Co-Generation of Hydrogen from Nuclear and Wind: the Effect on Costs of Realistic Variations in Wind Capacity and Power Prices

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Canada

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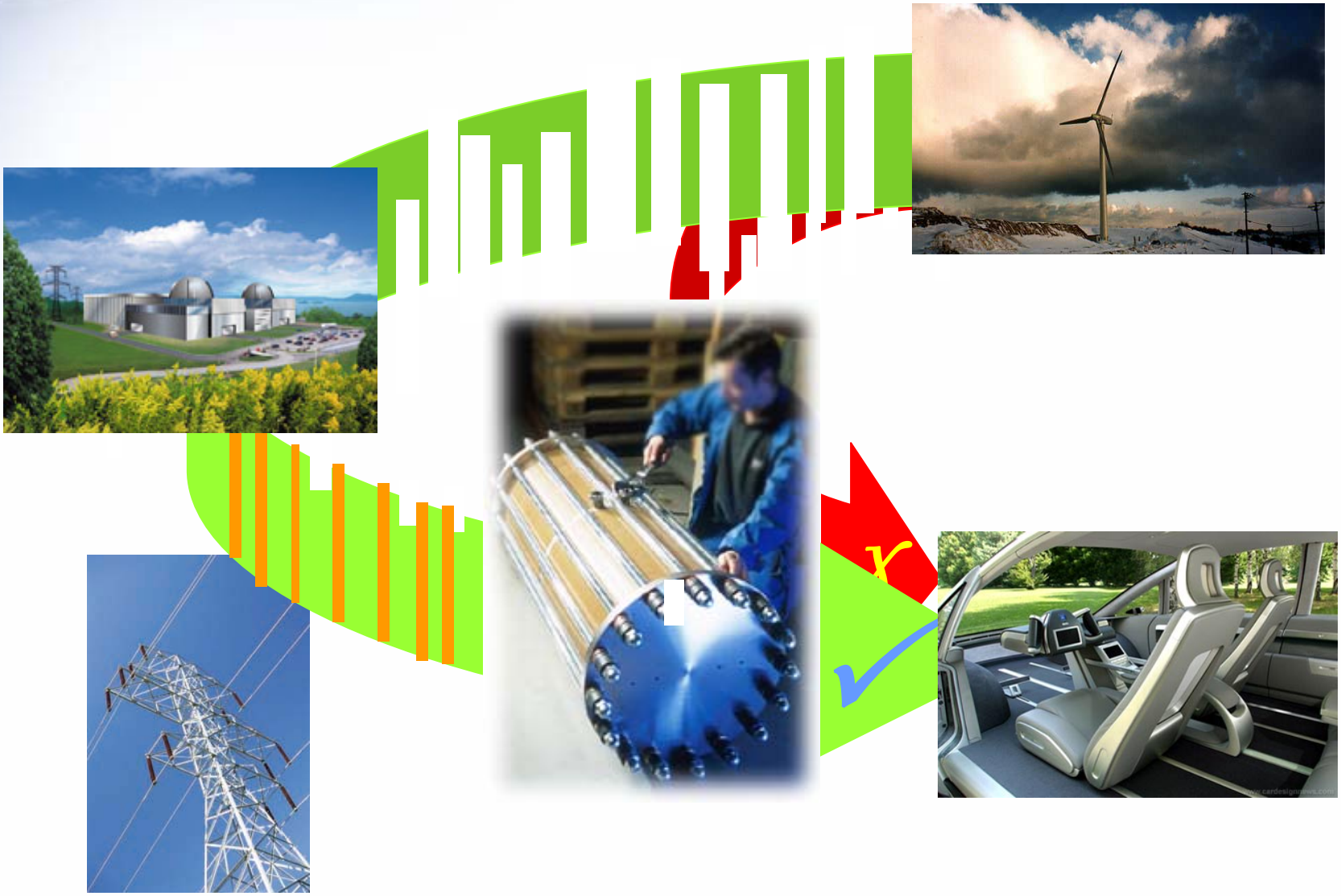
EACL Énergie atomique du Canada limitée

