.58</td>
</tr>
<tr>
<td>Venezuela</td>
<td>983.80</td>
</tr>
<tr>
<td>Thailand</td>
<td>903.21</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>682.51</td>
</tr>
<tr>
<td>Ukraine</td>
<td>637.90</td>
</tr>
<tr>
<td>Brazil</td>
<td>581.64</td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>563.72</td>
</tr>
<tr>
<td>Bolivia</td>
<td>550.46</td>
</tr>
<tr>
<td>Peru</td>
<td>482.93</td>
</tr>
<tr>
<td>Kuwait</td>
<td>453.99</td>
</tr>
<tr>
<td>Brunei Darussalam</td>
<td>439.48</td>
</tr>
<tr>
<td>Myanmar</td>
<td>412.89</td>
</tr>
<tr>
<td>Colombia</td>
<td>376.32</td>
</tr>
<tr>
<td>Romania</td>
<td>355.93</td>
</tr>
<tr>
<td>Yemen</td>
<td>353.48</td>
</tr>
<tr>
<td>Bahrain</td>
<td>328.55</td>
</tr>
<tr>
<td>Vietnam</td>
<td>305.87</td>
</tr>
<tr>
<td>Libya</td>
<td>263.68</td>
</tr>
<tr>
<td>Syrian Arab Republic</td>
<td>261.93</td>
</tr>
<tr>
<td>Iraq</td>
<td>205.60</td>
</tr>
</tbody>
</table>

*Source: IEA International Energy Agency*
Production of Natural Gas by IOCs (Mmcfd) 2010-2012

- 12,322 Mmcfd (2010)
- 9,449 Mmcfd (2011)
- 6,609 Mmcfd (2012)
- 5,880 Mmcfd (2010)
- 5,074 Mmcfd (2011)
- 4,540 Mmcfd (2012)
- 4,245 Mmcfd (2012)

Source: 2012 Annual Reports
Production of Natural Gas by NOCs (Mmcfd) 2010-2012

- 2010: 13,536 Mmcfd
- 2011: 2832 Mmcfd
- 2012: 7,511 Mmcfd
- 2010: 42,100 Mmcfd

Graph showing production by year and company.
Oil and Gas fields Middle East

Source: IHS (2014)
Oil and Gas fields Africa

Legend
- Undisclosed
- Coal Mine Gas, Developing
- Coal Mine Gas, Producing
- Dissolved Gas, Producing
- Coal Bed Methane, Discovery
- Coal Bed Methane, Developing
- Coal Bed Methane, Producing
- Gas Hydrates, Developing
- Gas Hydrates, Producing
- Gas, Discovery
- Gas, Developing
- Gas, Producing
- Oil Gas, Discovery
- Oil Gas, Developing
- Oil Gas, Producing
- Tight Gas, Discovery
- Tight Gas, Developing
- Tight Gas, Producing

Source: IHS (2014)
Oil and Gas fields Continental Europe

Source: IHS (2014)
Oil and Gas fields Far East

Source: IHS (2014)
Oil and Gas fields North Sea

Source: IHS (2014)
Oil and Gas fields Asia Pacific

Legend

Fields
- Undisclosed
- Coal Mine Gas, Developing
- Coal Mine Gas, Producing
- Dissolved Gas, Producing
- Coal Bed Methane, Discovery
- Coal Bed Methane, Developing
- Coal Bed Methane, Producing
- Gas Hydrates, Developing
- Gas Hydrates, Producing
- Gas, Discovery
- Gas, Developing
- Gas, Producing
- Oil Gas, Discovery
- Oil Gas, Developing
- Oil Gas, Producing
- Tight Gas, Discovery
- Tight Gas, Developing
- Tight Gas, Producing

Source: IHS (2014)
Oil and Gas fields Latin America

Source: IHS (2014)
Unconventional resources
### Types of Unconventional Gas

<table>
<thead>
<tr>
<th>Tight Gas</th>
<th>Shale Gas</th>
<th>Coalbed Methane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurs in ‘tight’ sandstone</td>
<td>Natural gas trapped between layers of shale</td>
<td>Natural gas in coal (organic material converted to methane)</td>
</tr>
<tr>
<td>Low porosity = Little pore space between the rock grains</td>
<td>Low porosity &amp; ultra-low permeability</td>
<td>Permeability low</td>
</tr>
<tr>
<td>Low permeability = gas does not move easily through the rock</td>
<td>Production via triggered fractures</td>
<td>Production via natural fractures (“cleats”) in coal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery rates low</td>
</tr>
</tbody>
</table>

Source: Shell
Types of Unconventional Gas

- **Tight Gas**: Natural gas produced from reservoir rocks with such low permeability ($\leq 0.1 \text{md}$) that massive hydraulic fracturing is necessary to produce the well at economic rates. The gas is sourced outside the reservoir and migrates into the reservoir over geological time.

- **Shale Gas**: Natural gas produced from ultra-low permeability (0.001-0.0001md) formations that may also be the source rock for other gas reservoirs.

- **Coal Bed Methane (CBM)**: Gas associated and produced from coal beds, its composition is predominately methane, but can also include other constituents, such as ethane, carbon dioxide, nitrogen and hydrogen.

