Gas vs Renewables: Recent Insights from Germany and Beyond

The need to complement renewables by decarbonised gas*

Energetika Work Stream on Decarbonising Natural Gas
St. Petersburg, 14 November 2018
Ralf Dickel, Independent Expert

*Based on OIES Paper NG 129
• We live in an era in the history of nations where there is greater need than ever for co-ordinated political action and responsibility

• Perhaps our most urgent task is to persuade nations of the need to return to multilateralism

From the Foreword to Our Common Future, World Commission on Environment and Development, Gro Harlem Brundtland, Oslo, 20 March 1987
## Developments 2000-2016 (WEO2017)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2016</th>
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<tbody>
<tr>
<td><strong>Total primary energy demand (Mtoe)</strong></td>
<td>10035</td>
<td>13760</td>
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<tr>
<td><strong>of which:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Coal</td>
<td>2311</td>
<td>3755</td>
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<tr>
<td>Oil</td>
<td>3670</td>
<td>4388</td>
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<td>Gas</td>
<td>2071</td>
<td>3007</td>
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<tr>
<td>Nuclear</td>
<td>676</td>
<td>681</td>
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<tr>
<td>Hydro</td>
<td>225</td>
<td>350</td>
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<td>Bioenergy*</td>
<td>1023</td>
<td>1354</td>
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<td>other renewable (Mtoe)</td>
<td>60</td>
<td>225</td>
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<tr>
<td><strong>Share of fossil fuel (%)</strong></td>
<td>80%</td>
<td>81%</td>
</tr>
<tr>
<td><strong>CO2 emissions (Gt)</strong></td>
<td>23.0</td>
<td>32.1</td>
</tr>
</tbody>
</table>

*includes traditional biomass
Time is of the essence! Renewables will not deliver in time
Wind and PV in DE (2011-2014) even out (more or less)
January 2017 “Dunkelflaute”
Electricity production in Germany in January 2017

Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, Netztransparenz.de
Last update: 01 Oct 2017 11:22
Challenges posed by wind and PV

Challenges of intermittence

- Low wind in dark winter: dispatchable power must cover all peak load! (2\textsuperscript{nd} half of January 2017)
- Strong wind / PV > low demand: cut REN or export surplus + must-run thermal (1 January 2018)
- High volatility (during storms): all thermal in load following: 2-3 GW/h
- High less low wind: 200 h/a x 50 GW = 10 TWh (aluminium: 8 GWh/a)
- Export / import as a buffer, how long?

Wind, PV during 1-6 Jan 2018 (Eleanor)

Source: 50 Hertz, Amprion, Tenet, TransnetBW, ENSO-E
Monthly consumption and storage volume: power vs. gas (2012, TWh)

Source: Frontier Economics on the basis of ENTSO-E, IEA and the German Bundestag (2017)
Energy efficiency in buildings

Saving in building stock stagnates

• Energy saving in existing buildings (42 mln dwellings) is decisive
• Easy / economical measures have been implemented
• Lower gas prices make insulation unattractive
• Polystyrol on the decline (impact of the Grenfell disaster)

Sales of insulation materials in 1000 m³

Source: Interconnection Consulting
Heat pumps as major renewables in heating?

Obstacles to further deployment of heat pumps (6 mln by 2030)

- Major effect from use in existing building stock (42 mln dwellings)
- Only one third installed in existing buildings
- Restrictions in urban areas
- Decreasing yields at low temperatures
- Add to the winter peak load

Number of heat pumps and power consumption of heat pumps

Source: Bundesumweltamt
Renewables in industry

Renewables in industry: marginal

- Renewables ca 5%, constrained to waste from paper and pulp
- 50% of process heat > 500 degrees C
- Gas easy to handle at all temperatures
- Still 20% coal
- CHP potential for gas

Industrial heat consumption in TWh

Lessons from Germany on Renewables and Energy Efficiency

• 20-30 billion € / year since 2010

Result:

• Achieving share in electric renewables, but not in CO₂ reduction
• No substantial effect on energy efficiency / renewables outside electric renewables
• No all-electric world on the horizon
• Hydrogen produced via electrolysis needed to solve power storage
• Industry and heating can hardly switch to renewable electricity
Using up the carbon budget

• Estimates for the remaining carbon budget (for 1.5°C)
  • using global mean surface air temperature:
    • 580 Gt CO$_{2eq}$ at 50% probability or 420 Gt CO$_{2eq}$ at 66% probability
  • Or using GMST (global mean surface temperature):
    • 770 Gt CO$_{2eq}$ at 50% probability or 570 Gt CO$_{2eq}$ at 66% probability