Affordable Hydrogen from Electrolysis



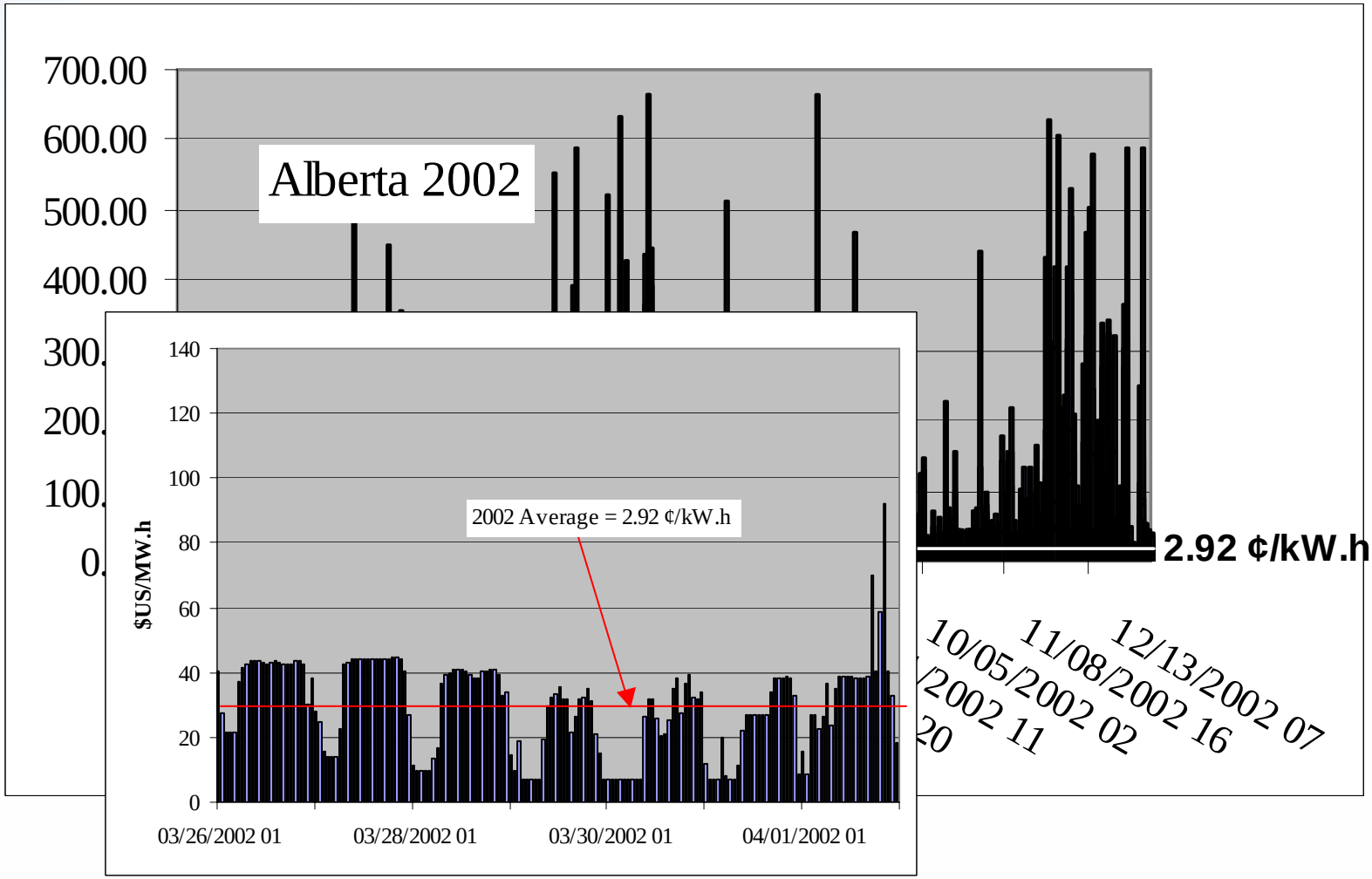
Typically, Wind is Seasonally Fickle

	Percent Generated		Ratio to Minimum	
Av. wind speed (m/s)	8.37	7.37	8.37	7.37
January	42%	32%	1.69	1.86
February	37%	28%	1.52	1.63
March	55%	45%	2.23	2.60
April	51%	41%	2.06	2.36
May	44%	34%	1.77	1.97
June	28%	20%	1.14	1.16
July	25%	17%	1.00	1.00
August	27%	20%	1.11	1.12
September	40%	31%	1.64	1.79
October	41%	32%	1.67	1.84
November	48%	39%	1.95	2.21
December	60%	51%	2.43	2.92