- **Gas Hydrates**: Also called methane hydrate, methane clathrate, or natural gas hydrate. Gas hydrate – is an ice-like crystalline solid consisting of gas molecules (usually methane, but also ethane, carbon dioxide, etc.) each surrounded by a cage of water molecules (clathrate).
## Technically Recoverable Shale Gas Resources by Country (Tcf)

<table>
<thead>
<tr>
<th>Country</th>
<th>Resources (Tcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1275</td>
</tr>
<tr>
<td>United States</td>
<td>862</td>
</tr>
<tr>
<td>Argentina</td>
<td>774</td>
</tr>
<tr>
<td>Mexico</td>
<td>681</td>
</tr>
<tr>
<td>South Africa</td>
<td>485</td>
</tr>
<tr>
<td>Australia</td>
<td>396</td>
</tr>
<tr>
<td>Canada</td>
<td>388</td>
</tr>
<tr>
<td>Libya</td>
<td>290</td>
</tr>
<tr>
<td>Algeria</td>
<td>231</td>
</tr>
<tr>
<td>Brazil</td>
<td>226</td>
</tr>
<tr>
<td>Poland</td>
<td>187</td>
</tr>
<tr>
<td>France</td>
<td>180</td>
</tr>
<tr>
<td>Norway</td>
<td>83</td>
</tr>
<tr>
<td>Chile</td>
<td>64</td>
</tr>
<tr>
<td>India</td>
<td>63</td>
</tr>
<tr>
<td>Paraguay</td>
<td>62</td>
</tr>
<tr>
<td>Pakistan</td>
<td>51</td>
</tr>
<tr>
<td>Bolivia</td>
<td>48</td>
</tr>
<tr>
<td>Ukraine</td>
<td>42</td>
</tr>
<tr>
<td>Sweden</td>
<td>41</td>
</tr>
<tr>
<td>Denmark</td>
<td>23</td>
</tr>
<tr>
<td>Uruguay</td>
<td>21</td>
</tr>
<tr>
<td>U.K.</td>
<td>20</td>
</tr>
<tr>
<td>Colombia</td>
<td>19</td>
</tr>
<tr>
<td>Tunisia</td>
<td>18</td>
</tr>
<tr>
<td>Netherlands</td>
<td>17</td>
</tr>
<tr>
<td>Turkey</td>
<td>15</td>
</tr>
<tr>
<td>Venezuela</td>
<td>11</td>
</tr>
<tr>
<td>Morocco</td>
<td>11</td>
</tr>
<tr>
<td>Germany</td>
<td>8</td>
</tr>
<tr>
<td>Western Sahara</td>
<td>7</td>
</tr>
<tr>
<td>Lithuania</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: DOE Energy Information Administration 2013
Map of basins with assessed shale oil and shale gas formations, as of May 2013
North American gas forecast: the growing importance of US Shale Gas

Source: Canadian Imperial Bank of Commerce (CIBC)
US current and prospective shale plays

Source: DOE Energy Information Administration 2013
China’s Shale Gas and Shale Oil Basins

Source: EIA/ARI 2013; PETRONAS SR Unit
Unconventional Plays – L.A.

Source: IHS
Brazilian Pre-Salt

- Heterogeneous carbonate reservoirs, with highly variable petrophysical properties.
- Pre-Salt fields mostly located at water depths exceeding 2,000m.
- Reservoirs depths at 5,000 to 6,000 meters below sea level.
- Natural gas associated with oil, in a gas-oil ratio between 200 and 300 m$^3$/m$^3$
- Variable contents of CO2, ranging from 8 to 12% under an extensive salt layer (up to 2,000 meters in some areas)
New technics and developments

Arctic Shelf in Russia

Special physical hurdles – lots of ice, extremely low temperatures, remote locations and long periods of darkness

Challenges:
✓ Geographic Location
✓ Deep Water
✓ Large fields
✓ Ultra long distance
New techniques and developments

Example: Shtokman

1. Gas is produced by twin four-slot templates
2. Produced gas is conveyed by flexible production risers (vertical pipes) from a template to the FPU
3. Mid-water arches support risers before hydrocarbons are supplied to the FPU
4. Gas and condensate separation, and gas processing operations are performed aboard the FPU
5. Processed gas is exported from the FPU by flexible risers
6. A special device connects risers to the trunkline
7. Two trunklines carry gas to onshore facilities

Shtokman gas and condensate field pre-development scheme

Location of Shtokman field
Technical challenges

- **Deep gas (below 4500m) and ultra-deep gas (below 7500m)**
  
  **Some examples**
  
  - Russia: structure of Achimov of the Urengoy fields
  - China: Dina2 gas field in the Tarim basin
  - Azerbaidjan: Shaz Deniz II
  - Australia: Martell, Noblige and Larsen

- **HP/HT**

- **Sour gas (H2S and CO2)**
  
  **Some examples**
  
  - US Norphlet play
  - China Puguang field, with H2S at 15%
  - Tunisia Hasdrubal plant
2. Transmission

- Gas pipelines
  - Main roads and infrastructures
  - New projects
  - Costs, losses, ..

