RUNNING THE WORLD ON RENEWABLES VIA HYDROGEN TRANSMISSION PIPELINES WITH FIRMING GEOLOGIC STORAGE

William C. Leighty [1]

Fritz Crotogino [2]

ABSTRACT

Four problems seriously interfere with sustainable development and compel humanity to soon energize the world on renewable energy – plus probably a century of some nuclear energy:

1. Rapid climate change, also known as global warming or global climate change;
2. Depletion of conventional fossil fuels; eventual depletion of all fossil fuels;
3. Desired energy security via indigenous resources, both distributed and centralized;
4. Balance of trade payments, for energy imports.

The world's richest renewable energy resources – of large geographic extent and high intensity – are stranded: far from end-users with no gathering and transmission systems to deliver the energy. The energy output of most renewables varies greatly, at time scales of seconds to seasons: the energy capture assets thus operate at inherently low capacity factor (CF); energy delivery to end-users is not "firm". New electric transmission systems, or fractions thereof, dedicated to renewables, will suffer the same low CF as the energy sources, and represent substantial stranded capital assets, which increases the cost of delivered renewable-source energy.

At gigawatt (GW) scale, renewable-source electricity from diverse sources, worldwide, can be converted to hydrogen and oxygen, via high-pressure-output electrolyzers, with the gaseous hydrogen (GH2) fuel pipelined to load centers (cities, refineries, chemical plants) for use as vehicle fuel, combined-heat-and-power generation on the retail side of the customers' meters, ammonia production, and petroleum refinery feedstock. The oxygen byproduct may be sold to adjacent dry biomass and / or coal gasification plants. Figures 1-2. New, large, solution-mined salt caverns in the southern Great Plains, USA, northern Germany, and elsewhere in the world, can economically store enough energy as compressed GH2 to "firm" renewables at annual scale, adding great market and strategic value to diverse, stranded, rich, renewable resources. Figure 3. For example, Great Plains, USA, wind energy, if fully harvested, "firmed" at annual scale, and transmitted to markets, could supply the entire annual energy consumption of the USA: ~ 100 exajoules; ~ 100 quads. Firming this quantity as GH2 fuel would require about 15,000 new solution-mined salt caverns, at an incremental capital cost to the GH2 generation-transmission system of ~ 5%.

Germany has found that GH2 geologic storage in salt caverns is superior to compressed air energy storage (CAES) in several ways important to firming and integrating wind energy on the electricity "grid". [3] Figure 4.

---

[1] Director, The Leighty Foundation, Box 20993, Juneau, AK 99802 USA, wleighty@earthlink.net , www.leightyfoundation.org/earth.php

[2] Fritz Crotogino, KBB Underground Technologies Gmbh, Hannover, Germany

[3] Fritz Crotogino, Sabine Huebner, KBB Underground Technologies Gmbh, Hannover, Germany, "Energy Storage in Salt Caverns: Developments and Concrete Projects for Adiabatic Compressed Air and for Hydrogen Storage", SMRI 2008 Spring Technical Conference, 28-29 April, Porto, Portugal

We report the results of several studies of the technical and economic feasibility of large-scale renewables – hydrogen systems. Windplants are now the lowest-cost new renewable energy sources; we focus on wind, although photovoltaic (PV) and concentrating solar power (CSP) are probably synergistic and will become attractive in cost. The largest and richest renewable resources in North America, with high average annual windspeed and sunlight, are stranded in the Great Plains: extant electric transmission capacity is insignificant relative to the resource potential. Large, new, electric transmission systems will be difficult to site and permit and may be difficult to finance, because of public opposition, uncertainties about transmission cost recovery, and inherently low CF in renewables service. This is a global opportunity.

The natural gas pipeline and storage industry's good economic and safety record are an encouraging example for GH2 fuel. The industrial gas companies' decades of success and safety in operating thousands of km of GH2 pipelines worldwide is encouraging, but these are relatively short, small-diameter pipelines, and operating at low and constant pressure: not subject to the technical demands of renewables-hydrogen service, nor to the economic challenge of delivering low-volumetric-energy-density GH2 over hundreds or thousands of miles to compete with other hydrogen sources at the destination. The salt cavern storage industry is also mature; several GH2 storage caverns have been in service for over twenty years; construction and O&M costs are well understood.

A pilot plant will now be needed to discover and demonstrate the technical and economic advantages of renewable-source GH2 pipeline transmission, delivery, storage, and utilization, for worldwide sustainable development potential. A public-private collaborative must be assembled to begin the process to conceive, design, bid, build, own, and operate the pilot plant. This process will identify upstream necessary R+D, be alert for "show-stopper" fatal flaws in this transmission + storage scheme, and identify candidate sites for the pipeline corridor and destination community. Issuing a credible RFP or RFQ will be a major milestone; responses thereto will determine at least the construction cost. This project transcends the EC's "NaturalHY" project, whereby renewable-source GH2 fuel is injected into the extant EU natural gas transmission pipeline system, to deliver a lower-volumetric-energy, cleaner-burning fuel of limited GH2 content.

