Large Stranded Renewables: the International Renewable Hydrogen Transmission Demonstration Facility (IRHTDF)

Larges Renouvelables Isolées: Centre international de démonstration pour le transport d'hydrogène renouvelable (CIDTHR)

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1. Introduction *Introduction*

We assume humanity's goal is an equitable, affordable, accessible global energy system based on benign, renewable sources: "solar" in its many forms, including PV, wind, biomass, biological, thermal, geothermal; perhaps others than solar. Earth's richest renewable resources are generally stranded, requiring costly new gathering and transmission systems to bring this energy to distant markets.

We propose that the international hydrogen (H_2) community starts immediately to design and build a pilot-scale gaseous hydrogen (GH2) pipeline system that would collect energy from diverse renewable sources, such as wind and biomass, and transport it cross-country to a small community or a university campus where it would be used for vehicle and distributed-generation fuel. This would be an international renewable-source hydrogen transmission demonstration facility (IRHTDF). International collaboration on preliminary design would lead to an RFP for final design, construction, and operation: an ideal project for the International Partnership for the Hydrogen Economy (IPHE).[i]

Designing and building it would require us to confront and solve a variety of technical, economic, and social challenges. Its successful operation will allow us to estimate the cost of H_2 fuel, delivered to major markets, from large-scale gathering and long-distance transmission of diverse, stranded, renewable sources.

Pipelining GH2 will cost ~ 1.5 to 2 times the cost of natural gas (NG), per unit energy-distance. [ii], [iii], [iv], [v] In a recent study, the cost per kg, at end-of-transmission-pipeline, for GH2 transported 1,600 km from a large wind-electrolysis source via dedicated pipeline, approaches $US 10. [vi] Absent very high energy taxes for external costs, this price seems not competitive. However, GH2 pipeline transmission of diverse renewables may provide important synergies and substantial added value.

Transmission pipelines are very complex and costly systems that must be optimized, from sources to end uses, for net present value, NPV. Some reject a GH2 energy sector as too inefficient. [vii] RMI's Amory Lovins and Germany's LBST respond. [viii], [ix] We need empirical results from the IRHTDF to reveal synergies and economic benefits, to resolve this efficiency-vs-cost conflict. If IRHTDF operation demonstrates low benefit / cost for delivered GH2, under favorable synergistic conditions, we have good cause to set aside this option for more attractive energy investments and policies. Meantime, the EC, via Gasunie Research and the "NaturalHy Project", will "… test all the critical components of a full hydrogen system by adding hydrogen to natural gas in existing [pipeline] networks" . [x]

2. Launching the renewables-hydrogen sector

Lancement du secteur d'hydrogène renouvelable

We should launch the renewables-hydrogen energy sector of a carbon-emissions-free global energy economy now, fueling ICE-hybrid vehicles until fuel cells are widely available. Renewables are ready. Windpower now costs US 4 – 5 cents per kWh, unsubsidized, at the windplant gate, at a good wind resource; perhaps US 3 cents long-term, at large scale. But, much of the world's richest wind, and other renewable, resources are stranded. We will need to build many large, new transmission systems to bring this energy to distant markets. The wind resources of the twelve Great Plains states of the USA, if fully harvested annually, would equal the entire energy consumption of the USA in year 2002: about 10,000 TWh (~ 900 Mtoe).

Delivering all Great Plains wind energy as electricity would require about 900 of the largest-practical new electric transmission lines: 3,000 MW, HVDC, +/- 600 kv. Fossil generation would be displaced, and H_2 fuel could then be made, at or near point-of-use, from electricity by large or small electrolyzers. At large scale, electric distribution systems must be enlarged to bring this new energy to "distributed generation" (DG) in large or small electrolyzers.

Alternatively, we could deliver all this wind energy as compressed H_2 gas, via about 400 new GH2 pipelines, ~1 m (36") diam, ~7 MPa, capacity ~2,400 ton/day. GH2 pipelines provide valuable energy storage, which electricity transmission cannot. New underground GH2 pipelines might be easier to site and permit than large, new overhead electric transmission lines. H_2 fuel from large pipeline terminals would be distributed via GH2 tube trailers, LH2 trucks, and low-pressure GH2 pipelines.

3. Gaseous hydrogen (GH2) pipelines *Pipelines d'hydrogène gazeux (H2G)*

Figure I. A 1998 NREL study [xi] shows that, at large-scale (> 1 GW) and long distance (> 500 km), GH2 pipeline is the lowest-cost way to transport H_2. A new UC Davis study confirms; see Figure II [xii]. Although industry has been safely pipelining H_2 for decades, no pipeline system has been designed and optimized for large-scale, long-distance, cross-country transmission of diverse, dispersed, time-varying renewable sources, at minimum cost, and providing energy storage.

The capital, O+M, and transmission loss costs of large electricity and GH2 pipeline systems are comparable: at ~ 1,200 km delivered wind energy cost is twice plant-gate cost. Pipelining GH2 at large scale will cost ~ 1.5 – 2 times more than pipelining NG, per unit energy, because:

1. GH2 volumetric energy density is only one-third that of NG;
2. H_2 attack on steel ("hydrogen embrittlement") must be prevented;
3. Low H_2 molecular weight requires more compression power and energy;
4. Compressors, meters, valves, fittings are more costly.

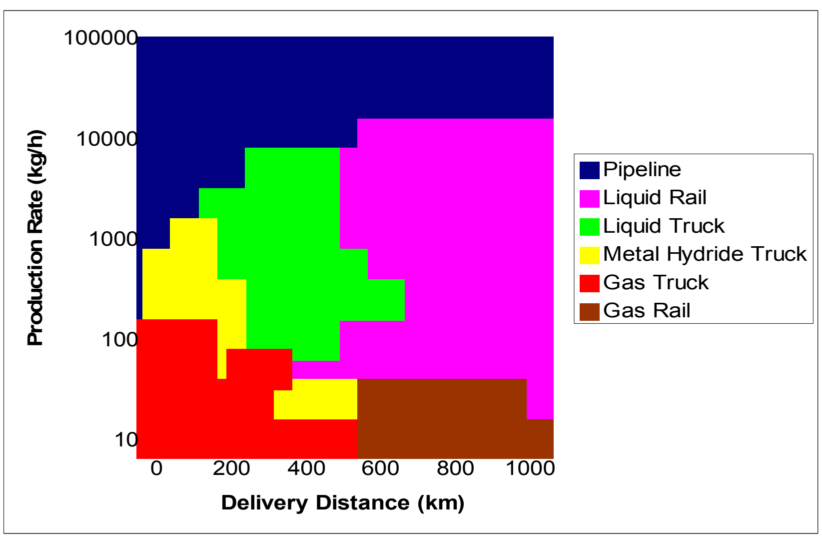

Figure I. Cost of transporting H_2. [xi]. GH2 pipeline (blue) is the lowest-cost H_2 transmission path at high-capacity and long-distance. Approximate capacity of 12" pipeline @ 7 MPa = 10,000 kg/hr = 240 tons per day = 400 MW. Approximate capacity of ~1m (36") diameter GH2 pipeline @ 7 MPa = 100,000 kg/hr = 2,400 tons per day = 4,000 MW.