Sources: WOC3, Total G&P
Infrastructures Australasia

IHS January 2014
Infrastructures South America

LNG Liquefaction Plant
- Operating
- Planned
- Under Construction

LNG Regasification Plant
- Operating
- Planned
- Under Construction

Pipelines
- Operating, under 13"
- Operating, 13" to 34"
- Operating, above 34"
- Under construction
- Planned

IHS January 2014
Infrastructures Africa

LNG Liquefaction Plant
- Operating
- Planned
- Under Construction

LNG Regasification Plant
- Operating
- Planned
- Under Construction

Pipelines
- Operating, under 13"
- Operating, 13" to 34"
- Operating, above 34"
- Under construction
- Planned

IHS January 2014
Infrastructures Far East

LNG Liquefaction Plant
- Operating
- Planned
- Under Construction

LNG Regasification Plant
- Operating
- Planned
- Under Construction

Pipelines
- Operating, under 13"
- Operating, 13" to 34"
- Operating, above 34"
- Under construction
- Planned

IHS January 2014
Infrastructures North America

LNG Liquefaction Plant
- Operating
- Planned
- Under Construction

LNG Regasification Plant
- Operating
- Planned
- Under Construction

Pipelines
- Operating, under 13"
- Operating, 13" to 34"
- Operating, above 34"
- Under construction
- Planned
Major gas pipelines in China

Source: SIA Energy
Gas Supply System of Russia

Unified Gas Supply System of Russia (source Gazprom)
3. LNG

- Trade movements
- Terminals for import, terminals for exports
- Liquefaction, regasification
- LNG Fleet

- LNG by road, fluvial
LNG: More flexibility through new technology

On-board regasification offers low cost and convenient option to supply gas to new and existing markets
LNG: More flexibility through new technology

Small scale LNG offers opportunities to produce otherwise stranded gas and reduce gas flaring

Source: Skaugen
LNG Exports by Country

Source: Waterborne LNG Reports, US DOE, PFC Energy Global LNG Service
LNG Imports by Country

Figure 3.6: LNG Imports by Country: 2012 Imports & Incremental Change Relative to 2011 (in MTPA)

“Other” includes Canada, UAE, Greece, Thailand, Puerto Rico, Dominican Republic, Indonesia, and the Netherlands

Sources: Waterborne LNG, US DOE, PFC Energy Global LNG Service
Map of inter basin Trade

Source: PFC Energy Global LNG Service
Liquefaction capacity by Country

Liquefaction Capacity by Country in 2012 and 2017

Source: PFC Energy Global LNG Service, Company Announcements
# Small scale export projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Country</th>
<th>Status</th>
<th>Original Capacity</th>
<th>Announced Start</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Phase of LNG Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenai LNG</td>
<td>US</td>
<td>Existing</td>
<td>0.9</td>
<td>1969</td>
<td>ConocoPhillips</td>
</tr>
<tr>
<td>Brunei LNG T1-5</td>
<td>Brunei</td>
<td>Existing</td>
<td>1.5</td>
<td>1972</td>
<td>Brunei LNG JV</td>
</tr>
<tr>
<td>Skikda - GL1K (T1-4)</td>
<td>Algeria</td>
<td>Existing</td>
<td>1.4</td>
<td>1972</td>
<td>Sonatrach</td>
</tr>
<tr>
<td>ADGAS LNG T1-2</td>
<td>UAE</td>
<td>Existing</td>
<td>1</td>
<td>1977</td>
<td>ADGAS LNG JV</td>
</tr>
<tr>
<td>Arzew - GL1Z (T1-6)</td>
<td>Algeria</td>
<td>Existing</td>
<td>1.1</td>
<td>1978</td>
<td>Sonatrach</td>
</tr>
<tr>
<td>Arzew - GL2Z (T1-6)</td>
<td>Algeria</td>
<td>Existing</td>
<td>1.1</td>
<td>1981</td>
<td>Sonatrach</td>
</tr>
<tr>
<td>Skikda - GL2K (T5-6)</td>
<td>Algeria</td>
<td>Existing</td>
<td>1.4</td>
<td>1981</td>
<td>Sonatrach</td>
</tr>
<tr>
<td>Recent Onshore</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skangass LNG</td>
<td>Norway</td>
<td>Existing</td>
<td>0.3</td>
<td>2010</td>
<td>Lyse</td>
</tr>
<tr>
<td>Sengkang LNG T1</td>
<td>Indonesia</td>
<td>Construction</td>
<td>0.5</td>
<td>2013</td>
<td>Energy World Corp.</td>
</tr>
<tr>
<td>Sengkang LNG T2</td>
<td>Indonesia</td>
<td>Construction</td>
<td>0.5</td>
<td>2013</td>
<td>Energy World Corp.</td>
</tr>
</tbody>
</table>

Table 4.2: Small-Scale Liquefaction Export Projects

*Source: PFC Energy Global LNG Service*
Annual send-out capacity

Annual Send-out Capacity of LNG Terminals in 2012 and 2017

Sources: PFC Energy Global LNG Service, Company Announcements
Receiving terminal import capacity

