Benchmarking of Nuclear-Hydrogen Cogeneration Economics Tools

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Outline

- Hydrogen in Canada
- Case study for benchmarking (G4-ECONS vs HEEP)
- Comparison of economic models for nuclear hydrogen
- Comparison with convention steam-methane reforming process (H2A)

Hydrogen in Canada

- The 6th largest producer of hydrogen in the world.
  - Primarily used for upgrading heavy oil or as a feedstock in the chemical industry.
  - Oil sands bitumen upgrading alone uses 4,000 tonnes/day of hydrogen
- A global leader in hydrogen and fuel cell research and manufacturing.
  - Home to two of the top manufacturers in the world: Hydrogenics Inc. and Ballard Power Systems.
- Canadian Nuclear Laboratories (CNL) and the University of Ontario Institute of Technology (UOIT) are developing a copper-chorine cycle based hydrogen production process capable of producing more than 100 tonnes/day.
  - Plans are in place for a demonstration plant this year at 0.1 kg/day.

Case Study for Benchmarking

- Large scale hydrogen production for direct use in petroleum upgrading (no storage or liquefaction)
  - 520 tonnes/day, similar to a large steam-methane reforming plant.
- Hydrogen produced by High Temperature Steam Electrolysis (HTSE).
  - 637 MWe electrical energy requirement
  - 147 MWth thermal energy requirement
- NPP: 1,200 MWe Canadian SCWR concept.
  - 46.3% efficiency, direct 3-stage steam cycle.
- Overnight Cost (2007 US dollars)
  - NPP: $4,000 M
  - HTSE Plant: $700 M
- 40 years operating life, 5% real discount rate, all country specific indicators, such as inflation rate and tax rate, were not considered.

