LARGE STRANDED RENEWABLES:

the International Renewable Hydrogen Transmission Demonstration Facility (IRHTDF)

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A pilot-scale gaseous hydrogen (GH2) transmission pipeline system optimized to bring large-scale, remote, diverse, dispersed, stranded, renewable resources to distant markets, in "renewables-hydrogen service"

- No pipelines for renewables-hydrogen service exist.
- Major new industrial processes require pilot plants like IRHTDF.
- Electricity lines and GH2 pipelines are comparable in capital and O&M cost.
- GH2 transmission provides valuable storage, in the pipeline and in geologic formations.
- New underground GH2 pipelines may be more secure, socially acceptable, permittable, and bankable than new overhead electric lines.

Global Energy Strategy Challenge

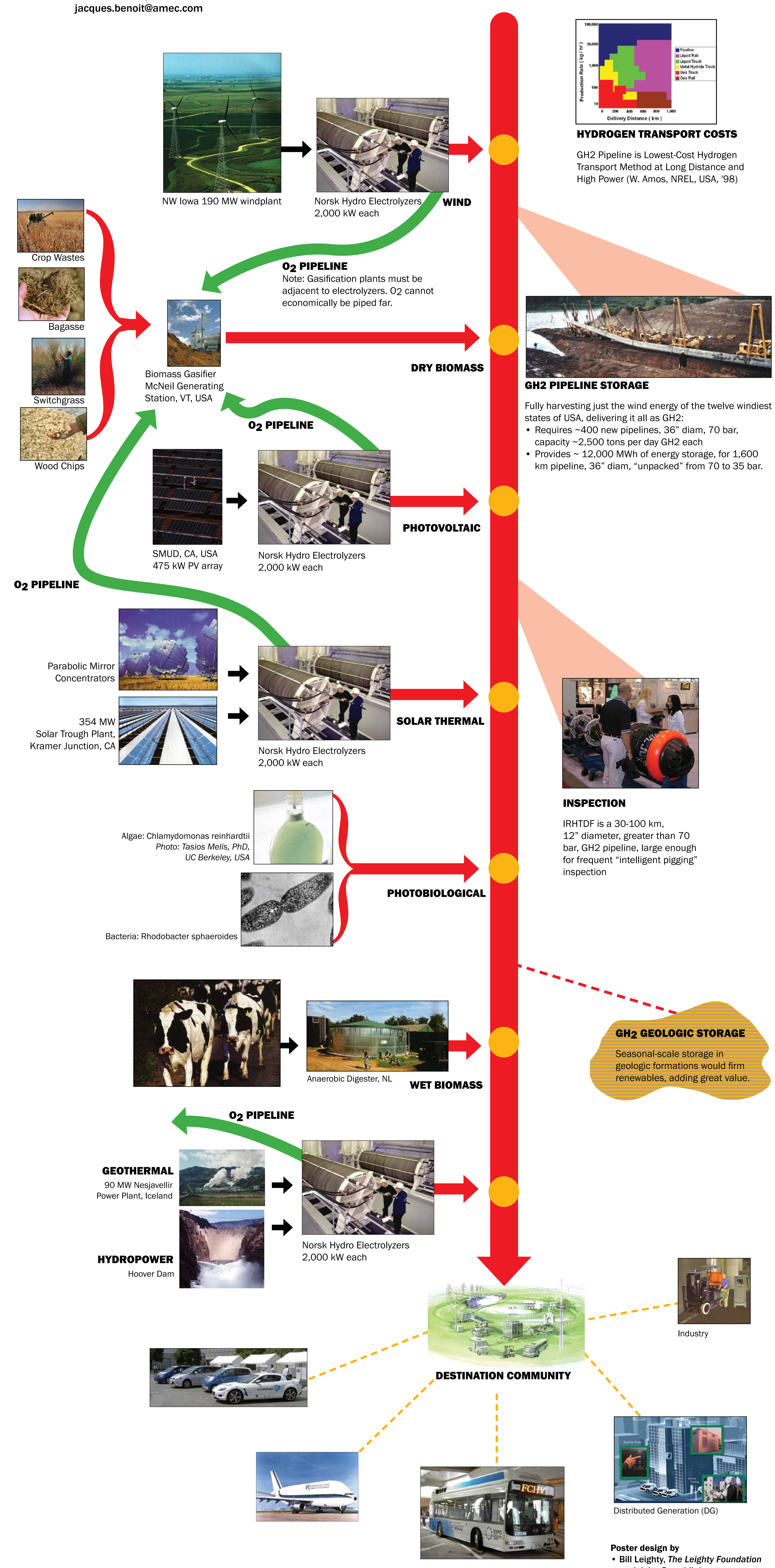
- How shall we bring Earth's large, stranded, renewable resources to distant markets? Transmission options for large-scale stranded renewables:
  - New high voltage direct current (HVDC) electric lines
  - New gaseous hydrogen (GH2) transmission pipelines
  - Synthetic liquid hydrocarbons, with net-zero C emissions
  - Superconducting "Energy Pipeline" (EPRI, USA concept)
- Pipelining GH2 is costly, ~ 1.5 – 2 x that of natural gas :
  - Low volumetric energy density of hydrogen: one-third that of natural gas
  - Pipeline systems must be safe from hydrogen attack: corrosion, cracking, embrittlement
  - Special compressors, valves, and meters required
- Will gaseous hydrogen (GH2) transmission pipelines be a major part of humanity's sustainable energy future? Under what circumstances? Can pipelined renewable-source hydrogen compete with hydrogen from other sources?
- To discover, quantify, and demonstrate answers, we should begin, now, to:
  - Assemble and fund an international consortium
  - Design, build, and operate the IRHTDF
  - Operate IRHTDF first as an R&D lab, then as a test facility, then as a demonstration facility
  - Guide our global energy strategy