• Present use: 42 +/- 3 Gt CO$_{2eq}$/year

• Estimate: current national mitigation ambitions would lead to global GHG emissions in 2030 of 52-58 GtCO$_{2eq}$/year

Source: IPCC, Global Warming of 1.5°C, summary for policymakers, p. 16
Breakdown of contributions to global net CO$_2$ emissions in four illustrative model pathways

P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

AFOLU: Agriculture, Forestry and other Land Use
BECCS: Bioenergy with Carbon Capture and Storage
from IPCC, October 2018 SPM, p. 19
Global indicators

<table>
<thead>
<tr>
<th>Pathway classification</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
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</thead>
<tbody>
<tr>
<td><strong>CO₂ emission change in 2030 (% rel to 2010)</strong></td>
<td>-58</td>
<td>-47</td>
<td>-41</td>
<td>4</td>
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<tr>
<td>→ in 2050 (% rel to 2010)</td>
<td>-93</td>
<td>-95</td>
<td>-91</td>
<td>-97</td>
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<td><em><em>Kyoto-GHG emissions</em> in 2030 (% rel to 2010)</em>*</td>
<td>-50</td>
<td>-49</td>
<td>-35</td>
<td>-2</td>
</tr>
<tr>
<td>→ in 2050 (% rel to 2010)</td>
<td>-82</td>
<td>-89</td>
<td>-78</td>
<td>-80</td>
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<tr>
<td><strong>Final energy demand</strong></td>
<td>-15</td>
<td>-5</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>→ in 2050 (% rel to 2010)</td>
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<td>21</td>
<td>44</td>
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<tr>
<td><strong>Renewable share in electricity in 2030 (%)</strong></td>
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<td>58</td>
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<td>25</td>
</tr>
<tr>
<td>→ in 2050 (%)</td>
<td>77</td>
<td>81</td>
<td>63</td>
<td>70</td>
</tr>
<tr>
<td><strong>Primary energy from gas in 2030 (% rel to 2010)</strong></td>
<td>-25</td>
<td>-20</td>
<td>33</td>
<td>37</td>
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<tr>
<td>→ in 2050 (% rel to 2010)</td>
<td>-74</td>
<td>-53</td>
<td>21</td>
<td>-48</td>
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<tr>
<td><strong>Primary energy from non-biomass renewables in 2030 (% rel to 2010)</strong></td>
<td>430</td>
<td>470</td>
<td>315</td>
<td>110</td>
</tr>
<tr>
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<td>1327</td>
<td>878</td>
<td>1137</td>
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<td><strong>Cumulative CCS until 2100 (GtCO₂)</strong></td>
<td>0</td>
<td>348</td>
<td>687</td>
<td>1218</td>
</tr>
<tr>
<td>→ of wich BECCS (GtCO₂)</td>
<td>0</td>
<td>151</td>
<td>414</td>
<td>1191</td>
</tr>
</tbody>
</table>

* Kyoto-gas emissions are based on SAR GWP-100
** Changes in energy demand are associated with improvements in energy efficiency and behaviour change
PA* and its consequences: a common global logic

PA: keeping well below 2.0°C, if possible 1.5°C

⇒ Keep within a budget of 770 mln t CO$_2$ eq; use of 42 Gt CO$_2$ eq/year: time is running

• renewables and energy efficiency will not deliver in time; nuclear limited and problematic

• overshooting 1.5°C, later compensated by BECCS ** – a mortgage on the future

⇒ fossil fuels have to be decarbonised quickly and on a large scale

⇒ decarbonisation pre-combustion*** of hydrocarbons to H$_2$ by MSR**** with large-scale disposal of CO$_2$

(disparity of the supply and demand pattern of electric renewables ⇒ balance by electrolysis of surplus power to H$_2$, use CH$_4$ system for transportation and storage; some energy to be delivered as molecules, not by wire ⇒ need for power **AND** H$_2$ infrastructure)

⇒ Fast system transformation from CH$_4$ to H$_2$ and push for large-scale carbon capture

* Sustainable atmosphere under the Paris Agreement implies carbon-free energy, not necessarily renewable, as long-term sustainable energy

** BECCS: bioenergy with carbon capture and storage

*** post-combustion produces energy as power, not as molecules

**** MSR: methane steam reforming
Properties

\( \text{CH}_4 \)
- GCV: 889 kJ/mol
Relevant for energy stored
- Wobbe Index: 53.45 MJ/Nm\(^3\)
Relevant for energy transport capacity

\( \text{H}_2 \)
- GCV: 286 kJ/mol
= 32% of \( \text{CH}_4 \)
- Wobbe Index: 48.34 MJ/Nm\(^3\)
= 90% of methane
(L – Gas: up to 46,8 MJ/Nm\(^3\))
- More compression needed
- More aggressive than \( \text{CH}_4 \)
- Check compatibility along chain and in applications
Decarbonising CH\textsubscript{4} pre-combustion by steam reforming: producing H\textsubscript{2} and safely disposing of CO\textsubscript{2}