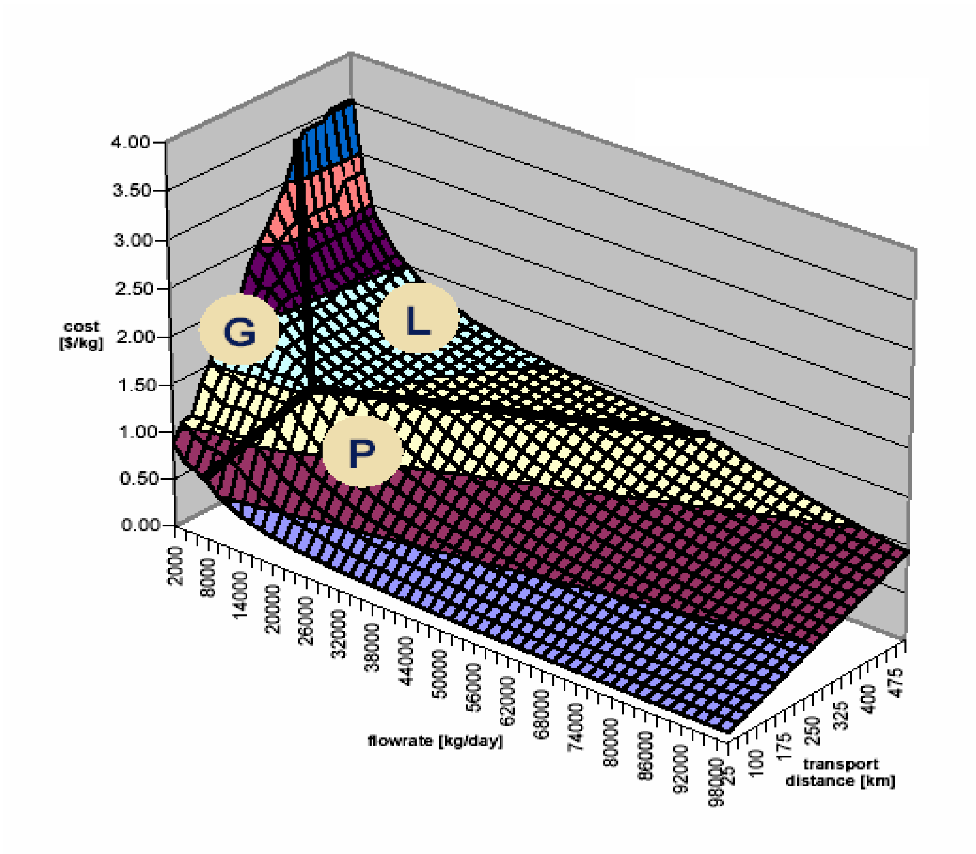

Figure II. Costs of transporting hydrogen as function of distance and flowrate; G is compressed gas cylinders; L is liquefied; P is compressed gas pipeline. Combined analyses of three scenarios. [xii]

But, GH2 pipeline transmission adds important value to renewable-source energy:

1. Energy storage, as compressed GH2, in:
    a. Source equipment, such as wind generator tubular towers; [xiii]
    b. The gathering and transmission pipelines;
    c. Geologic formations along the pipeline system corridor;
    d. End-use facilities and equipment, such as vehicle fuel tanks;
2. Higher transmission system capacity factor;
3. Byproduct oxygen from electrolysis is available for dry biomass gasification;
4. Seasonal resource variability is complemented, among diverse renewables;
5. Small sources may deliver to the pipeline, via simple and low-cost "on ramps";
6. Electric generating system, on wind turbine or other renewable source, is simpler, lower in capital and O&M cost, if driving only a DC electrolyzer load rather than a utility grid.

We must both minimize the costs and enhance the value-adding benefits of GH2 pipelining if large-scale stranded renewable energy sources are to be brought to market at competitive prices.

We must empirically discover and demonstrate what these costs and synergistic benefits will be, for H_2 from large-scale, distant, diverse, diffuse, dispersed renewable energy sources, whose output varies widely at minute to hourly, and seasonal to decadal, time scales. We can then estimate the long-term cost of H_2 delivered to load centers for vehicle and distributed generation (DG) fuel, to guide policy and resource allocation among the several salient methods of H_2 generation. A pilot-scale IRHTDF is necessary for this research; on the critical path to renewable-hydrogen energy sectors.

Electricity transmission for large-scale stranded renewables is a mature, available, and economical alternative to GH2 pipelines. But new electric transmission lines are difficult to site and permit; pipelines may be easier, faster. Pipelines provide significant energy storage; electric lines do not. [xiv]

