Power2Gas

CENTER OR PERIPHERY IN FUTURE ENERGY SYSTEMS

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PRESENTED BY
Jurgen Weiss

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There are many potential applications of P2G (and broader P2X) to replace NG

Global Gas Consumption by Sector

Source: BP Energy Outlook 2019
Climate change is the primary driver of interest in P2G

In many States/countries, gas use in power sector and buildings represents half of GHG emissions => huge potential for (renewable) P2G to address GHG issues
Replacing all NG with P2G by 2040/2050 seems unlikely (even without cost considerations)

Doing so would require about 10 times current global power generation capacity, and 75 times current wind and solar capacity.

The cost of P2G and its substitutes determines the potential role in electricity, buildings and industry.

Notes and Sources: Assumes 60% P2G conversion efficiency; Uses 2016 blend of wind and solar and 2016 capacity factor;
The future cost of P2G is highly uncertain and depends on the evolution of capital costs, operations and input costs.

P2G Cost Drivers

**Capital Costs**
*Electrolizer, Methanizer*

Q: Will capex decline like solar PV, batteries or less?

**Input Costs**
*Power, H₂O, CO₂*

Q: How cheap is power? Carbon, Water?

**Operations**
*Efficiency, Hours, OPEX*

Q: How much efficiency increase? How many full load hours?

2050 costs below $10/MMBtu seem possible only if electricity is very cheap, learning rates (20%) and annual deployment growth (30%) similar to solar PV.
Highly renewable electricity systems will likely have prolonged periods of surplus generation

- The IEA identifies the “sweet spot” for electrolyzer use between 3,000 and 6,000 hours per year, based primarily on electricity price duration curve
- Highly renewable/decarbonized electricity systems could have a significantly different price duration curve with significant hours of excess (curtailed) generation.
- Excess generation tends to occur during consecutive hours, so that low-cost electricity compatible with electrolyzer/methanizer operations may be available.

As a result, (very) low cost electricity may be a reasonable assumption.
Without carbon a price and cost declines P2G is more expensive than NG.
Even if “in the money”, P2G has to compete with other technologies.

<table>
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<th>Potential P2G Applications</th>
<th>Potential P2G Substitutes</th>
<th>Most likely P2G Applications</th>
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<tr>
<td><strong>Power</strong></td>
<td>Replace current gas-fired generation; long-term/seasonal storage</td>
<td>Seasonal or Multi-year storage</td>
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<td>Wind, solar PV, solar CSP, Nuclear, Batteries, Demand Response, EE, NG fired generation with CCUS Thermal storage, gravity storage</td>
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<td><strong>Transport</strong></td>
<td>Hydrogen Fuel Cell Vehicles or CNG</td>
<td>Aviation, shipping, some HDV</td>
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<td>Evs, drop-in biofuels</td>
<td>All with carbon price/High NG price markets</td>
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<td><strong>Non Combusted</strong></td>
<td>Hydrogen or RNG as feedstock</td>
<td>Very cold climates/HPs not feasible</td>
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<td>Hydrogen from NG with or without CCUS</td>
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<td><strong>Buildings</strong></td>
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<td>EE, Heat Pumps (GSHP, ASHP)</td>
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<td><strong>Industry</strong></td>
<td>Hydrogen/RNG for process heat</td>
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<td>NG/Hydrogen from NG with or without CCUS</td>
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100% renewable electricity system will have significant seasonal storage needs

**Hourly Electric Sector Load and Supply (New England)**

**Winter**
- Insufficient clean energy throughout the day; primarily gas required to meet load.

**Summer**
- Balancing required between day and night hours using storage.

**Spring**
- Excess clean generation throughout the day.

**Fall**
- Limited excess mid-day generation can be stored to meet some hours of deficiency; require gas for remaining supply.

Note: The figures show the generation and load profiles during a high demand day of the respective season.
P2G gas could be the “dispatchable fuel” needed in decarbonized power systems.

- Higher renewables shares likely increase both low and high price hours in the future, making P2G potentially competitive
- BUT: Other technologies may also compete (gravity storage, thermal storage, ??)
Some potential conclusions

- Evolution of Future P2G costs is highly uncertain
  - If cost declines like solar PV/batteries and power cheap, could be in the money with little/low carbon prices between 2030 and 2050 everywhere outside North America

- But Direct Electrification likely beats P2G where feasible/implementable
  - In transportation, personal transport, most MDV, perhaps even LDV – only some air travel, ships?!
  - In buildings, heat pumps – but serious implementation challenges

- Most likely markets where direct electrification is either infeasible or very hard to implement
  - Air travel, shipping, industrial (if carbon constraint), places where heat pumps don’t work or need expensive electrical upgrades

- When P2G delivery requires infrastructure (pipelines, distribution networks), question about P2G costs including network costs likely important if/as overall gas demand declines due to electrification
Dr. Jurgen Weiss is an energy economist with 25 years of consulting experience. He specializes in issues broadly motivated by climate change concerns, such as renewable energy, energy efficiency, energy storage and the interaction between electricity, gas and transportation. He spearheads Brattle’s electrification and deep decarbonization efforts. He works for electric utilities, NGOs and government entities in North America, Europe, and the Middle East.

Dr. Weiss holds a Ph.D. in Business Economics from Harvard University, an M.B.A. from Columbia University and a B.A. from the European Partnership of Business Schools. As a high school student growing up in Stuttgart, he worked on the Mercedes assembly line putting gas tanks into cars.

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