Rationale, purpose

- We need to rebuild humanity's energy system for all-renewable resources
- Earth's largest, richest renewable resources are stranded:
  - Far from population and load centers
  - Without gathering and transmission systems to deliver their energy
- Many costly, new, high-capacity transmission systems will be needed, worldwide, for these large, remote, stranded resources
- GH2 pipelines compete with HVDC electric transmission lines, in capital and O&M costs, conversion and transmission losses
- GH2 pipeline is the lowest-cost hydrogen transport mode for long distance and high power (flowrate)
- GH2 pipeline transmission systems must be optimized for renewables-hydrogen service:
  - High capacity: high pressure, large diameter, long distance
  - Accommodate frequent, large pressure cycles
  - Avoid hydrogen attack: corrosion, cracking, embrittlement
  - Provide storage in pipeline and in geologic formations
  - Deliver renewable-source GH2 at competitive cost
  - Add value from synergies among diverse renewable resources
  - Use valuable O2 byproduct of electrolysis for adjacent dry-biomass gasification plants
- No GH2 pipelines for renewables-hydrogen service exist; the extensive extant industrial GH2 pipeline system is not capable of renewables-hydrogen service
- All major new processes require pilot plants:
  - Benefits, costs, synergies, technical obstacles must be identified and quantified; IRR and NPV predicted for full-scale facilities
  - IRHTDF is the ideal test and demonstration facility for renewables-hydrogen service, for GH2
- Will GH2 pipelines have a major role in humanity's sustainable energy future? Under what circumstances? IRHTDF is on the critical path to finding these answers.

IRHTDF status

- Concept only; no detailed engineering or economics studies
- No funding or consortium in place: now a leadership opportunity
- Probable $US 50 – 100M cost, 5 years, requires international effort
- Ideal project for:
  - IPHE (International Partnership for the Hydrogen Economy)
  - IEA Hydrogen Implementation Agreement (HIA)
  - EC, PATH (Partnership Advancing Transition to Hydrogen)