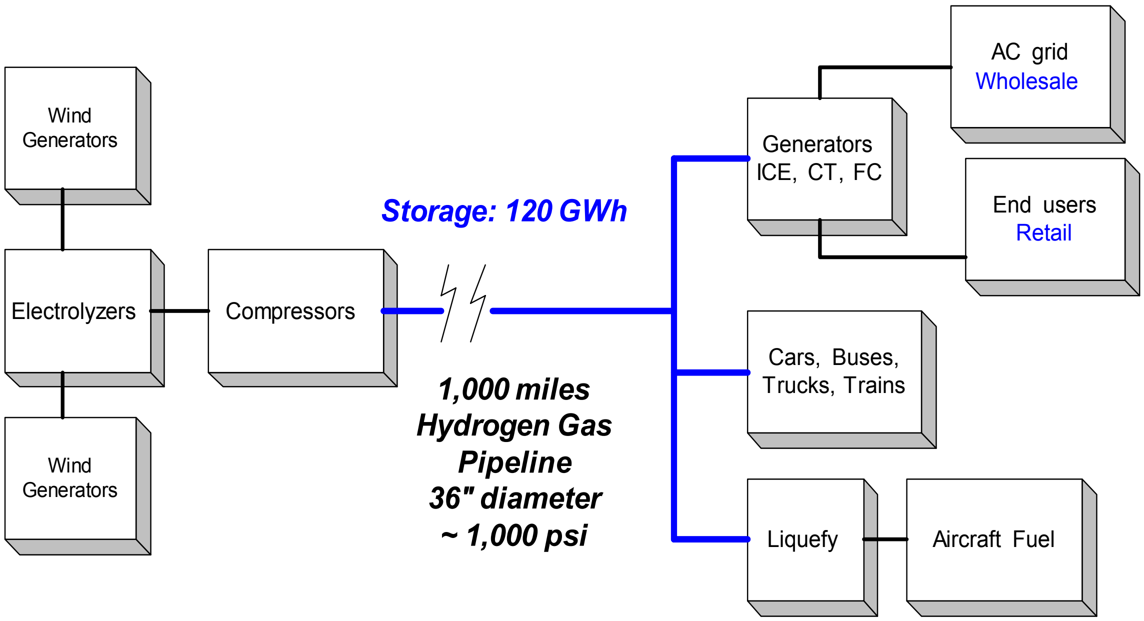

Figure III. Hydrogen transmission system for wind generation, with low-pressure-output electrolyzers and multiple end-users. A 1 m-diameter pipeline, packed to 70 bar when the wind is strong, will store 120 GWh as the customers un-pack the pipeline to 35 bar when the wind, or other electricity-generating renewable source, is interrupted.

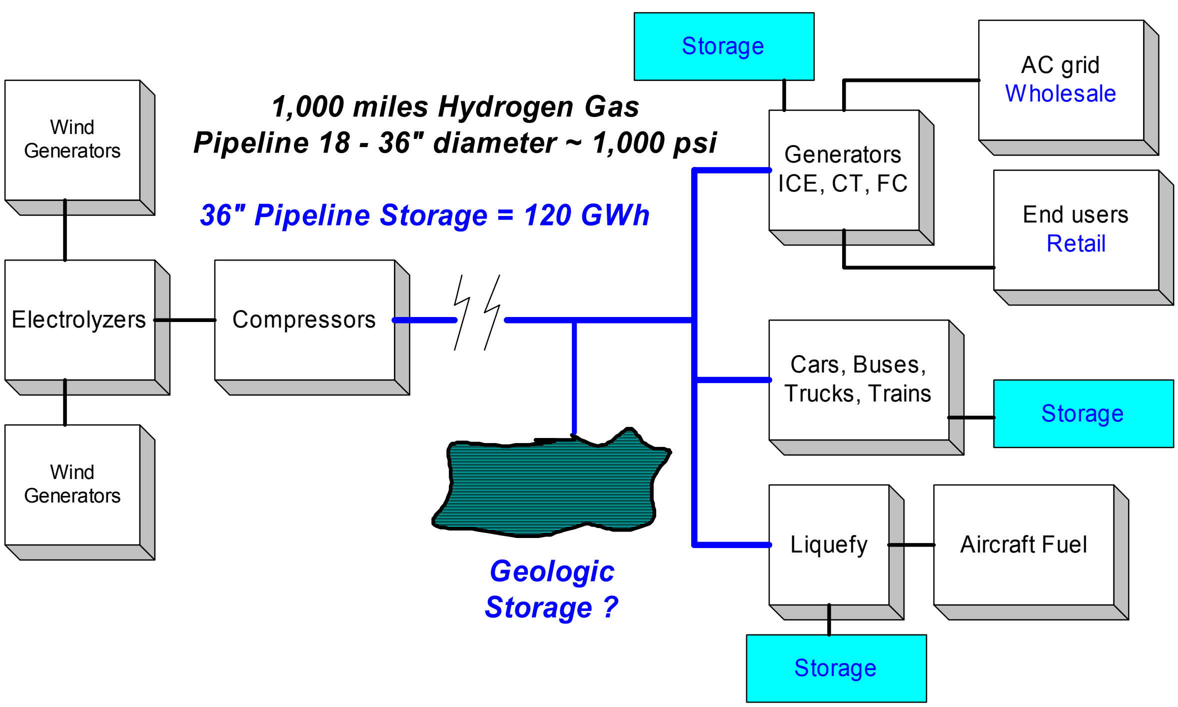

Figure IV. Value added to time-varying renewable energy sources by storage as compressed GH2 in source and destination devices, in pipeline, and perhaps in geologic formations along the corridor.

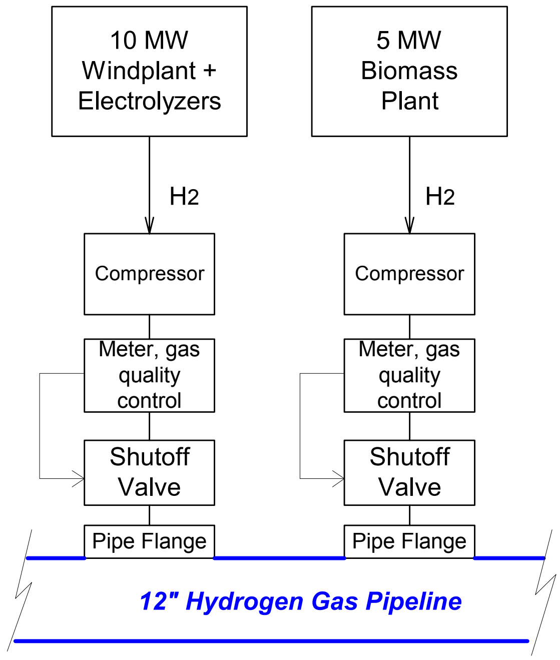

Figure V. GH2 is delivered to the IRHTDF, as it would be to all GH2 pipelines, via a large number of simple, low-cost nodes of widely varying capacity.