The incremental capital cost and O&M cost of enough salt cavern storage to "firm" renewables, excluding geothermal which is baseload and inherently firm, at annual scale, are explored. "Firm" shall mean the ability to deliver the contracted amount of energy every hour of every year; no known or anticipated scheme of "electricity" storage can affordably firm renewables at annual scale.

Earth's aggregate diverse renewable energy resources can supply all humanity's energy needs, but GH2 transmission and storage will be needed to approach this sustainable development goal. We cannot achieve sustainability with electricity transmission, alone.

This paper builds on work previously presented at two World Gas Conferences, International Gas Union, in '03 and '06. [4, 5, 6]

---

4 *Large Renewables - Hydrogen Energy Systems: Gathering and Transmission Pipelines for Windpower and other Diffuse, Dispersed Sources,* World Gas Conference 2003, Tokyo, International Gas Union

5 *Compressorless Hydrogen Transmission Pipelines Deliver Large-scale Stranded Renewable Energy at Competitive Cost*, World Gas Conference 2006, Amsterdam, International Gas Union

6 *From a Natural-gas-based to a Hydrogen-based Society: Proposal for a Northeast Asian Hydrogen Highway,* World Gas Conference 2006, Amsterdam, International Gas Union

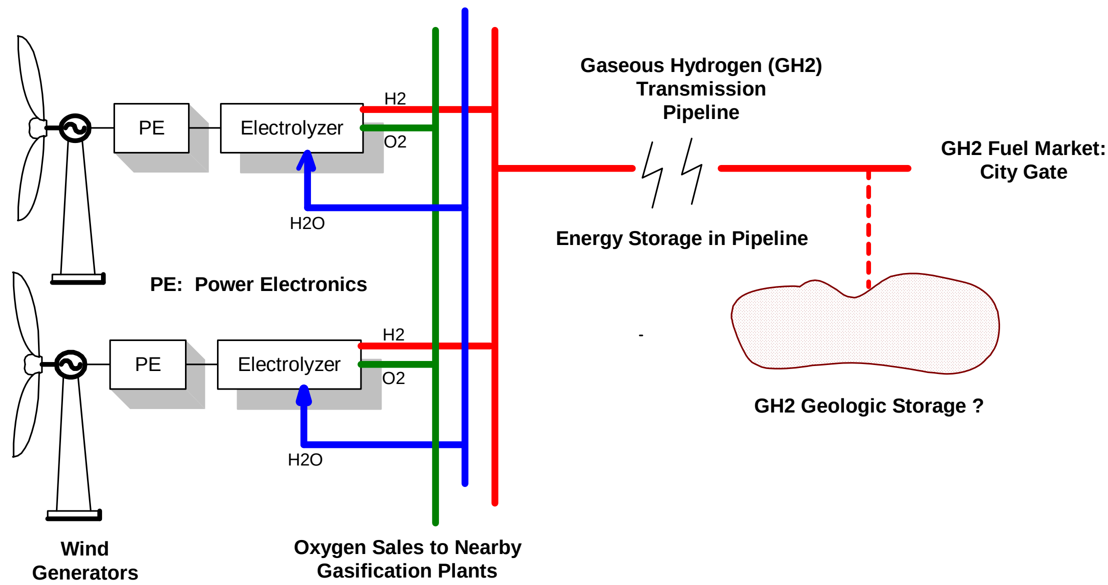

Figure 1. Generation, conversion, gathering, firming storage, and transmission of diverse renewable resources