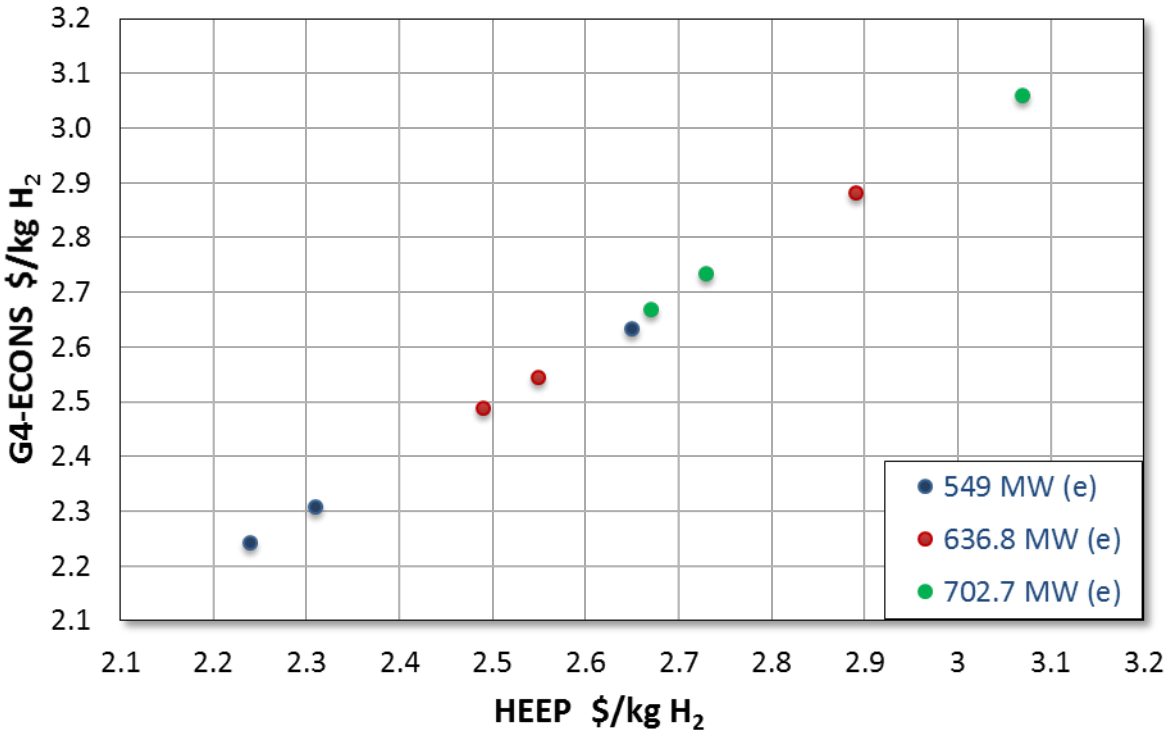
Economic Tools

- G4-ECONS v2.0 – developed by Economic Modeling Working Group of Generation IV International Forum.
  - Excel-based for economic assessment of NPP.
  - Module for co-gen applications – hydrogen, desalination, etc.
- HEEP – developed by Nuclear Energy Division of IAEA.
  - A single window application.
  - Preforms economic calculations for NPP, hydrogen plant, and hydrogen storage/liquefaction/piping.
- H2A – developed by National Renewable Energy Lab, US DOE.
  - Excel-based for hydrogen production by steam-methane reforming.

Comparison of H_2 Cost ($/kg)

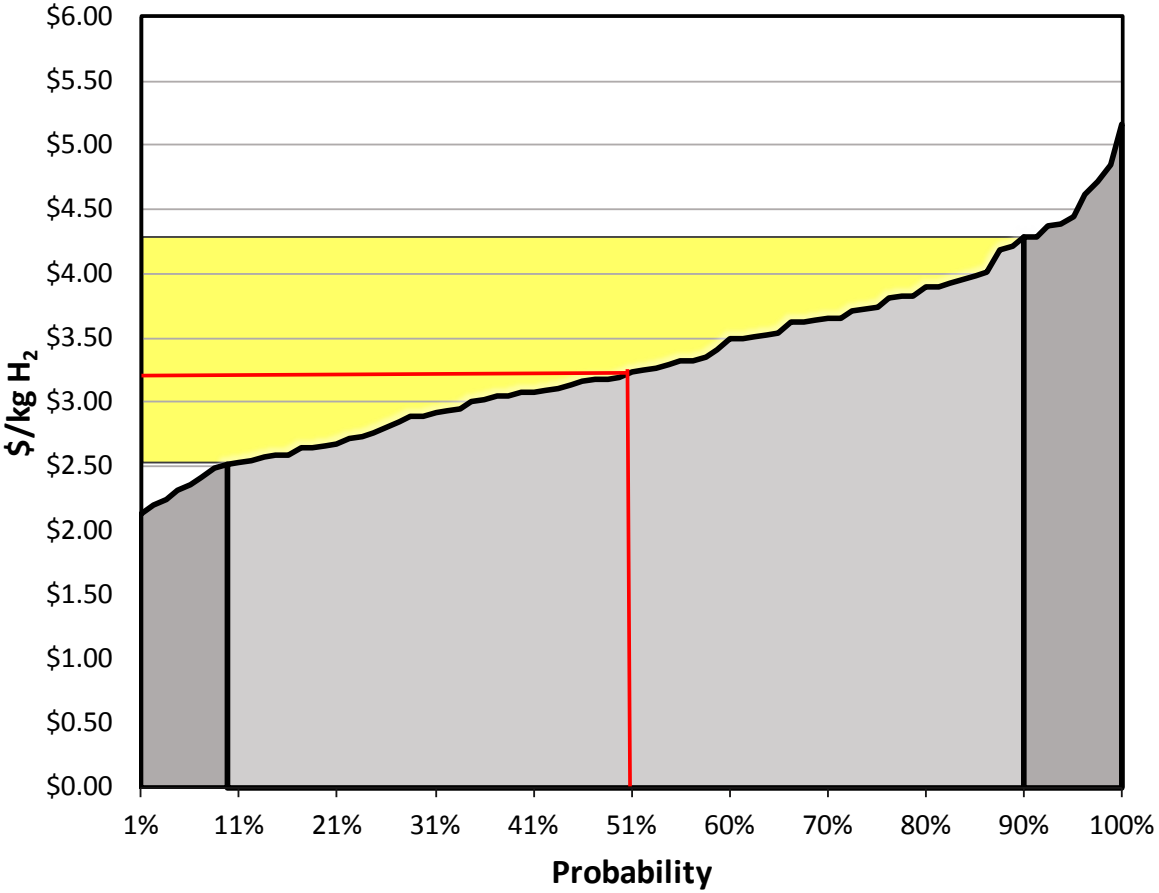
	G4-ECONS	HEEP
H2 Unit cost, $/kg	**3.61**	**3.56**
Cost Breakdown		
H2 Plant Capital Component	0.27	0.28
H2 Plant Non-energy Component	0.39	0.39
H2 Plant Energy Component	2.95	2.89