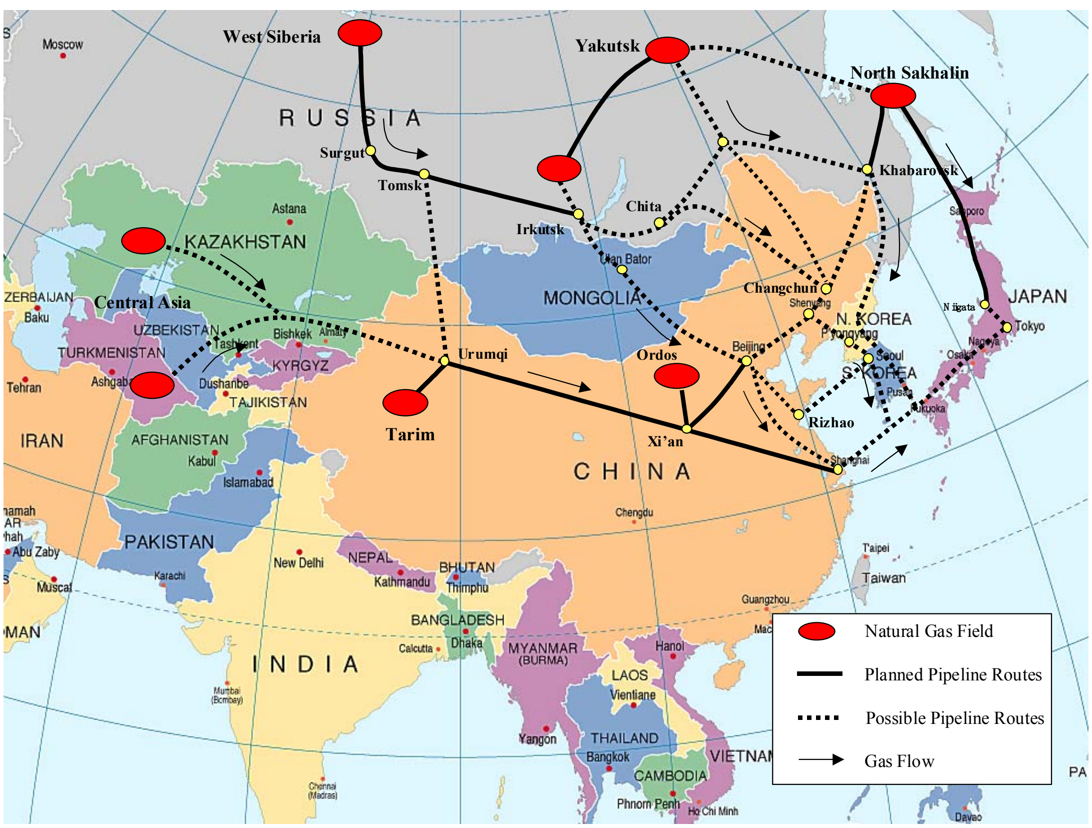

Figure VI. Northeast Asia Natural Gas Pipeline Network, Proposed by Northeast Asia Natural Gas & Pipeline Forum in 2000, which might be built of GH2-capable line pipe for future RHS.

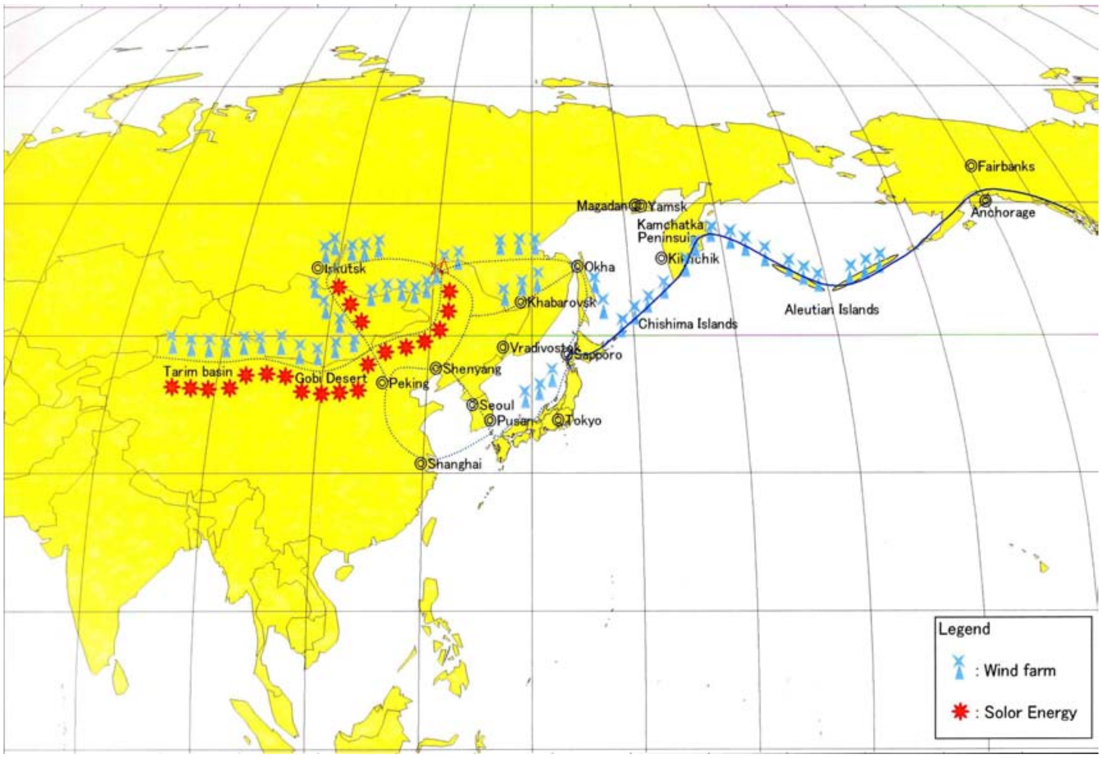

Figure VII. Future large-scale renewable energy sources may deliver GH2 to a new, RHS - capable, NG gathering and transmission pipeline system.

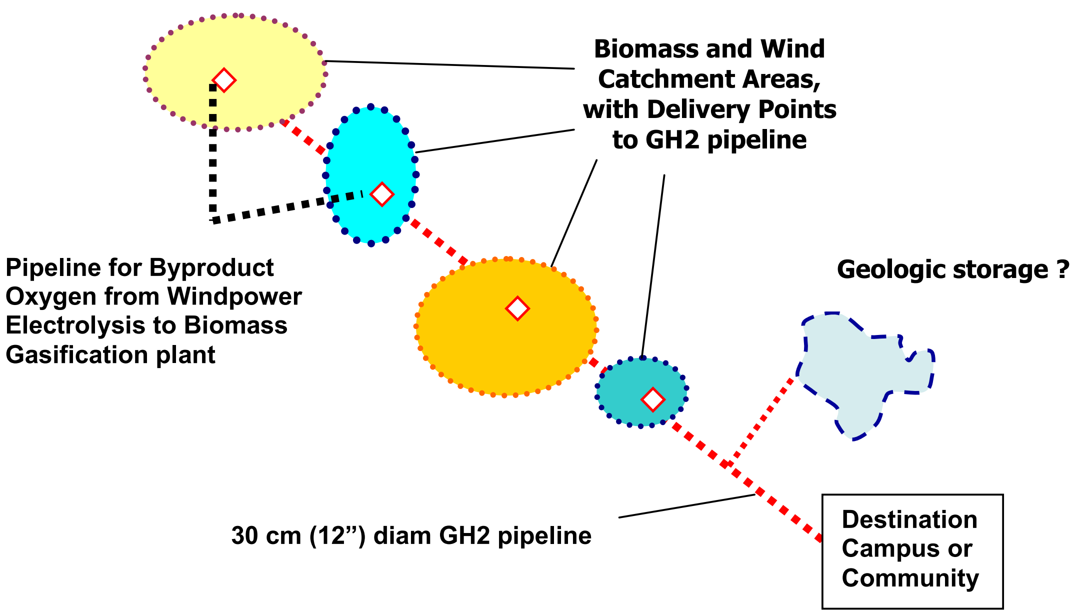

Figure VIII. IRHTDF is not only a pipeline, but a corridor of synergistic renewable energy generation, conversion, transmission, storage, and end-use, plus utilization of the oxygen byproduct of electrolysis. Such corridors must be optimized systems to deliver GH2 at competitive cost.