- Site average wind strength is important too.
- 8.37 m/s (Type G) would be exceptional with 41.5% average availability
- 7.37 m/s (Type H) would be typical with 32.6% average availability
- Electrolysis is too underutilized to produce H_2 affordably

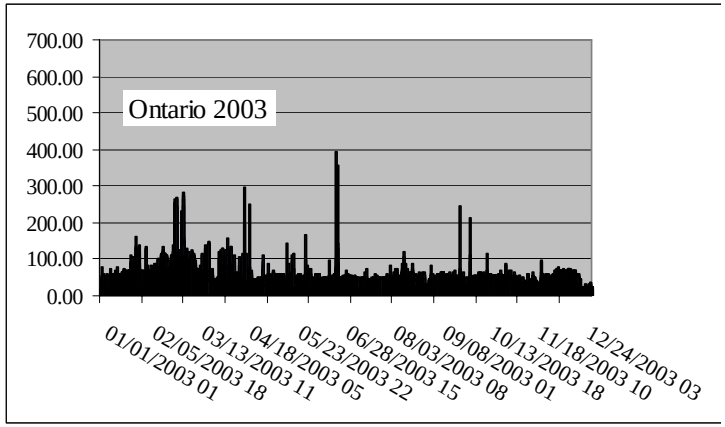
Electricity Price is Fickle too:

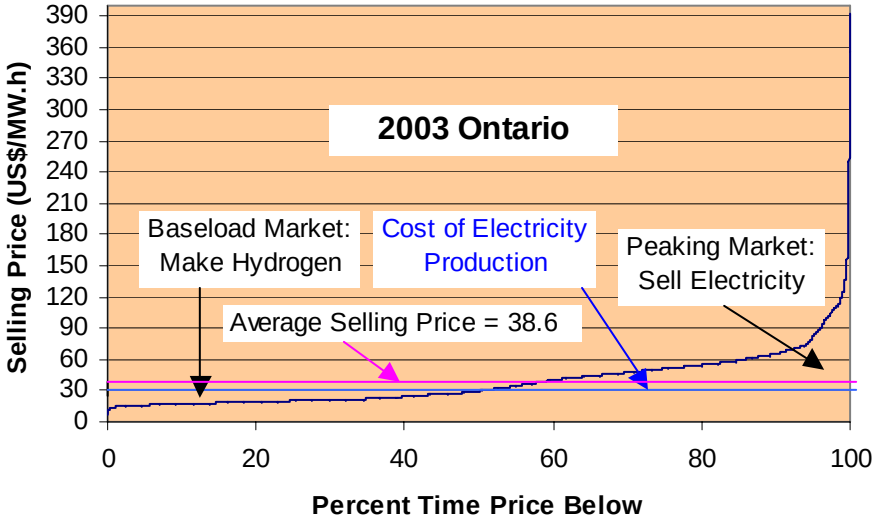
Alberta Pool Electricity Price (US$/MW.h)



And on Average, Electricity is too Costly

- Need 2 to 2.5 ¢/kW.h to make 2000 $/tonne hydrogen
- Gen III+ nuclear and wind generating costs are ~3 ¢/kW.h
- Value feeding grid is typically 3 to 4.5 ¢/kW.h
- Averages conceal much variation





= Make H_2 when electricity price is low; sell electricity when high

Could Wind's Variation also be Accommodated?