Steam reforming (getting the energy out of C and of H\textsubscript{4}, less process losses):

- add H\textsubscript{2}O (steam) plus energy (endothermic reaction)
- Global industrial application (ca 150 bcm/year of natural gas)
- Possible for C, CH\textsubscript{4}, C\textsubscript{n}H\textsubscript{2n+2}, i.e. coal, gas and liquid hydrocarbons
  - C + 2 H\textsubscript{2}O \rightarrow CO\textsubscript{2} + 2 x H\textsubscript{2} \quad \text{coal: } 2 \text{H}_2 \text{pro } 1 \text{CO}_2
  - 2n x H\textsubscript{2}O + C\textsubscript{n}H\textsubscript{2n+2}, \quad \text{gas: } 4 \text{H}_2 \text{pro } 1 \text{CO}_2
    => n x CO\textsubscript{2} + 2n H\textsubscript{2} + n+1 H\textsubscript{2} \quad \text{hydrocarbons in general:}
    (3 + 1/n) H\textsubscript{2} \text{pro } 1 \text{CO}_2
  - Dispose of CO\textsubscript{2} in geological structures (EOR, EGR, depleted reservoirs, aquifers)
Decarbonising \( \text{CH}_4 \) pre-combustion by methane cracking: producing \( \text{H}_2 \) and safely disposing of \( \text{C} \)

Methane cracking: (getting the energy of \( \text{H}_2 \), less process losses plus getting carbon black)

- Experimental stage, next step TRL 6, using 3 m\(^3\)/h = 25 000 m\(^3\)/year
- \( \text{CH}_4 \) (889 kJ/mol) => C (carbon black) + 2 \( \text{H}_2 \) (GCV = 2 x 286 kJ/mol)
- Use C = carbon black, limited by market (<10 mln t/year at present), beyond that => dispose of C!
- Energy contained in C is produced (and transported), but principally lost (40% of energy of \( \text{CH}_4 \) plus process losses = more than 50%)
Time is of the essence!
And cooperation!
Reserve slides
Germany will fall short of its decarbonisation targets

GHG emissions in Germany as of 1990 (mln t CO$_2$ eq)

But it will meet its electric renewables target

Source: 50 Hertz, Amprion, Tennet, TransnetBW, Destatis, EEX
Eleanor in January 2018: testing the power system

Strömproduktion in Deutschland | Energy Charts

- Gestapelt
- Prozent
- Import Saldo
- Wasserkraft
- Biomasse
- Kernenergie
- Braunkohle
- Steinkohle
- Öl

Leistung (GW)

Datum

Notverzeichnung von Kraftwerken zur öffentlichen Stromversorgung.
Datengrundlage: 50 Hertz, Amprion, Tennet, TransnetBW, EEX
letztes Update: 24 Jan 2018 09:29
Structure of primary energy demand in Germany in 2017: gas 80% higher than all renewables

Source: www.statista.be
Sol lucet omnibus: but will PV come in time?
From: IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways (6 October 2018)

B. Projected Climate Change, Potential Impacts and Associated Risks

B1. Climate models project robust differences in regional climate characteristics between the present day and global warming of 1.5°C, and between 1.5°C and 2°C

C. Emission Pathways, System Transitions Consistent with 1.5°C Global Warming

C1. In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO₂ emissions decline by about 45% from 2010 levels by 2030, reaching net zero around 2050. Non-CO₂ emissions in pathways that limit global warming to 1.5°C show deep reductions, similar to pathways limiting warming to 2°C

C3. All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) in the order of 100-1000 Gt CO₂ over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak

D. Strengthening the Global Response in the Context of Sustainable Development and Efforts to Eradicate Poverty

D1. Estimate: current national mitigation ambitions would lead to global GHG emissions in 2030 of 52-58 GtCO₂eq/year. Avoiding the reliance on the future largescale deployment of CDR can only be achieved if global CO₂ emissions start to decline well before 2030
## Global indicators

The table below summarizes key indicators for global warming mitigation strategies.