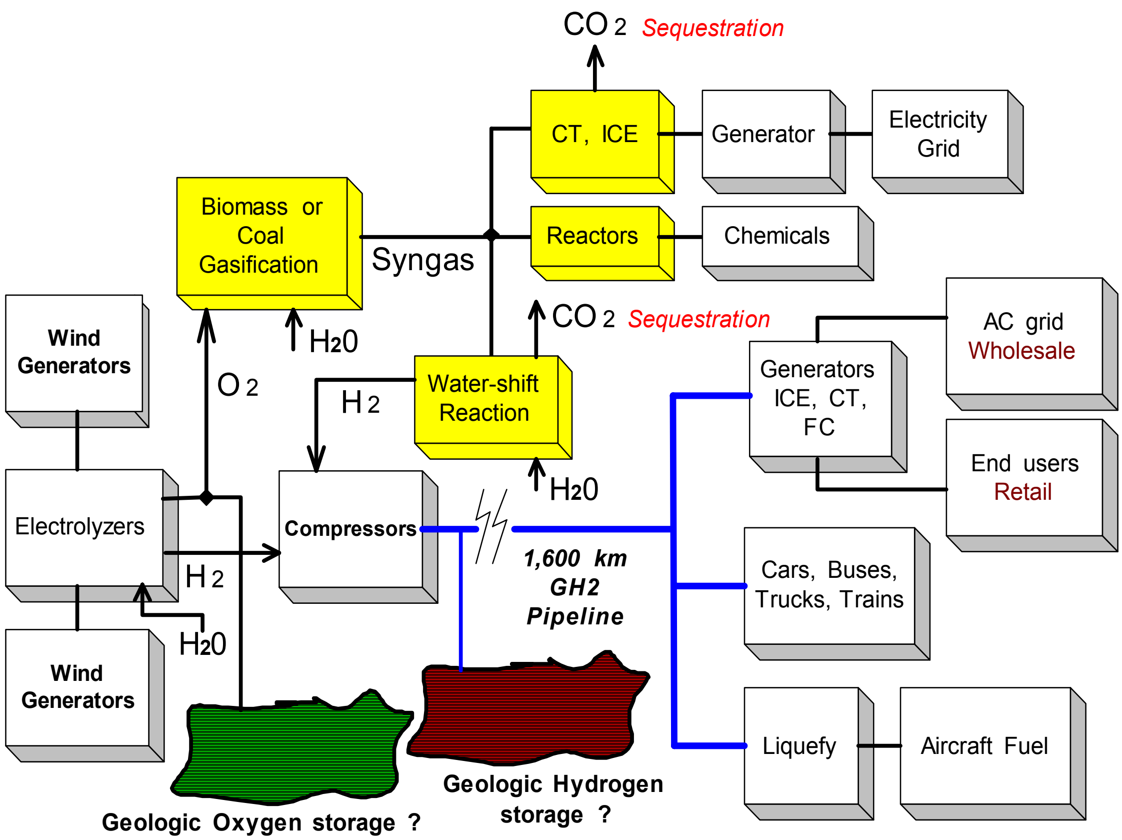

Figure IX. IRHTDF advanced system, using oxygen (O_2) byproduct of electrolysis for synergistic biomass and "near zero emissions" coal gasification. Feasibility of large-scale geologic storage of H_2 and O_2 is unknown.

4. New NG pipelines may be GH2-capable, for Renewables-Hydrogen Service (RHS)

Nouveaux pipelines de gaz naturel capables de transporter de l'hydrogène gazeux produits d'hydrogène renouvelables

Japan, Russia, China, and others plan a very large new NG transmission pipeline system in the Russian Far East. [xv], [xvi] See Figures VI, VII. Japan asks:

1. Whether it should be built of hydrogen-capable line pipe, so that GH2 may be added to the natural gas from diverse renewable sources all along the route, finally to 100% H_2;
2. What line pipe is suitable;
3. What is the incremental capital cost for this capability for 100% H_2 transmission from diverse, distributed, time-varying renewable sources?

Should all new NG pipelines, globally, be designed and constructed as GH2-compatible? The initial incremental investment in line pipe oversized in diameter and pressure capability for NG service may be difficult to justify; it represents excess, unused capacity during the period of NG service.

5. IRHTDF concept: a pilot-scale GH2 pipeline system

Le concept CIDTHR: un pipeline d'hydrogène gazeux à l'échelle pilot

See Figures III, IV, V, VIII, IX, which emphasize system design, and technical and economic synergy. The IRHTDF is essentially:

1. A GH2 pipeline, ~ 30 cm (12") diam, for easy pigging inspection and for energy storage;
2. >100 MW (2,500 kg / hr) capacity;
3. ~ 30 – 100 km long, cross-country, through public and private land, to destination community or campus;

4. > 10 MPa; capable of 2:1 pressure cycling at daily time scale without H_2 - attack damage;
5. 100% GH2 from multiple, diverse renewable sources and sizes: wind, biomass, etc.;
6. Optimized to demonstrate GH2 generation, conversion, gathering, transmission, storage, and distribution.

The IRHTDF embraces several opportunities, problems, and hypotheses at once:

1. Renewable-source H_2 can make a major contribution, in both short and long term;
2. GH2 can be transported long distance, at large scale, economically and safely;
3. Large scale energy storage can firm renewables, by:
    a. Integrating energy harvest over very large catchment areas;
    b. Stockpiling biomass feedstocks;
    c. Perhaps storing GH2 in geologic formations at very large, seasonal scale.
4. Synergy among diverse renewable sources at a wide range of generation capacity;
5. Synergistic use of oxygen byproduct of electrolysis for dry biomass gasification;
6. We needn't wait for fuel cell cars, for "Nextgen" coal and HTGR nuclear plants, to launch a limited "hydrogen economy" now with renewables and H_2-fueled-ICE-hybrid vehicles;
7. New, large, electric transmission lines will be costly and controversial; GH2 pipelines may be the better way to bring large-scale stranded renewables to markets.