Receiving Terminal Import Capacity by Country in 2012 and 2017

Source: PFC Energy Global LNG Service, Company Announcements
LNG fleet

Global LNG Fleet by Year of Delivery

Sources: PFC Energy Global LNG Service

New-build Orders (3 or more vessels)

Source: PFC Energy Global LNG Service
Liquefaction capacity: operating and planned

- Operating Capacity
- Under Construction Capacity
- Planned Capacity *

* All on-going planned projects till 2023

IHS January 2014
<table>
<thead>
<tr>
<th>Region</th>
<th>Operating Capacity</th>
<th>Under Construction Capacity</th>
<th>Planned Capacity *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>62,1</td>
<td>4,7</td>
<td>187,5</td>
</tr>
<tr>
<td>Australasia</td>
<td>24,95</td>
<td>68,7</td>
<td>152,47</td>
</tr>
<tr>
<td>C.I.S.</td>
<td>10,61</td>
<td>10</td>
<td>153,77</td>
</tr>
<tr>
<td>Europe</td>
<td>4,76</td>
<td></td>
<td>19,1</td>
</tr>
<tr>
<td>Far East</td>
<td>74,7</td>
<td>21,45</td>
<td>38,68</td>
</tr>
<tr>
<td>Latin America</td>
<td>19,92</td>
<td>0,54</td>
<td>33,01</td>
</tr>
<tr>
<td>Middle East</td>
<td>100,25</td>
<td>10,8</td>
<td>59,15</td>
</tr>
<tr>
<td>North America</td>
<td></td>
<td></td>
<td>449,63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>297.29</strong></td>
<td><strong>125,19</strong></td>
<td><strong>1093,31</strong></td>
</tr>
</tbody>
</table>

* All on-going planned projects till 2023

IHS January 2014
Regasification capacity: operating and planned

* All on-going planned projects till 2020
IHS January 2014
### Regasification capacity: operating and planned

<table>
<thead>
<tr>
<th>Region</th>
<th>Operating Capacity</th>
<th>Under Construction Capacity</th>
<th>Planned Capacity *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td>11,54</td>
</tr>
<tr>
<td>Australasia</td>
<td></td>
<td></td>
<td>1,17</td>
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<tr>
<td>C.I.S.</td>
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<td>9,07</td>
</tr>
<tr>
<td>Europe</td>
<td>137,08</td>
<td>3,49</td>
<td>121,74</td>
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<tr>
<td>Far East</td>
<td>379,12</td>
<td>20,46</td>
<td>249,35</td>
</tr>
<tr>
<td>Latin America</td>
<td>41,64</td>
<td>1,7</td>
<td>76,66</td>
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<tr>
<td>Middle East</td>
<td>17,41</td>
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<td>14,77</td>
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<tr>
<td>North America</td>
<td>83,95</td>
<td></td>
<td>17,45</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>659,2</strong></td>
<td><strong>25,65</strong></td>
<td><strong>501,75</strong></td>
</tr>
</tbody>
</table>

* All on-going planned projects till 2020

IHS January 2014
Overland transport of LNG: By road trucks and railcars

- LNG is transported by road truck in many countries
- Trucked LNG has many small-scale uses:
  - Domestic and commercial piped gas supply from satellite re-gasification terminals located in places remote from pipelines
  - Small industrial users (electric power, engine tests, glass, paper)
  - Commercial users (trains, buses, ferries, institutions)
  - Supply to peak-shaving plants
  - Supply to pipeline network during repairs or maintenance
4. Underground Gas Storage

Source: WOC2 database

- Types of UGS,
- per countries: distribution, WGV, maps
- per type: distribution, WGV,
- TPA
- Projects
UGS Working Gas Volume by Countries (bcm)

- USA
- Russia
- Ukraine
- Germany
- Italy
- Canada
- France
- Austria
- Hungary
- Uzbekistan
- Netherlands
- Kazakhstan
- China
- Czech Republic
- Romania
- Spain
- Slovakia
- Poland
- Latvia
- Turkey
- Bulgaria
- Australia
- Iran
- Belarus
- Japan
- Bulgaria
- Denmark
- Belgium
- Croatia
- Sweden
- New Zealand
- Ireland
- Portugal
- Armenia
- Kyrgyzstan
- Australia
- Iran
- Belarus
- Japan
- Bulgaria
- Denmark
- Belgium
- Croatia
- Sweden
- New Zealand
- Ireland
- Portugal
- Armenia
- Kyrgyzstan
- Australia
- Iran
- Belarus
- Japan
- Bulgaria
- Denmark
- Belgium
- Croatia
- Sweden
- New Zealand
- Ireland
- Portugal
- Armenia
- Kyrgyzstan

UGS Working Gas Volume by Countries smaller than 2.0 bcm
UGS Working Gas Volume by regions

UGS in the World
Working Gas Volume Distribution by Regions (bcm)

- Asia: 138,1 bcm (38%)
- Europe: 113,6 bcm (32%)
- Asia Pacific: 98,7 bcm (28%)
- L.America & Caribbean: 3,0 bcm (1%)
- CIS: 1,4 bcm (0%)
- Middle-East: 0,1 bcm (0%)
- North America: 4,0 bcm (1%)