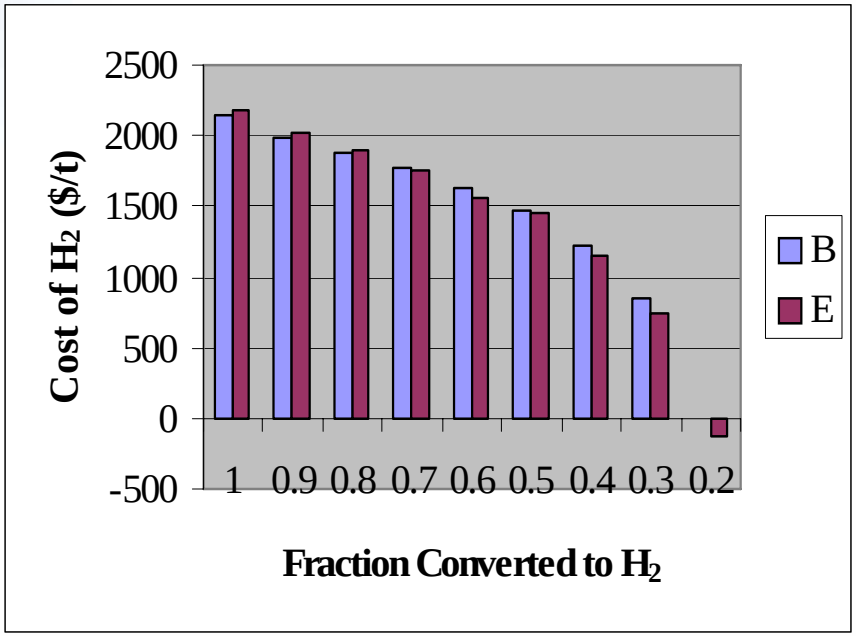
- Go beyond intermittency and introduce concept of variable cell current
  - Electrolysis cells can accept a broad range of current density
  - Needs adaptation to handle maximum H_2 flow
  - Raises cell voltage
    - Both add modestly to costs
- Make H_2 or sell all electricity still applies
  - Now intermittent wind enters grid only at times of high demand
- Cell capacity with extended current must exceed nuclear component

Modelling and Optimization

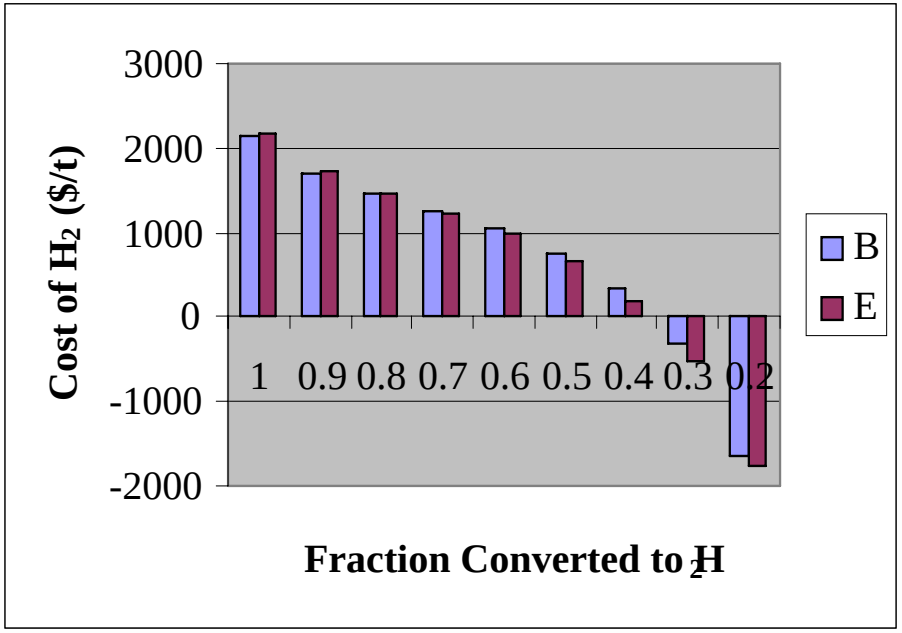
- Choose an average fraction of conversion to H_2
- Optimize
  - Size of electrolysis installation
  - Quantity of H_2 storage
  - Threshold price for electricity to be sold or converted