The IRHTDF is an international research and demonstration facility; perhaps an ideal IPHE project:

1. Worldwide application to large stranded renewable resources;
2. Open, non-proprietary results from multi-national collaborative R+D and demonstration;
3. Shared multi-national large capital cost, probably > $US 50 million;
4. Develop credible globally-applicable system design, synergy, and benefit - cost models.

5.1 IRHTDF purpose *Objectif du CIDTHR*

The IRHTDF would:

1. Help us decide under what circumstances large-scale, cross-country collection and transmission of renewable-source energy in GH2 pipelines will be technically and economically attractive; it will demonstrate the probable long-term costs of such GH2 pipeline systems for large "stranded" renewable resources.
2. Demonstrate economic and technical value-adding synergy and benefits among renewable GH2 sources -- wind, biomass, and perhaps others -- embracing:
    a. Availability and output variations at hourly to seasonal time scales;
    b. Stockpiling and dispatch, especially of biomass;
    c. Possibly "near-zero-emissions" coal gasification plants.
3. Demonstrate "distributed collection" of diverse, dispersed, diffuse renewable resources, large and small, continuously along the GH2 pipeline right-of-way (ROW) via frequently-spaced GH2 gathering input points; design and test the system topology and components to accomplish this.
4. Demonstrate the pipeline as an energy storage medium; discover pressure range limits and dynamics, management techniques; develop economic valuation models for this storage.
5. Investigate and prove feasibility and cost of large-scale geologic storage of GH2, along pipeline ROW, in:
    a. Extant NG storage structures, as available;
    b. Other geological formations.
6. Bring hydrogen production, transmission, and use out of the laboratory and out of established industrial reservations, and into farmers' fields, across private and public lands, to utilization at a major research university campus or community; improve public familiarity with hydrogen.
7. Encounter and solve public and professional misunderstanding, apprehension, and impediments in:
    a. Land use and zoning;
    b. Perception of hydrogen and hydrogen systems: design, function, and safety;
    c. Codes and standards;
    d. The insurance and banking industries.
8. Induce codes, standards, and insurance problem resolution via operating experience on a "real project".
9. Encounter and solve novel ROW acquisition and permitting problems.

10. Estimate feasibility and costs of scale-up to multi-GW, long-distance, cross-country GH2 gathering and transmission pipeline systems; project what the cost of diverse large-scale Great Plains and Northeast Asia renewable energy resources, delivered at long distances as GH2, could be.
11. Verify long-term system:
    a. O+M costs;
    b. Component degradation;
    c. Integrity inspection methods, especially for hydrogen corrosion and embrittlement of steel.
12. Be a dynamic test bed for evolving technology in GH2 collection and transmission:
    a. Electrolyzers;
    b. Compressors;
    c. Meters, valves, and other basic components;
    d. Gas quality monitoring, control, leak detection, and shutdown systems;
    e. Software for modeling, management, and control;
    f. Line pipe and pipeline inspection and integrity.
13. Be a dynamic test bed for evolving technology in energy conversion:
    a. Wind energy conversion equipment optimized to feed electrolyzers;
    b. Biomass energy conversion to GH2;
    c. "Near-zero-emission" coal gasification plants.
14. Encourage industry to market GH2-fueled vehicles: buses, cars, and eventually ships and aircraft.
15. Encourage industry to invest in GH2 production, collection and transmission, and distribution, from renewable energy sources and possibly from new-design "zero emissions" coal.
16. Reveal energy policy implications for a carbon-emissions-free energy economy.

6. IRHTDF costs and economics *CIDTHR coûts et rentabilité*

Large, new, terrestrial, cross-country, NG transmission pipeline systems typically cost $US 1 per mm diameter per meter length, complete with compressors, meters, controls, etc. Minimum ~30 cm diameter is necessary for inspection by "smart pigging." Thus, total installed capital cost of a 30 cm diam NG pipeline 50 km long would be ~ $US 15 million. The novel GH2 pipeline for the IRHTDF might cost 2 - 3 times as much, ~ $US 40 million. The lab-scale precursor planning, design, and research work to precede it might also cost as much. Thus, the IRHTDF might be a $US 50 - 80 million project, suggesting an international effort, perhaps via IPHE. The next step is to compose a credible and attractive RFP for design, construction, and perhaps long-term management of the IRHTDF. Composing the RFP will refine the IRHTDF concept and design, at modest cost.

No recent studies of GH2 pipeline economics for RHS have been done, resulting in a circular-reference consensus in the literature that large-scale GH2 pipeline transmission will cost ~ 1.5 to 2 times the cost of NG transmission, per unit energy-distance. For designers and investors to have adequate confidence to consider new RHS-capable pipelines, we need to:

1. Build a public-domain Excel model for GH2 pipeline design and economic analysis, proceeding from hydraulic equations and gas properties, with open access to all parameters to encourage interactivity and improvement of the model by its users; USDOE National Renewable Energy Laboratory (NREL) has begun this task in the "Hydrogen Analysis – H2A" project; [xvii], [xviii]
2. Calculate the capital cost differential to build a typical high-capacity, long-distance NG pipeline as RHS-capable;
3. Analyze NPV and IRR of multiple scenarios for converting new RHS-capable NG pipelines to RHS, to determine if new pipelines should be built of RHS-capable line pipe.

6.1 Large-scale geologic storage *Stockage à grande échelle géologique*

Figures IV, IX. If large quantities of GH2 can be inexpensively stored in geologic formations along RHS pipeline routes, the value of renewable-source energy-- especially windpower-- will be greatly enhanced; this storage has not been tried, and should be investigated with the IRHTDF, if geology is promising along the chosen IRHTDF route, Solution-mined salt caverns are GH2-tight: the Tees Valley Hydrogen Project stores 1,000 tons. [xix] In Texas, ~ 10^6 Nm3 of helium is stored beneath a saturated aquifer. [xx]

7. IRHTDF candidate location: Ames, Iowa, USA *CIDTHR site potential: Ames, Iowa, USA*

Figure VIII. A new 30 cm (12") diameter pipeline, ~ 100 km long, ~ 100 MW capacity, optimized for 100% GH2 service, would be designed and built from west of Fort Dodge, Iowa to Ames, Iowa, home of USDOE Ames Laboratory, Iowa State University (ISU), and Iowa Department of Transportation (IADOT). The pipeline would collect pure GH2 from diverse, dispersed, renewable energy catchment areas and conversion systems -- wind generators, biomass reactors, and others -- to many acceptance points all along pipeline system corridor and ROW. It would deliver GH2 to the ISU campus, for vehicles and stationary fuel cells in combined-heat-and-power (CHP) systems. GH2 fuel could also be delivered to retail public vehicle fueling stations in Ames and to the IADOT fleet.