Total: 358,8 bcm
UGS Working Gas Volume by storage type

UGS in the World
Working Gas Volume Distribution by Storage Types (bcm)

Total = 358.8

Aquifer, Gas Field, Oil Field, Rock Cavern, Salt Cavern
UGS in Europe
Working Gas Volume Distribution by Storage Types (bcm)

Total = 98,7

- Aquifer
- Gas Field
- Oil Field
- Rock Cavern
- Salt Cavern

68,1
69 %

16,9
17 %

12,7
13 %

1,0
1 %

0,1
0 %
Specific Working Gas Volume and No. of UGS by Countries

- **No. of UGS Facilities**
- **Specific Working Gas Volume**

Excluding long-term strategic reserves in Russia.
Age of UGS facilities

Age of storages

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Abandoned mine</th>
<th>Aquifer</th>
<th>Gas Field</th>
<th>Oil Field</th>
<th>Rock Cavern</th>
<th>Salt Cavern</th>
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<tbody>
<tr>
<td>1900-1930</td>
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<td>1960-1970</td>
<td></td>
<td>73</td>
<td>11</td>
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<tr>
<td>1970-1980</td>
<td></td>
<td></td>
<td>80</td>
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<tr>
<td>1980-1990</td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990-2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>2000-2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
</tbody>
</table>

No. of UGS Facilities
UGS Working Gas Volume by Storage operators (Bcm)
Development of new storage capacity compared to the storage capacity in the previous triennium (bcm)


Working Gas Volume in operation (2010-2012)
UGS planned Working Gas Volume

UGS in the World
Reported Planned Working Gas Volume Distribution by Regions (bcm)

- Asia: 24.7 bcm (21%)
- Asia Pacific: 64.7 bcm (54%)
- Europe: 11.7 bcm (10%)
- L.America & Caribbean: 12.4 bcm (10%)
- Middle-East: 0 bcm (0%)
- CIS: 0 bcm (0%)
- North America: 2.1 bcm (2%)

Total ±18.6 bcm
UGS distribution worldwide

Legend

- Gas Field
- Oil Field
- Aquifer
- Salt Cavern
- Abandoned mine
- Rock Cavern
UGS distribution in Europe
5. Distribution

- Grids & networks (characteristics)
- Companies ?
- Gas quality
- Smart grids
- TPA

Source: Woc4 and national websites
Smart Grids

Definition of a Smart Grids

Smart Gas Grid
Land is building a safe and flexible gas grid.

Intelligent Gas Network Instrumentation
- Gas Grid Monitoring: Sensor measure around vibrations, traffic loads, ground settlement, gas leaks, etc., around gas mains.
- Smart Metering: Gas meter to record gas consumption profile and make this data available in digital format.
- Measurements in stations: Remote monitoring of gas inlet and outlet pressures, volumes, and temperatures.
- Gas Diffusion: Sensors and computer models to measure and predict gas flow diffusion and tubing.
- Dynamic Pressure Management: Fitting the gas pressure depending on demand and supply.
- City Gate: Near the CNG (Compressed) gas inlet data for gas outlet pressure, volumes, temperatures and quality.
- Monitoring Gas Quality: The quality of new methane added to the grid is maintained to T.
- Station Diagnostics: Periodical diagnostics are run to ensure control systems are working properly.
- Cathodic Protection: Remote diagnostics and monitoring of the corrosion checking around steel assets.
- Gas for mobility: Filling stations for gas used as vehicle fuel on the road and on the water.
- Local Storage: Storage of overcapacity of bio-methane.
- Energy hub in residential area: CHP driving gas driven heat pump for district heating and electricity.
- Inspection Robots: Internal pipeline inspection.
- Satellite Monitoring: Monitoring ground settlement at a street and neighborhood level.
6. Utilisation

- Industrial uses
- Domestic and commercial uses
- Natural gas vehicles
- LNG vehicles

Source: WOC5, SG5,3
Evolution of consumption by region (Bcf) 2000 - 2011

Source: DOE Energy Information Agency
Demand Evolution of Asian Countries (Bcf) 2000-2011

Source: DOE Energy Information Agency
Growing Global Demand for Gas

Gas overtakes coal before 2030 and meets one quarter of global energy demand by 2035 – demand grows by 2% annually, compared with just 1.2% for total energy.

Gas: Convenient & Efficient Source of Energy
Economic and Clean

- Easy handling, lower installation and maintenance cost
- Good controllability of processes and high efficiency
- Direct heating or drying of products or materials
- Clean and environment-friendly
- Less CO₂ emission rights needed (where applicable)
Green houses – use

↑ Boiler house in green house. Gas use temperature dependent.

← Assimilation illumination
  + Use of CO₂ from exhaust gases as fertiliser
Industrial Utilization of gas
Natural gas consumption within industrial sector about 23% of the world natural gas consumption.
Natural gas is the most effective to reduce CO2 emissions and to carry out the fuel switching from oil and coal in the industrial sector where fuel consumption is large.