<table>
<thead>
<tr>
<th>Global indicators</th>
<th>P1: No or low overshoot</th>
<th>P2: No or low overshoot</th>
<th>P3: No or low overshoot</th>
<th>P4: High overshoot</th>
<th>Interquartile range</th>
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<tbody>
<tr>
<td>Pathway classification</td>
<td></td>
<td></td>
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<tr>
<td>CO₂ emission change in 2030 (%)</td>
<td>-58</td>
<td>-47</td>
<td>-41</td>
<td>4</td>
<td>(-59, -40)</td>
</tr>
<tr>
<td>in 2050 (%)</td>
<td>-93</td>
<td>-95</td>
<td>-91</td>
<td>-97</td>
<td>(-104, -91)</td>
</tr>
<tr>
<td>Kyoto-GHG emissions* in 2030 (%)</td>
<td>-50</td>
<td>-49</td>
<td>-35</td>
<td>2</td>
<td>(-55, -38)</td>
</tr>
<tr>
<td>in 2050 (%)</td>
<td>-82</td>
<td>-89</td>
<td>-78</td>
<td>-80</td>
<td>(-93, -81)</td>
</tr>
<tr>
<td>Final energy demand** in 2030 (%)</td>
<td>-15</td>
<td>-5</td>
<td>17</td>
<td>39</td>
<td>(-12, 7)</td>
</tr>
<tr>
<td>in 2050 (%)</td>
<td>-32</td>
<td>2</td>
<td>21</td>
<td>44</td>
<td>(-11, 22)</td>
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<tr>
<td>Renewable share in electricity in</td>
<td>60</td>
<td>58</td>
<td>48</td>
<td>25</td>
<td>(47, 65)</td>
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<tr>
<td>2030 (%)</td>
<td>77</td>
<td>81</td>
<td>63</td>
<td>70</td>
<td>(69, 87)</td>
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<tr>
<td>Primary energy from coal in 2030</td>
<td>-78</td>
<td>-61</td>
<td>-75</td>
<td>-59</td>
<td>(-78, -59)</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>from oil in 2030 (%)</td>
<td>-97</td>
<td>-77</td>
<td>-73</td>
<td>-97</td>
<td>(-95, -74)</td>
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<tr>
<td>in 2050 (%)</td>
<td>-37</td>
<td>-13</td>
<td>-3</td>
<td>86</td>
<td>(-34, 3)</td>
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<td>from gas in 2030 (%)</td>
<td>-87</td>
<td>-50</td>
<td>-81</td>
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<td>(-78, -31)</td>
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<td>in 2050 (%)</td>
<td>-25</td>
<td>-20</td>
<td>33</td>
<td>37</td>
<td>(-26, 21)</td>
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<td>from nuclear in 2030 (%)</td>
<td>-74</td>
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<td>21</td>
<td>-48</td>
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<td>in 2050 (%)</td>
<td>59</td>
<td>83</td>
<td>98</td>
<td>106</td>
<td>(44, 102)</td>
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<td>from biomass in 2050 (%)</td>
<td>150</td>
<td>98</td>
<td>501</td>
<td>468</td>
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<td>in 2050 (%)</td>
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<td>36</td>
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<td>from non-biomass renewables in</td>
<td>-16</td>
<td>49</td>
<td>121</td>
<td>418</td>
<td>(123, 261)</td>
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<tr>
<td>2030 (%)</td>
<td>450</td>
<td>470</td>
<td>315</td>
<td>110</td>
<td>(243, 435)</td>
</tr>
<tr>
<td>in 2050 (%)</td>
<td>832</td>
<td>1327</td>
<td>878</td>
<td>1137</td>
<td>(575, 1300)</td>
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<tr>
<td>Cumulative CCS until 2100 (GtCO₂)</td>
<td>0</td>
<td>348</td>
<td>687</td>
<td>1218</td>
<td>(550, 1017)</td>
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<td>of which BECCS (GtCO₂)</td>
<td>0</td>
<td>151</td>
<td>414</td>
<td>1191</td>
<td>(364, 662)</td>
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<td>Land area of bioenergy crops in</td>
<td>22</td>
<td>93</td>
<td>283</td>
<td>724</td>
<td>(151, 320)</td>
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<td>2050 (million hectare)</td>
<td>-24</td>
<td>-48</td>
<td>1</td>
<td>14</td>
<td>(-30, -11)</td>
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<td>Agricultural CH₄ emissions in 2030</td>
<td>-33</td>
<td>-69</td>
<td>-23</td>
<td>2</td>
<td>(-46, -23)</td>
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<tr>
<td>(%)</td>
<td>5</td>
<td>15</td>
<td>3</td>
<td>-21</td>
<td>(-32, 4)</td>
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<tr>
<td>in 2050 (%)</td>
<td>6</td>
<td>-26</td>
<td>0</td>
<td>39</td>
<td>(-26, 1)</td>
</tr>
</tbody>
</table>

**NOTE:** Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above. *Kyoto-gas emissions are based on SAR GWP-100**

**Changes in energy demand are associated with improvements in energy efficiency and behaviour change.**