Nuclear Electricity Alone

- Variable current is useful with lower fractions of conversion to H_2

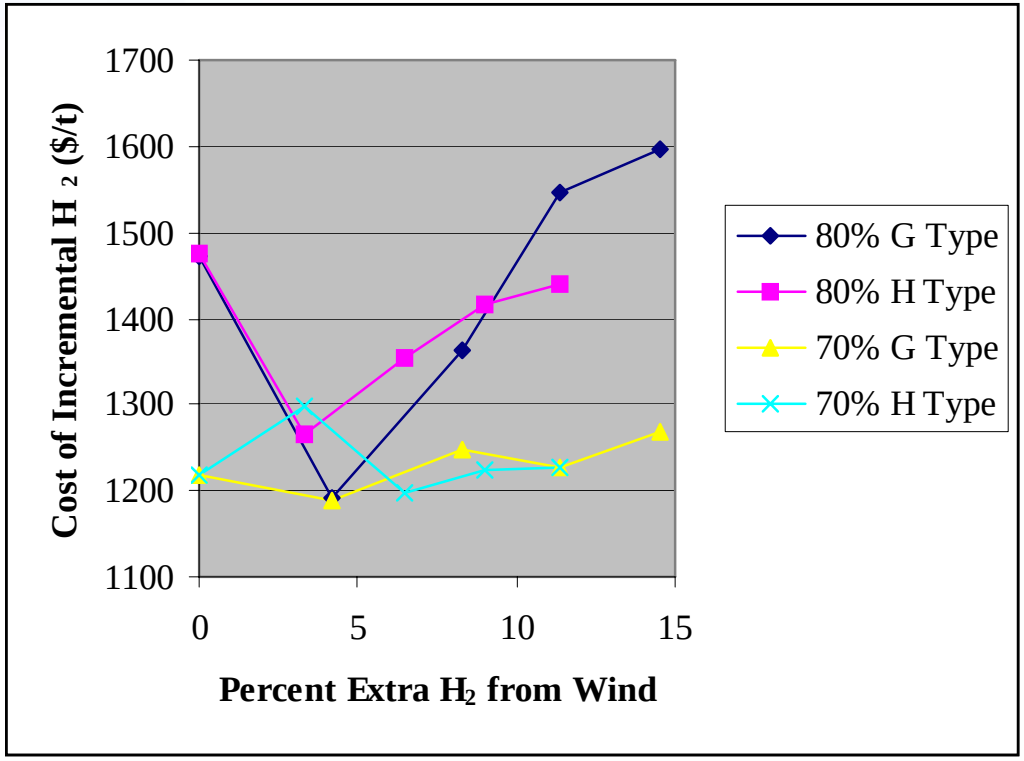


Ontario 2003



Alberta 2003

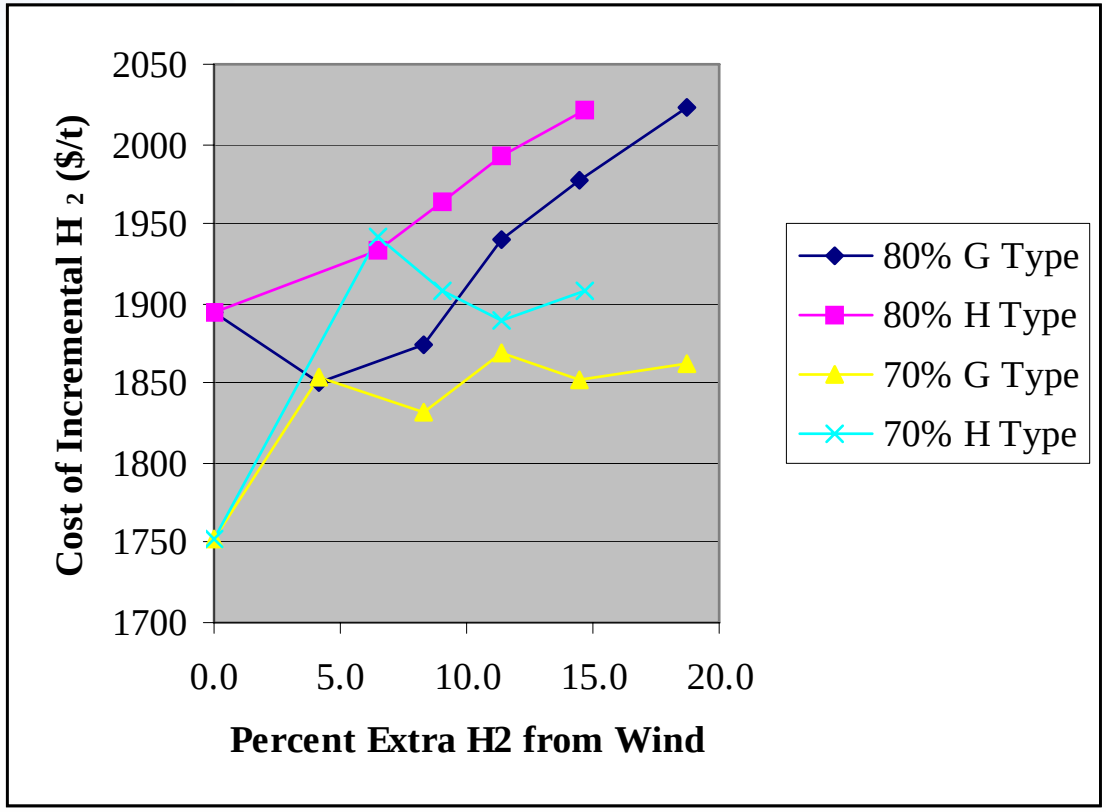
Now Add Wind



Alberta 2003

- At 80% level of conversion, modest wind is attractive
- At 70% level of conversion, 15% average electricity from wind is easily accommodated
- Alberta 2003's 4.5¢/kW.h leads to excellent H_2 economics