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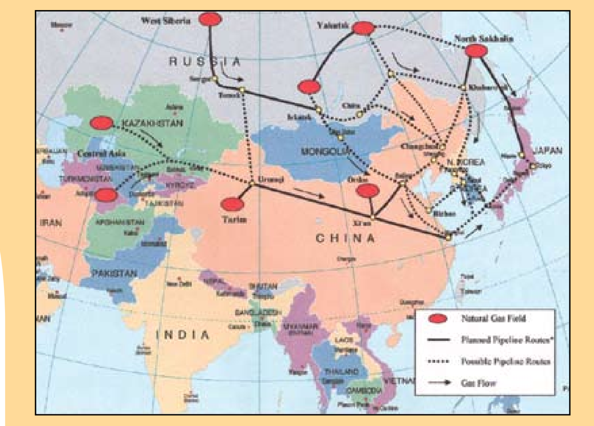
YOUR CARD, PLEASE

TAKE ONE, PLEASE



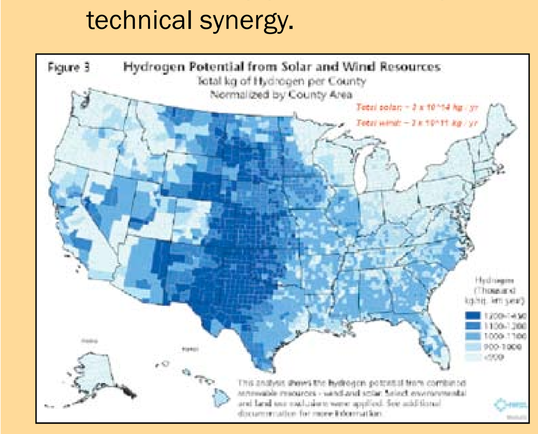
Opportunity: Proposed Northeast Asia Natural Gas Pipeline

Japan asks:
- Shall we build this large, new, natural gas pipeline system of hydrogen-capable line pipe, so that we may transition to 100% GH2 transmission, from abundant renewable sources along the pipeline route, as the natural gas is depleted?
- What is the incremental cost, if any, of building a new natural gas pipeline as 100% hydrogen-capable?
- What line pipe material(s) are capable of renewables-hydrogen service?

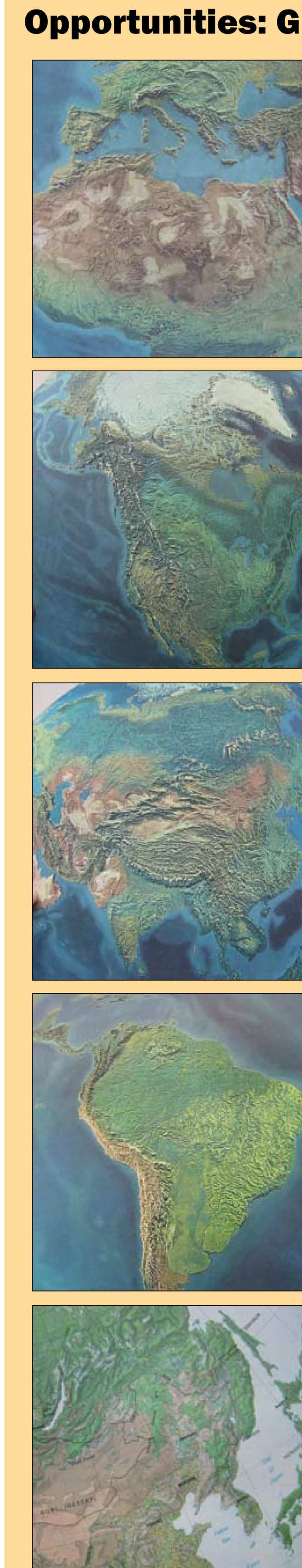
Opportunity: Great Plains, North America

Total annual wind energy, fully-harvested on half the land area of the twelve Great Plains states, would equal the TOTAL annual energy consumption of the USA. Delivering all this energy as GH2 would require ~ 400 new pipelines, 36" diameter, 70 bar.

Abundant wet and dry biomass, and other radiant-solar-driven energy conversion, could supply more GH2 to these transmission pipelines, in temporal and technical synergy.



Opportunities: Global



Every continent has large, diverse, dispersed, renewable resources: enough for humanity's needs, but stranded and time-varying in output. How shall we bring this energy to distant markets, at large scale, at competitive cost?