8. Renewables-Hydrogen Service (RHS) technical challenges [xxi]

Difficultés techniques pour l'hydrogène renouvelable (HR)

Renewable energy sources are time-varying at minute to hourly to seasonal scales. Using GH2 transmission pipelines as storage buffers to damp such frequent pressure fluctuations, often at 2:1 scale, will exacerbate H_2 attack on the pipeline steel. Described variously as hydrogen-induced cracking (or corrosion) (HIC), hydrogen corrosion cracking (HCC), stress corrosion cracking (SCC), and hydrogen embrittlement (HE), this fatigue phenomenon has always troubled the oil and gas industry; frequent pipeline inspection and occasional major repairs are necessary. Valves, meters, and compressors are similarly affected. The IRHTDF will motivate novel, economical solutions for preventing and mitigating this H_2 attack danger.

8.1 RHS system design and optimization *Le design et l'optimisation de system HR*

We need to simulate GH2 pipeline system behavior with time-varying renewable energy inputs, at 100% renewable-source energy, to determine delivery point pressure variability and expected number and magnitude of annual pressure variation cycles, over a range of assumed:

1. Mix of renewable sources, up to 100% wind;
2. Smoothing of renewable-source variability, from geographic diversity [xxii];
3. Ratio of peak generation to maximum power transmission rating of pipeline; optimum CF;
4. Adjunct GH2 storage, geologic or other, directly available to the pipeline.

This simulation is necessary to define RHS and to optimize pipeline system design and economics: pipeline size and material, pressure range, compression power and station spacing, block valve spacing, and control strategy.

8.2 RHS specification; codes and standards *Spécifications HR : codes et standards*

Engineering, permitting, insuring, and financing RHS pipelines will require confidence in understanding and accommodating their service conditions. RHS must be defined for pipelines capable of and optimized for:

1. Mixtures of NG and GH2 up to 100% GH2; long-term service at 100% GH2;
2. High-pressure (>14 MPa), high-capacity (>5 GW), long-distance (>500 km), cross-country;
3. Buried terrestrial or subsea for their entire length;
4. >100 pressure cycles per year to 50% of design operating pressure.

Ensuing from this service definition, appropriate codes, specifications, and engineering standards must be developed for:

1. Line pipe, compressors, meters, and other pipeline system components;
2. Pipeline system design, inspection, and operation.

8.3 Materials and components *Matériaux et composantes*

Gathering and transmission line pipe must be technically and economically optimized for RHS, as yet to be defined, including steel and other metals, composites, and metal-composite hybrids like CRLP™. The line pipe specs must include material composition (alloy; allowed impurities), processing method, microstructure, and allowed inclusions (type, number, size, location, orientation, i.e."quality"); such extreme care is justified as GH2 pipelines emerge from industrial reservations and regions into more public exposure in the nascent "hydrogen economy", in novel RHS.

Nippon Steel has done extensive laboratory testing of line pipe materials exposed to hydrogen, concluding that "sour service X65" of high quality should be suitable for GH2 service. [xxiii], [xxiv] However, they have not operated a long-term test loop at RHS conditions to subject the pipe to cyclic loading, fatigue, and delayed failure. Designers and investors could not now confidently specify line pipe to build an RHS-capable pipeline.

Materials and designs for large-scale compressors, valves, leak detection, and other components must be developed, proven, and optimized.

8.4 Composite Reinforced Line Pipe (CRLP ™) for RHS [xxv]

Le composite renforci pour un pipeline HR

Figure X. Composite Reinforced Line Pipe, CRLP™, may be especially attractive for RHS, but it has not been tested for GH2 service. A high performance composite material reinforces a thin-wall, high strength low alloy steel pipe. The steel and composite work together, creating a hybrid that provides an economical alternative to higher strength all-steel pipe. The composite increases the pressure carrying capacity of the pipeline by reinforcing the steel pipe in the hoop direction, and is an external anti-corrosion coating.

In hydrostatic testing the completed pipeline, the correct overpressure is applied to expand and deform the steel liner against the composite, leaving the steel in static compression, the composite in static tension, over the complete pipeline operating pressure range. This maintains hoop strain compatibility, and will help prevent SCC and room temperature creep that may result from long-term cyclic loading.

Other benefits:
1. Lower total installed capital cost than all-steel pipe, at large size and high pressure;
2. Low alloy steel liner, which is more weldable and inherently less susceptible to HIC, HE, and SCC; girth welds designed for fatigue resistance; wide choice of liner pipe material;
3. Thin wall steel liner, reducing weight per unit length and welding time;
4. Effective elimination of axial crack propagation by rapid arrest of axial crack growth;
5. Higher burst to operating pressure ratio;

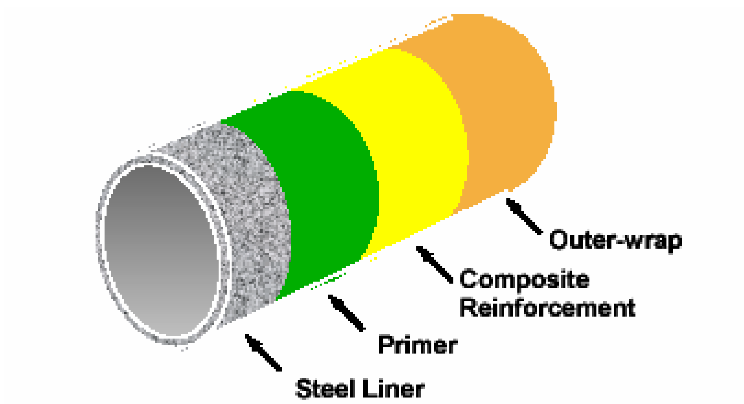

Figure X. Composite Reinforced Line Pipe (CRLP™).
TransCanada Pipelines, manufactured under license from NCF Industries, Inc.