**Advantages of Natural Gas**

- Easy to reduce CO2 emission: natural gas is the least CO2 emitting fuel among all fossil fuels. Only shifting to natural gas, CO2 emission can be reduced by 20% from heavy oil and 40% from coal.
- Easy to achieve massive energy saving
- Easy to improve customers product quality and yield of product
- Good affinity with renewable energy.
Natural gas is a sustainable and environmentally friendly source for power generation (source: IEA)

Power generation

Natural gas is the most suitable fuel for Combined Heat And Power - CHP
Natural gas vs energy efficiency

Natural gas is a leading fuel to achieve energy efficiency, which is today considered as the “first” source of renewable energy.

To achieve such result a precise methodology is of outmost importance.

Case study: implementation of regenerative burners.
Available technologies

Case study: Metal Treatment Factory
1. Furnace: Surface Hardening Furnace
   Rotary Retort Vessel Type
2. Product: Automobile Parts
3. Burner type: Insert Type
Technologies for fuel switch

Cost effective technologies

Economic Benefits
(Cumulative amount of 10 years)

Dollar

<table>
<thead>
<tr>
<th>Country</th>
<th>Simple</th>
<th>Simple + readjust air ratio</th>
<th>RE-gene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
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<td></td>
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<tr>
<td>USA</td>
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<tr>
<td>Italy</td>
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<td></td>
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<tr>
<td>Canada</td>
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<tr>
<td>Belgium</td>
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<td>Czech</td>
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<td>Germany</td>
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<td>Portugal</td>
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<td>Switzerland</td>
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<td>Spain</td>
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<td>U.K.</td>
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<td>Poland</td>
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<tr>
<td>Denmark</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Natural Gas Vehicles
Natural gas for road transport

Natural gas is the cleanest fossil fuel

Source: Gasunie ‘Natural gas, part of an efficient sustainable energy future, The Dutch case’, Feb 2010
Transportation fuel growth in 2004 – 2013
Average retail price at pump in Europe

Average Growth Rates

NGV population: 18% per annum
Natural Gas demand: 17% per annum
Number of NGV: 13% per annum

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
World NGV Recognition Level

NGVs per 1000 people (2013 World top 20)

- Armenia: 80.6
- Argentina: 54.4
- Iran: 42.7
- Bolivia: 24.9
- Pakistan: 13.7
- Italy: 12.3
- Uzbekistan: 10.3
- Colombia: 9.6
- Brazil: 8.7
- Ukraine: 8.5
- Bulgaria: 8.5
- Thailand: 6.1
- Peru: 5.2
- Sweden: 4.6
- Liechtenstein: 3.9
- Venezuela: 3.0
- Iceland: 2.9
- Egypt: 2.7
- Malaysia: 2.1
- Average World: 2.5

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
Worldwide Natural Gas Vehicle (NGV) population other than ships, trains and aircraft

Data source: NGVA Europe, NGVs and fuel consumption worldwide, June 2013

- Light vehicles = 16,310,105
- Medium and Heavy Duty Buses = 781,396
- Medium and Heavy Duty Trucks = 368,000
- Others = 270,932

Total NGV population = 17,730,433
# Regional NGV Markets

<table>
<thead>
<tr>
<th>Region (UN definition)</th>
<th>Population of NGVs, thousands, 2013</th>
<th>NG Demand, MCM/2012</th>
<th>Number of Filling Stations, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Asia</td>
<td>7 810,0</td>
<td>11 766,1</td>
<td>6 299</td>
</tr>
<tr>
<td>South America</td>
<td>4 949,8</td>
<td>5 518,1</td>
<td>4 955</td>
</tr>
<tr>
<td>East Asia</td>
<td>1 578,5</td>
<td></td>
<td>3 305</td>
</tr>
<tr>
<td>South Europe</td>
<td>751,9</td>
<td>939,3</td>
<td>997</td>
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<tr>
<td>East Europe</td>
<td>551,1</td>
<td>1 249,3</td>
<td>882</td>
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<tr>
<td>South East Asia</td>
<td>492,0</td>
<td>3 612,0</td>
<td>732</td>
</tr>
<tr>
<td>Central Asia</td>
<td>332,6</td>
<td>56,8</td>
<td>254</td>
</tr>
<tr>
<td>North America</td>
<td>264,2</td>
<td>930,2</td>
<td>1 521</td>
</tr>
<tr>
<td>West Asia</td>
<td>250,9</td>
<td></td>
<td>410</td>
</tr>
<tr>
<td>West Africa</td>
<td>180,5</td>
<td>458,9</td>
<td>175</td>
</tr>
<tr>
<td>South Europe</td>
<td>133,2</td>
<td>531,2</td>
<td>1 627</td>
</tr>
<tr>
<td>North Europe</td>
<td>48,4</td>
<td>377,5</td>
<td>282</td>
</tr>
<tr>
<td>Central America &amp; Caribbean</td>
<td>17,0</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Oceania</td>
<td>3,7</td>
<td></td>
<td>65</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>173 633,7</strong></td>
<td><strong>2 693 711</strong></td>
<td><strong>2 153 300</strong></td>
</tr>
</tbody>
</table>

Data source: NGVA Europe, *Worldwide shares in vehicle market*, June 2013
Population of Natural gas vehicles in Europe

