Compressorless Hydrogen Transmission Pipelines Deliver Large-scale Stranded Renewable Energy at Competitive Cost

- May hydrogen fuel be a bigger market for GW-scale wind than electricity transmitted to the grid?
- How far may wind-source hydrogen (GH2) fuel be pipelined without costly compressors?
- What is the cost of wind-source GH2, pipelined 300 - 1,600 km, at a city-gate market?

Key assumptions:
1. Year 2010 technology and markets: results in 2005 $US
2. A single 1.000 MW (nameplate) windplant in Great Plains achieving maximum economies-of-scale and high windplant capacity factor (CF)
3. No connection to electric transmission grid, which, by 2020:
   - Has become saturated with windpower;
   - Has not been expanded, due to cost and permitting obstacles
4. All wind energy is converted to gaseous hydrogen (GH2), for pipeline transmission
5. Total installed capital costs:
   - Wind generators: $800 / kW
   - Electrolyzers, less transformer-rectifier subsystem: $300 / kW
   - Hydrogen pipeline, 100 bar, 20" diam: $880,000 / km
6. 40% windplant CF; 15% capital recovery factor (CRF)
7. High-pressure-output electrolyzers directly feed pipeline at 100 bar
8. No compressors, either at source nor along pipeline
t9. Hydrogen-capable pipelines can be built and safely operated for the same cost as natural gas pipelines of same diameter and pressure
10. Pipeline energy storage cannot "firm" windplant output at hourly-to-daily time scale
11. A market for GH2 hydrogen fuel at the pipeline destination city, but competition from "firm" GH2 fuel from natural gas via SMR
12. Hydrogen transmission pipelines can be built for the same cost as natural gas pipelines of same diameter and pressure. The critical materials problem of hydrogen embrittlement of pipeline steel will be managed.

* SMR: Steam Methane Reforming, a mature industrial process which produces >90% of world annual consumption of 90 million tons of hydrogen

Conclusions:
1. Wind-generated hydrogen fuel can be delivered to a city-gate market, 300 – 1,600 km away by pipeline, for $1.25 – 4.25 per kg, depending primarily on assumed:
   - Subsidies and value-adding features
   - Capital recovery factor (CRF): 15% assumed
   - Pipeline length
   This is competitive with today’s price of gasoline.
2. Potential “value-adding” economic features reduce cost of delivered GH2:
   - US federal PTC of $0.019 / kWh
   - Sales oxygen byproduct of electrolysis to adjacent gasification plants for $20 / ton O2
   - Carbon-emission-offset credit, estimated at $0.11 / kWh
3. 20" diam hydrogen pipeline capacity is – 1.8 GW at 100 bar input, 30 bar output, 320 km long
4. The pipeline provides valuable energy storage, smoothing windplant output, at minute-to-hourly time scale, but is inadequate for seasonal smoothing, for "firming" the wind energy supply. Large-scale, low-cost, GH2 geologic storage, in natural or man-made (solution-mined salt cavern) formations, will be needed to "firm" wind at annual scale.
5. High-pressure-output electrolyzers eliminate costly compressors from the entire system
6. The oxygen byproduct of electrolysis may be sold to nearby biomass or coal gasification plants, adding value and revenue
7. Biomass and other renewable energy sources may synergistically improve pipeline CF. We will need a pilot-scale pipeline system to explore and confirm this benefit.
8. Hydrogen system pipeline and other steel components must be designed to accommodate hydrogen embrittlement in “renewables-hydrogen service”.
9. New underground hydrogen pipelines may be more secure and easier to permit than new overhead electric lines.

We can deliver GW-scale windpower – source gaseous hydrogen (GH2) fuel, hundreds of km by pipeline, at an untaxed cost per unit energy comparable to today’s gasoline. But, will the urban market pay for this un-firm source of hydrogen?