9. International Partnership for the Hydrogen Economy (IPHE)

The IRHTDF may be an ideal IPHE project, per these expressions from the 18-21 Nov 03 Ministerial Meeting, Washington DC: [i]

"Goal: To provide a mechanism to efficiently organize, evaluate and coordinate multinational research, development and deployment programs that advance the transition to a global hydrogen economy…. The *Partnership* will provide a mechanism to organize, evaluate and coordinate multinational research, development and deployment programs that advance the transition to a global hydrogen economy… bring together the world's best intellectual skills and talents to solve difficult problems; and develop interoperable technology standards... public-private collaboration [on] technological, financial and institutional barriers to a cost-competitive, standardized, widely accessible, safe and environmentally benign hydrogen economy… advance research, development and deployment of hydrogen production, storage, transport and distribution technologies…foster large-scale, long-term public-private cooperation to advance hydrogen and fuel cell technology and infrastructure development; "

"…important that IPHE be a value-adding proposition for all countries…must be inclusive and offer a good return on investment for all participating countries…" (Australia)

"… large-scale demonstration projects… have the potential to provide the scale necessary for driving down costs and providing clear signals to industry… raise public's awareness of hydrogen's potential and reassure… about its safety…" (Canada)

"…the EC is considering jointly with European industry… large-scale deployment … Lighthouse Projects…" (European Commission)

"…the IPHE should focus on two main objectives: the launch of concrete international cooperation pilot projects, involving the private sector, for the development of technologies that are, at the same time, efficient and economically viable…" (Italy)

"…there is a diversity of views as to what is meant by the hydrogen economy. One size does not fit all…we don't see the hydrogen economy as just about transport… where there is a need to balance intermittent renewables and to store excess capacity…" (UK)

10. Conclusion *Conclusion*

Renewables are ready: we propose to begin this pilot-scale demonstration now, fueling ICE-hybrid vehicles and distributed generation. [xxvi] Wind is the lowest-cost renewable; the best wind is stranded; we will need many new transmission systems to bring Great Plains, USA wind, and other large worldwide renewable resources, to market. Two recent studies show GH2 pipelines to be the lowest-cost H_2 transmission path at high volume and long distance.

We need to learn, now, whether large-scale renewable-source H_2, including conversion and long-distance transmission costs, will be competitive with other H_2 sources, in the long term. We need to empirically discover and demonstrate costs, synergies, and value added for complex generation, conversion, storage, transmission, and distribution systems for multiple, diverse renewables. If such systems deliver GH2 fuel at uncompetitive cost, we will have good reason for setting them aside in our energy policy and investment strategies. This will guide public and private policy and resource allocation among the various H_2 sources in a sustainable "hydrogen component" of our nascent global energy economy.

Efficient high-pressure-output electrolyzers, and line pipe and other components resistant to hydrogen-embrittlement from severe cyclic loading need to be developed and proven, at MW scale, for which the IRHTDF is a necessary vehicle and strategy. It may be an ideal IPHE project. One such demonstration is worth many research projects, in popular and policy effect.

References *Références*

[i] Launched by the Ministerial Meeting, 18-21 Nov 03, Washington, DC. www.usea.org/iphe.htm

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Abstract

Large Stranded Renewables: International Renewable Hydrogen Transmission Demonstration Facility (IRHTDF)

Wind is the lowest-cost renewable energy source, but the largest and richest "deposits", including the Russian Far East and the Great Plains of North America, are stranded, without means for gathering and transmitting the energy to distant markets. Earth's richest biomass and direct-insolation resources are also stranded. We will need many large new transmission systems for gathering and delivering Earth's vast, diverse, dispersed, renewable energy resources. Both high voltage direct current (HVDC) electricity and gaseous hydrogen (GH2) pipeline are attractive, complementary, and competitive.

Pipelining GH2 costs ~1.3 - 1.8 times more than natural gas (NG). New NG transmission pipeline systems may be built with line pipe capable of 100% GH2, for future conversion to "renewables-hydrogen service" (RHS) at up to 100% GH2, to bring energy from windpower, biomass and other distant renewable sources to market as, and after, the NG is depleted. Since well-constructed and well-maintained pipelines have very long service lives, any increased investment required for construction with RHS-capable line pipe may be justified. These pipeline systems may be retrofitted with compressors, meters, valves and other fittings necessary for future RHS, for the nascent "renewables-hydrogen economy".

Although industry has been safely pipelining GH2 for decades, these systems are not designed for frequently-varying pressure and for large-scale, long-distance, cross-country collection, as required by RHS. No pipelines for such service exist. The public is unfamiliar with hydrogen (H_2) and anxious about its safety. Thus, a new pilot-scale R&D and demonstration pipeline system, an International Renewable Hydrogen Transmission Demonstration Facility (IRHTDF), is needed to demonstrate technical and economic feasibility of RHS. We describe and offer a conceptual design for the IRHTDF, which might be an ideal project for the International Partnership for the Hydrogen Economy (IPHE).

Sommaire

Larges Renouvelables Isolées: Centre international de démonstration pour le transport d'hydrogène renouvelable (CIDTHR)

Le vent est la source d'énergie renouvelable la moins dispendieuse mais les « dépôts » les plus grands et les plus riches, incluant la Russie et les plaines d'Amérique du Nord, sont isolés et sans aucun moyen d'amasser et de distribuer cette énergie aux marchés éloignés. Les plus riches ressources de biomasse et d'insolation directe de la terre sont également isolées. Nous aurons besoin de plusieurs grands systèmes pour amasser et distribuer les ressources d'énergie vastes, diverses, dispersées et renouvelables sur la terre. Le courant continu à haute tension (CCHT) ainsi que l'hydrogène gazeux (H2G) en pipeline sont tous deux complémentaires et compétitifs.

Le H2G en pipeline coûte de 1,3 à 1,8 fois plus chers que le gaz naturel (GN). Les nouveaux pipelines pour le GN peuvent être construits avec du matériel pouvant être utilisé pour l'H2G et pouvant être converti à « l'hydrogène renouvelable (HR) » dans le futur avec 100% d'H2G afin de transmettre au marché l'énergie éolienne, de biomasse et autres sources d'énergie renouvelable éloignée. Étant donné que les pipelines bien construits et bien entretenus ont une longue vie de service, toute augmentation d'investissement pour la construction d'un HR pourrait être justifiée. Ces systèmes de pipeline peuvent être modifiés avec des compresseurs, des compteurs, des valves et autres accessoires nécessaires pour l'HR futur et pour une économie d'hydrogène-renouvelable naissante.

Bien que l'industrie transmet le H2G par pipeline de façon sécuritaire depuis des décennies, ces systèmes ne sont pas construits pour des variations de pression fréquentes, ni pour la distribution à grande échelle, sur de longues distances à travers le pays, tel que requis pour l'HR. Aucun pipeline de ce genre n'existe aujourd'hui. Le public ne connaît pas l'hydrogène et se méfie de son innocuité. Alors, un projet pilote de recherche et développement pour un système de démonstration d'un pipeline, un Centre international de démonstration pour le transport d'hydrogène renouvelable (CIDTHR) est nécessaire pour démontrer la faisabilité technique et économique d'un tel système. Nous décrivons et offrons un plan conceptuel pour le CIDTHR qui pourrait être idéal pour l'International Partnership for the Hydrogen Economy (IPHE).