Total NGVs in Europe: 1,104,038

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
Population of NGVs in North and South America

Total NGVs in America: 5,141,109

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
Number of natural gas vehicles in Russia and Asia

Total NGVs in Asia: 7,738,863

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
Environmental efficiency

Well-to-wheel greenhouse gas emissions in g CO2 eq./km for different fuels

Source: Dena, German Energy Agency, The role of natural gas and biomethane in the fuel mix of the future in Germany, June 2010
Monthly theoretical consumption (M Nm3)

Data source: NGVA Europe, NGVs and fuel consumption worldwide, June 2013
Transportation fuel growth in 2004 – 2013
Average retail price at pump in Europe

Data source: NGVA Europe, Worldwide shares in vehicle market, June 2013
Applications of Natural gas as a fuel

Natural gas occupies more volume than traditional liquid fuels thus it must be compressed or liquefied to make it practical for transport applications.

- **Compressed Natural Gas (CNG)** is the most common application for NGVs. It can be installed wherever there is a natural gas pipe in the ground.

- **Liquefied Natural Gas (LNG)** use is becoming increasingly common. It needs a local supply of fuel.

- **Liquefied Compressed Natural Gas (LCNG)** combines LNG and CNG in one station. A typical LCNG station is supplied with LNG and has dispensers for both LNG and CNG vehicles.
Focus on CNG filling stations types

Worldwide types of CNG station

- Public CNG stations: 82%
- Private CNG stations: 10%
- L-CNG stations: 5%
- LNG stations: 2%

CNG stations = 22,162
L-CNG stations = 441
LNG stations = 1,433
Total = 24,036

NGV station population

Data source: NGVA Europe, NGVs and fuel consumption worldwide, June 2013
Examples of OEMs Natural gas light vehicle

Major NGV OEMs for

- Light vehicles /light duty vehicles: FIAT, Volkswagen, Skoda, Seat, Mercedes, Lancia, Iveco
- Buses: IVECO, MAN, Solaris, TEDOM, Van Hool, Volvo
- Trucks: SCANIA, DAIMLER, Volvo

Examples below

**Fiat 500 L Natural Power (bi-fuel)**
- Fuel capacity: 14 kg CNG + 50 L petrol
- Range (combined): 1206 km
- Engine Power: 80 hp
- Emission Standard: Euro 5
- CO2: 105 g/km

**Fiat Ducato Maxi Natural Power**
- Fuel Capacity: 37 kg + 19 L petrol
- Range (combined): 409 km
- Engine Power: 136 hp
- Emission Standard: Euro 5
- CO2: 134 g/km

**Mercedes-Benz Sprinter NGT (bi-fuel)**
- Fuel Capacity: 45 kg CNG + 19 L petrol
- Range (combined): 1070 km
- Engine Power: 156 hp
- Emission Standard: Euro 5
- CO2: 254 g/km

**Audi A3 Sportback g-tron (bi-fuel)**
- Fuel capacity: 14 kg CNG + 50 L petrol
- Range (combined): 1300 km
- Engine Power: 110 hp
- Emission Standard: EUR 5
- CO2: 95 g/km

**Opel Combo 1.4 CNG ecoFLEX (bi-fuel)**
- Fuel capacity: 16-22 kg CNG + 22 L petrol
- Range (combined): 750 km
- Engine Power: 120 hp
- Emission Standard: Euro 5
- CO2: 134 g/km

**Volvo FM Methane Diesel (dual-fuel)**
- Classification: Dual Fuel
- Engine: 7 litre CNG
- Engine Power: Up to 460 hp
- Emission Standard: EURO 5 Diesel
- Range: Up to 1,000 km

**VW Touran 1.4 TSI EcoFuel CrossTouran (mono-fuel)**
- Fuel capacity: 24 kg CNG + 11 L petrol
- Range (combined): 600 km
- Engine Power: 150 hp
- Emission Standard: Euro 5
- CO2: 136 g/km

**Iveco Bus Citelis CNG 12m**
- Configuration: dedicated
- Engine: Iveco Cursor 8
- Engine Power: 290 hp
- Emission Standard: EEV
- Seats: 29-34

**IVECO Stralis CNG**
- Classification: dedicated
- Engine: IVECO Cursor 8
- Engine Power: 272/300/330 hp
- Emission Standard: EEV
- Range: 450 km

Data source: NGVA Europe, more examples on http://www.ngvaeurope.eu/cars
### Examples of OEMs Natural gas light vehicle

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Aviat Husky CNG" /></td>
<td>Aviat Husky CNG (Airplane manufacturer Aviat Aircraft, inc), the first dual fuel, piston powered aircraft to operate on both compressed natural gas (CNG) and aviation gasoline.</td>
</tr>
<tr>
<td><img src="image2.png" alt="SUGAR Freeze" /></td>
<td>SUGAR Freeze is one of several notional concepts that a Boeing-led team is studying for NASA as part of the Subsonic Ultra-Green Aircraft Research (SUGAR) project.</td>
</tr>
<tr>
<td><img src="image3.png" alt="Sanmar" /></td>
<td>Sanmar constructed the world’s first Liquid Natural Gas (LNG) powered escort tugs. The vessels have been ordered by Buksér og Berging AS of Norway and entered the service in 2014.</td>
</tr>
</tbody>
</table>