HEEP and G4-ECONS Results Comparable



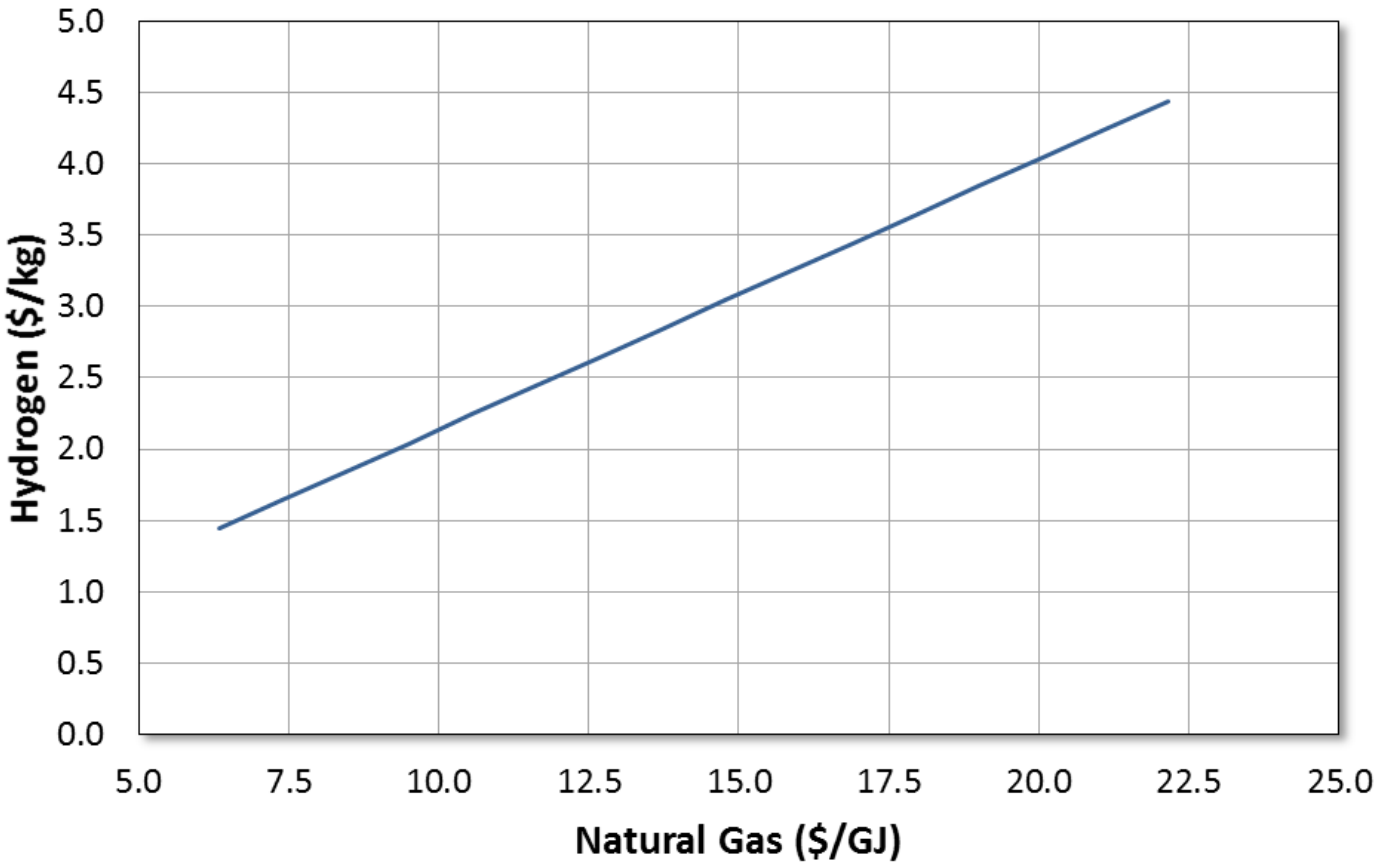
- HTSE capital cost: $630 M to $1,050 M
- HTSE electric requirement: 549 MWe to 793 MWe
- Thermal energy requirement constant at 147 MWth
- All SCWR costs constant

Uncertainty Analysis (using HEEP)



- SCWR capital cost: $3,600 M to $5,200 M
- HTSE capital cost: $630 M to $1,050 M
- HTSE electric requirement: 549 MWe to 793 MWe
- Discount rate: 5% to 10%