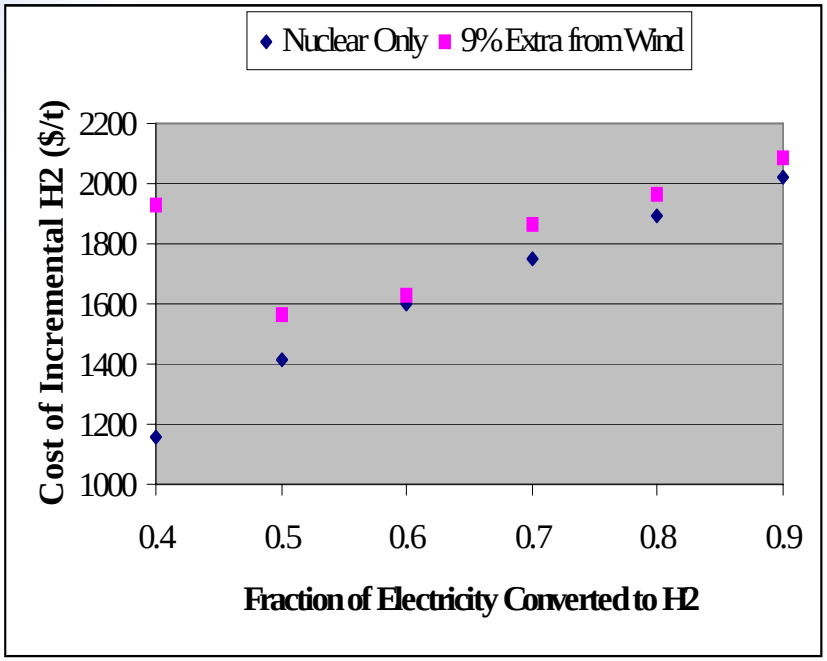
Even with Lower-Value Electricity



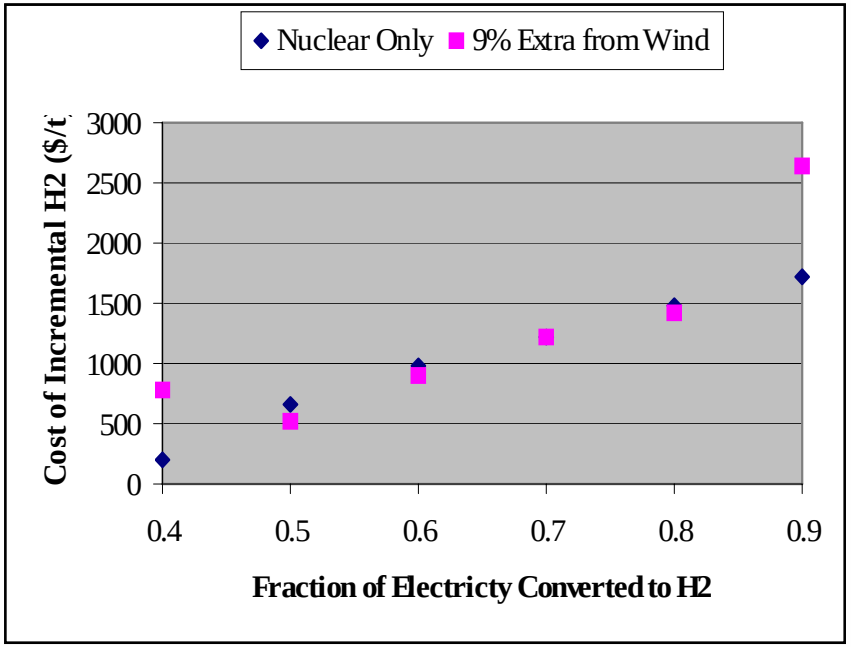
Ontario 2003

- At 80% level of conversion, wind is quickly squeezed out
- With Ontario 2003's lower average value of electricity (3.9 ¢/kW.h), wind is less easily accommodated but H_2 is still competitive at 70% level of conversion

