

## Attachment 1

### Annotated Bibliography of Power to Gas Studies

- 1) Altfeld, Klaus and Pinchbeck, Dave, *Admissable Hydrogen Concentrations in Natural Gas Systems*, Gas for Energy, March 2013.

“In certain parts of Europe we have the situation already where the generation of 'renewable' electricity from wind and solar energy has led, from time to time, to production plants being shut down because the electricity generated exceeds local requirements and the transportation or storage capacities are inadequate. It's a problem that will become even more severe in the future because construction of new electricity lines and high-capacity pumped storage power plants is a costly and very lengthy process. Projects are therefore being discussed in which the surplus electricity is used to power electrolyzers that will split water into its component parts, with the hydrogen being directly injected into natural gas pipelines for both storage and transportation. The concept has become known as "Power to Gas" or P2G. It is becoming more widely accepted that hydrogen could become an important energy carrier in the energy mix in the quest for sustainability, because it offers several benefits related particularly to the potential for energy storage. Indeed it's possible that, with the existing infrastructure, hydrogen/natural gas mixtures could be transported, stored and converted into electricity where required. However, if the addition of small quantities of hydrogen, up to 10 %, to natural gas pipelines is to be accepted, it must guarantee a technically feasible, economically viable and, crucially, safe system of storage, transportation and use...”

- 2) Harrison, K.W. and Martin, G.D., *Renewable Hydrogen: Integration, Validation, and Demonstration*, National Renewable Energy Laboratory, July 2008.

“One solution to this problem is to produce hydrogen through the electrolysis of water and use the hydrogen in a fuel cell or internal combustion engine to produce electricity during times of peak demand or as a transportation fuel.”

“Producing hydrogen with domestic renewable resources reduces the impact of greenhouse gases. Wind energy is currently the lowest cost renewable energy source, so it's the leading near-term candidate. Wind also is a variable energy source. In the mid- to long-term it may be beneficial to produce hydrogen when electricity created by the wind is not needed, and then add generation from hydrogen when electricity demand is high. Energy storage systems have the potential for addressing electric system integration issues inherent with variable wind energy resources, thereby enabling higher amounts of wind power on the electric system. This all aligns with the nation's interest in developing and demonstrating advanced hydrogen technologies to reduce our dependence on foreign energy resources, improve our air quality, and ultimately support our long-term economic viability.”

- 3) Altfeld, Klaus and Schley, Peter, *Development of Natural Gas Qualities in Europe*, European Journal of Gas Technologies, Distribution and Applications, February 2011.

“The concrete idea is therefore being pursued to use surplus electricity for the generation of hydrogen by electrolysis and inject the hydrogen generated directly into the natural gas network. This will cause natural gas and electricity networks to become ever more interdependent.”

- 4) Judd, Robert and Pinchbeck, Dave, *Power to Gas Research Roadmap: Offering a Solution to the Energy Storage Problem?*, Gas for Energy, February 2013.

“P2G approach uses the renewably generated (green) electricity for electrolysis to split water into hydrogen and oxygen. In some cases this could also be followed by methanation, combining carbon dioxide and hydrogen into methane, thereby re-using carbon dioxide and creating synthetic and renewable natural gas. The huge capacity of the existing natural gas grid can then be used to store and transport the renewably produced gas, positioning it at the heart of the transforming European energy system.”