*Data source: NGVA Europe, more examples on [http://www.ngvaeurope.eu/cars](http://www.ngvaeurope.eu/cars)*
Residential: Efficient and environmentally friendly fuel for heating, hot water and cooking

- Clean and easy handling once infrastructure is present
- Low installation cost vs. other fuels
- High efficiency heating equipment available
- High comfort factor
- Individual heating systems in apartment blocks

↑ High efficiency heating system (hot water boiler) with storage vessel
↑ High efficiency heating system
LNG as automotive fuel for heavy vehicles

- **LNG is used in increasingly many places for road transport fleets**: Buses, Dust Carts, Chilled Container Transporters – it gives good engine performance and a vehicle range comparable with other fuels.

- **LNG is suitable to fuel high-consumption transport** where space for the LNG storage is readily available: e.g. trains and sea ferries.

- **LNG is less-suitable for small privately-owned vehicles** because of more complex procedures and more expensive fuelling stations with special requirements regarding their location.

- **Heavy vehicles do not lend themselves to be run on electric power.**
7. Gas markets

- See trading aspect: LT contracts, open-season
- Industrial aspect: Power generation, Industry
- Markets lists or map

Source: PGCE, SGE1, Total G&P
8. Environmental impact

Source: PGCA, life cycle analysis

- Life Cycle Analysis approach
- Impact effect for each step of the chain (including uses)
- Greenhouse gases and others emissions
- Water management
- Energy efficiency (for all the chain)
- Gas advocacy
Natural Gas with or w/o CCS: Cleanest fossil fuel for power generation

<table>
<thead>
<tr>
<th>GHG Emissions</th>
<th>Metric Tons CO₂ per MWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind (0)</td>
<td>0</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
</tr>
<tr>
<td>Solar</td>
<td>(0.04)</td>
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<tr>
<td>&quot;Clean&quot; Coal*</td>
<td>(0.09)</td>
</tr>
<tr>
<td>&quot;Clean&quot; Natural Gas*</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>(0.85)</td>
</tr>
<tr>
<td>Oil</td>
<td>(0.80)</td>
</tr>
</tbody>
</table>

* With CCS

Source: IGU based on CERA
Natural Gas fired generation:
Smallest ecological footprint for power generation

Land use in acres to have 1,000 MW of capacity

Source: based on data from Union Gas Ltd.
Gas: Cleanest Fossil Fuel
Lowest emission of CO2

Emission of CO₂
(in kg CO₂/MWh)

- Lignite-fired power: 1,200 kg CO₂/MWh (340%)
- Hard coal-fired power: 850 kg CO₂/MWh (230%)
- Gas-fired CCGT: 350 kg CO₂/MWh (100%)

Source: US Department of Energy (DOE), US Energy Information Administration (EIA)
Particulate emissions from heating systems

mg/kWh

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Emission (mg/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>0.11</td>
</tr>
<tr>
<td>Heating oil</td>
<td>6.1</td>
</tr>
<tr>
<td>Lignite*</td>
<td>306</td>
</tr>
<tr>
<td>Hard coal**</td>
<td>554</td>
</tr>
</tbody>
</table>

* Emissions based on use of briquettes and lignite from the Rhineland-area in Germany
** Emissions based on use of briquettes

LUWB Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg; Average emission factors for small and medium combustion installations without exhaust gas after treatment. Status: 2006, BGW; Source: www.asue.de
Steps of the natural gas chain modeled

with the main trade movements in Europe

1 MJ of distributed NG

Production
Treatment
Liquefaction
Transport by pipeline from producing countries
Gasification
Transmission by LNG tanker
Storage
National transmission (high pressure)
National distribution (low pressure)

IGU

1.7%
2.0%
3.3%
4.9%
5.9%
8.4%
2.1%
2.6%
2.1%
4.7%
5.3%
1.7%
Results on the whole life cycle, including the final use

First example:

Electricity production: CCGT

The final use is not necessarily the only significant contributor to all the impacts
Results on the whole life cycle, including the final use

<table>
<thead>
<tr>
<th>Heat: Domestic use</th>
<th>Electricity production: CCGT</th>
<th>Electricity/Heat: CHP, tertiaire use</th>
</tr>
</thead>
<tbody>
<tr>
<td>238 g CO₂eq</td>
<td>96 mg SO₂eq</td>
<td>1.12 kWh</td>
</tr>
</tbody>
</table>

Differences observed between the 3 final uses:
mainly linked to the efficiency of the conversion process and to the type of combustion
Results: focus on the upstream chain

Different contributions of each step to the 3 impacts:

- Climate change
- Acidification
- Non-renewable energy depletion

Categories:
- Low pressure distribution in EU-25
- High pressure transmission in EU-25
- Storage in Europe
- Gasification in Europe
- Export by LNG tanker
- Liquefaction
- Transmission by pipeline
- Production/processing
Comparison of the repartition of GHG emissions along the upstream chains

GHG emissions ranging from 1 to 4 depending on the NG supply chain

- Low pressure distribution in EU-25
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