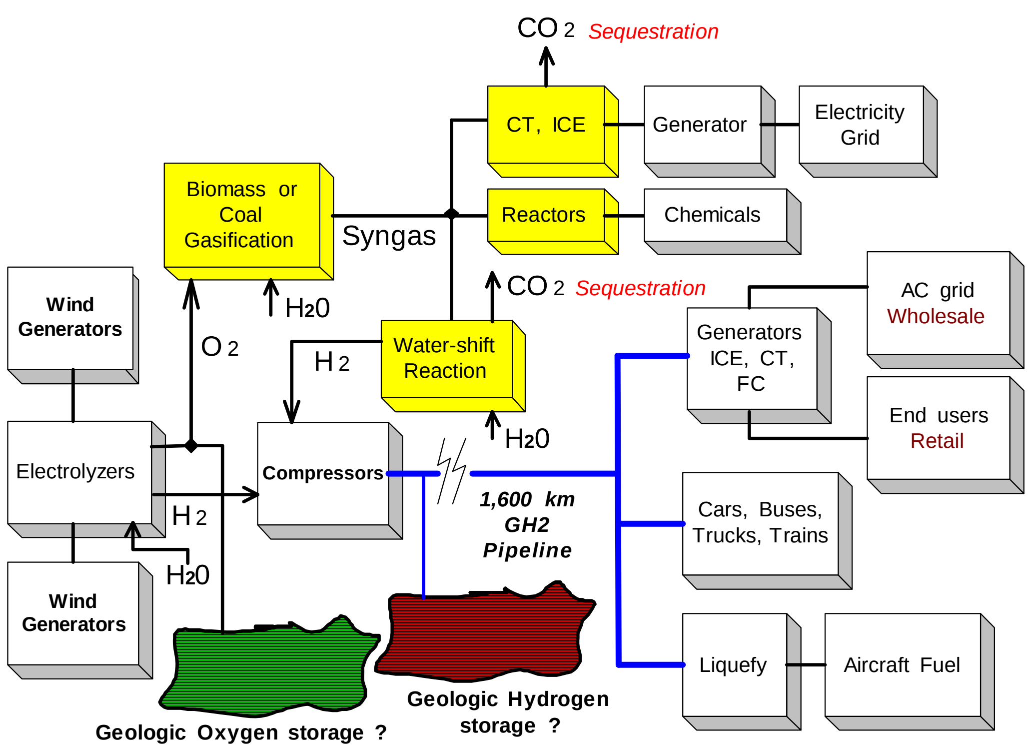

Figure 2. System options: compression and oxygen byproduct use at adjacent gasification plant

Figure 3. “Domal” and “bedded” salt deposits in USA; some are useful for cavern storage of GH2

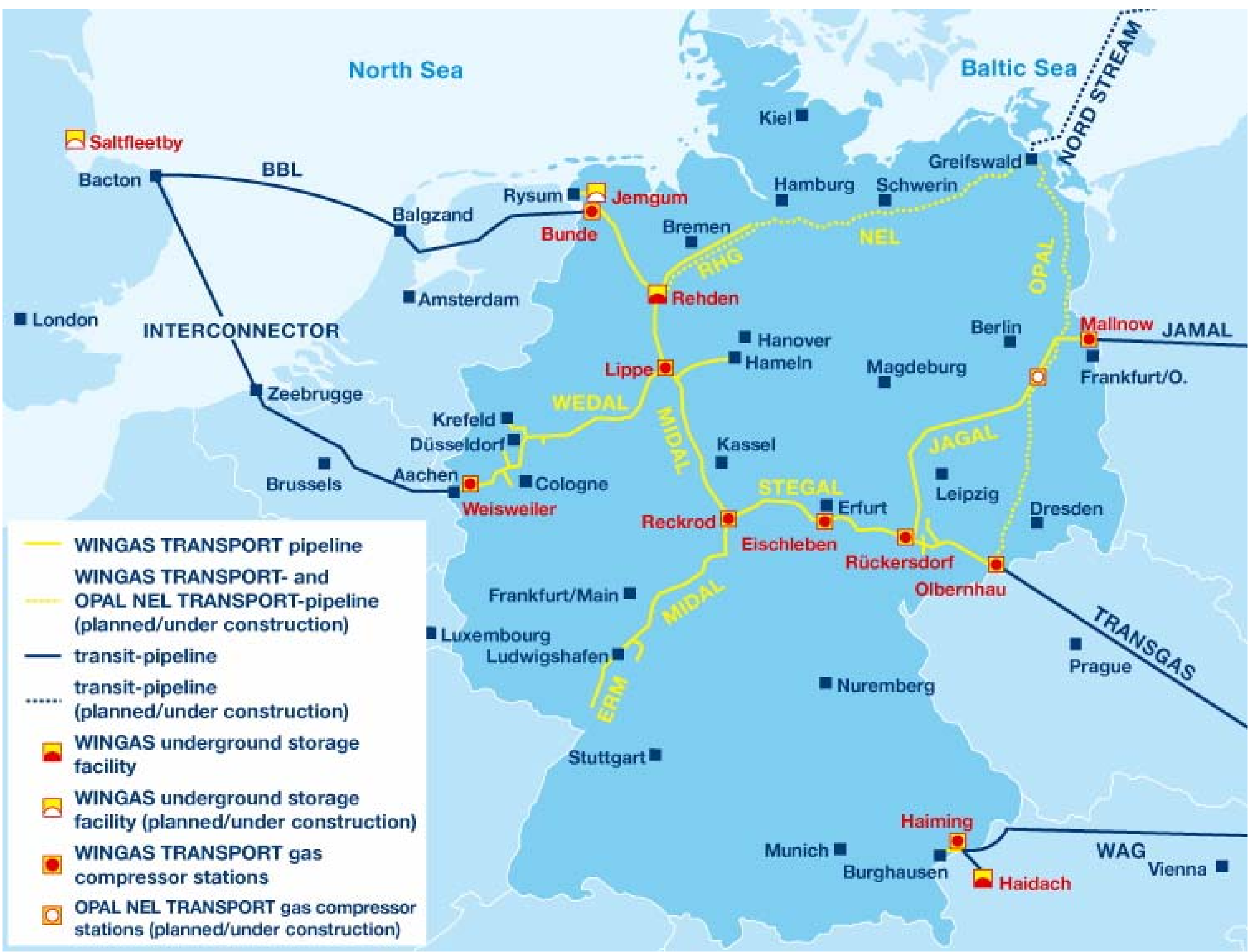

Figure 4. Germany natural gas transmission pipelines and underground storage