Comparison with Steam-Methane Reforming using H2A



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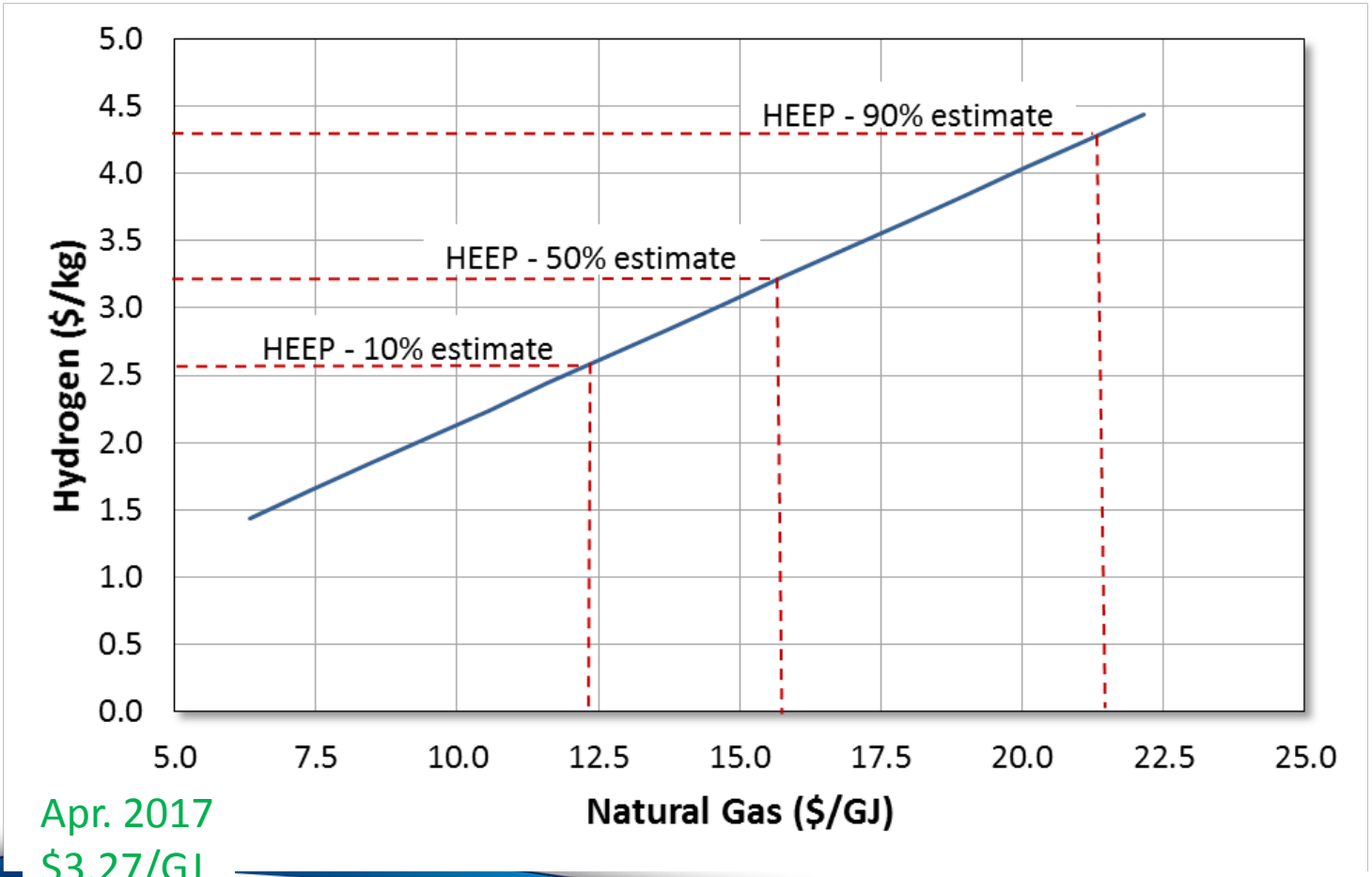

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$3.27/GJ

Conclusion

- Economic tools – G4-ECONS and HEEP give comparable results for nuclear hydrogen production costs
- Large uncertainty in the capital costs of next-generation, high-temperature reactors and high-temperature processes for hydrogen production using nuclear energy.
- Estimated cost of nuclear hydrogen is significantly higher than hydrogen produced by natural gas (H2A) in North America.
- Will required significant carbon tax for nuclear hydrogen to be competitive with conventional hydrogen produced from natural gas.