NuWind is Economic over a Broad Range of Conversion to H_2

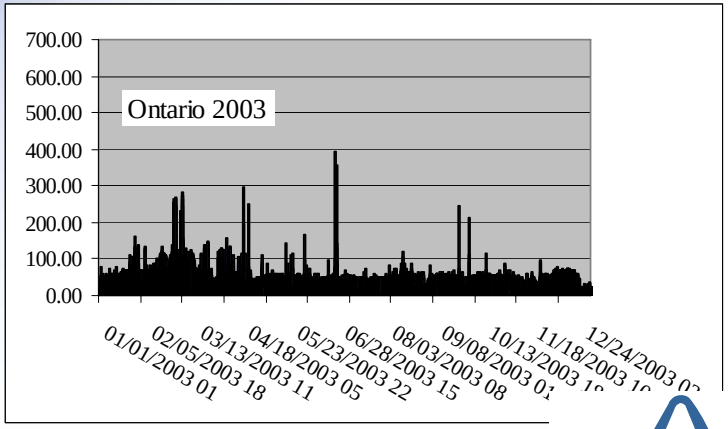


Ontario 2003



Alberta 2003

Real time market pricing and hydrogen cost optimization is a complex interplay …



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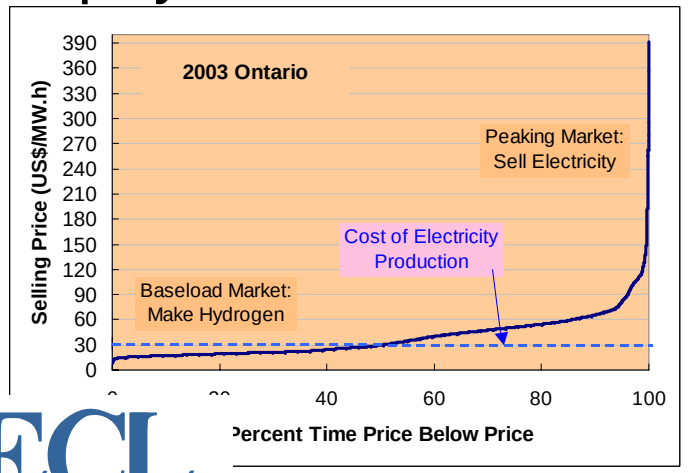

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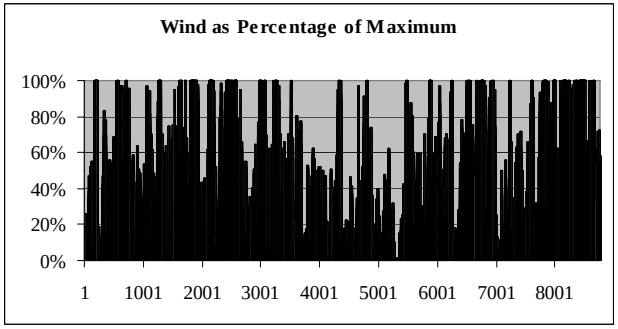

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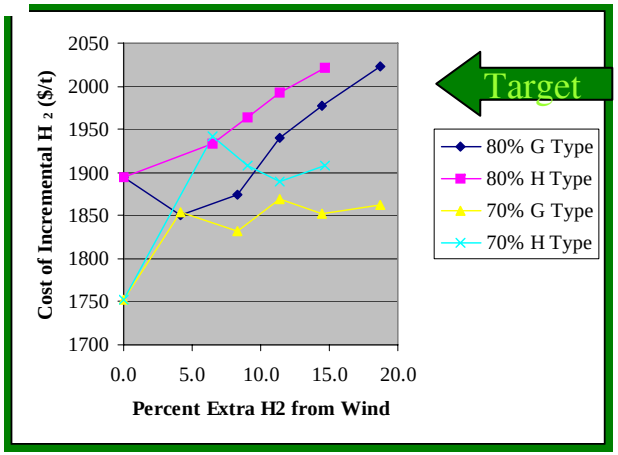

… but it makes
wind → H_2 economic