




The Case for Rail Conversion to Hydrogen-Powered Fuel Cells

*Alistair I. Miller
Senior Scientific Associate
Office of the Principal Scientist
Atomic Energy of Canada Limited
Chalk River Laboratories*



**First International Hydrail Conference
Charlotte, NC
2005 May 6**

Canada 



AECL
Atomic Energy
of Canada Limited

EACL
Énergie atomique
du Canada limitée



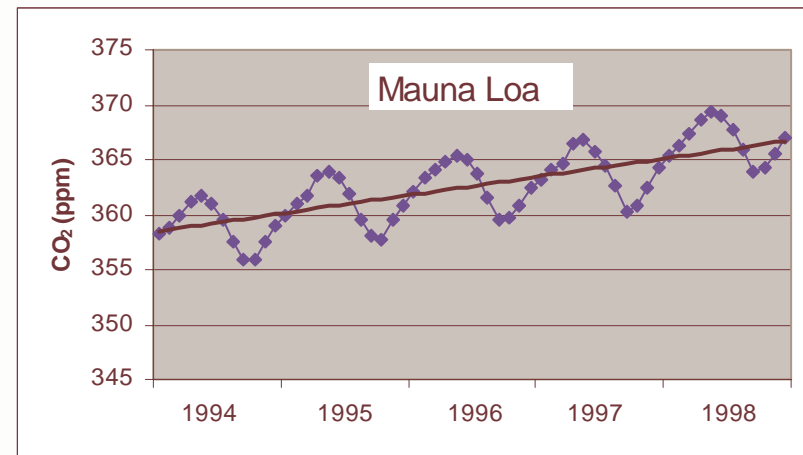
Since my Paper on Hydrail in 1999

- Atmospheric CO₂ has risen from 367 to 380 ppm
- Price of oil has more than doubled
- The cost of new nuclear-generated electricity has continued to fall
- The international GenIV initiative to develop advanced nuclear reactor types and the IPHE have been launched
- The “Hydrogen Economy” has entered popular consciousness
- Mooresville Hydrail Initiative is on track



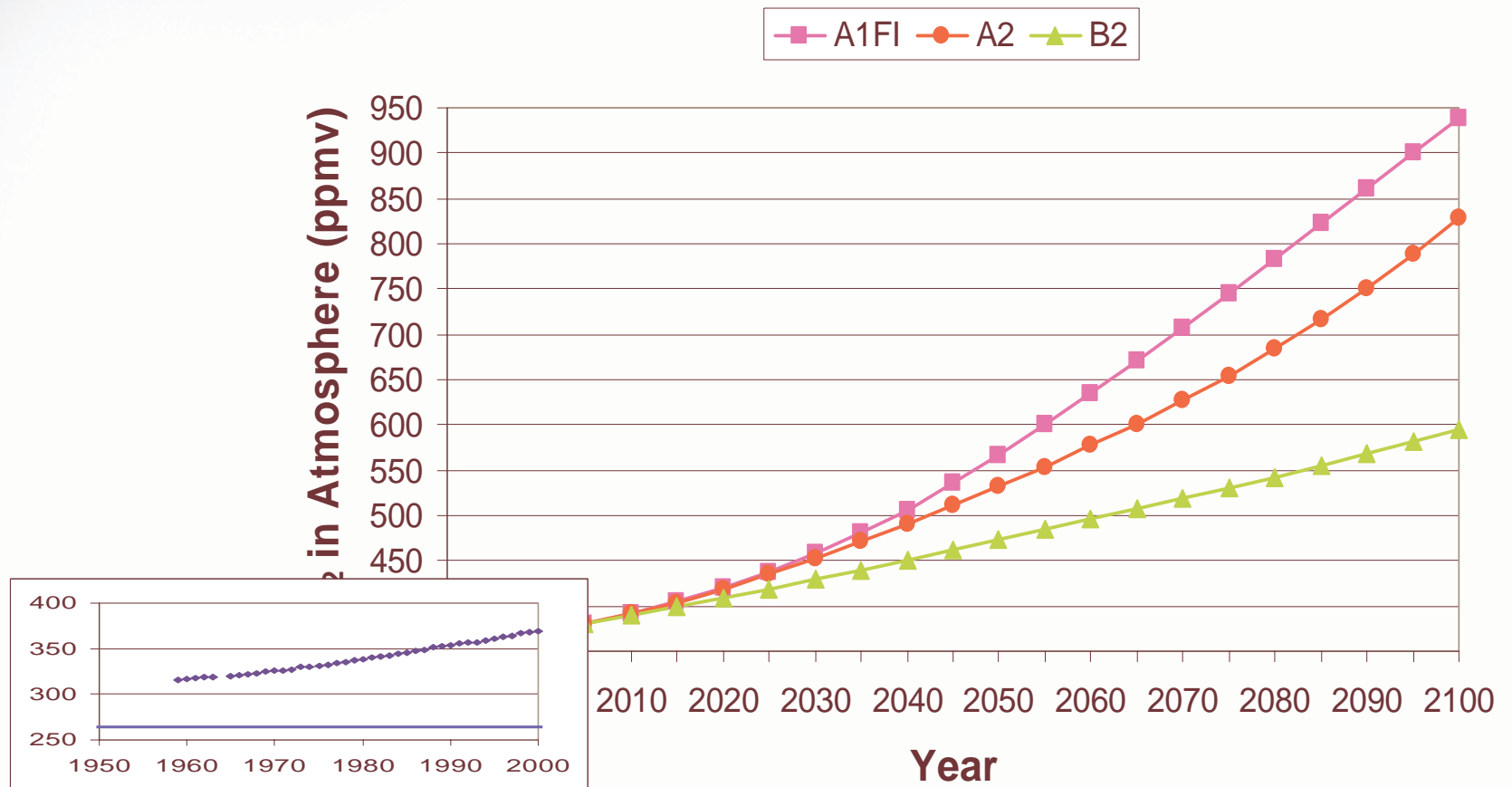
CO₂ Accumulates

- Over practical time horizons, anthropogenic CO₂ can only accumulate
 - The upper 100 metres or so of the oceans and the atmosphere are in near equilibrium
 - This is deeply troubling in its own right: $\text{CO}_3^{2-} + \text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons 2 \text{HCO}_3^-$
 - pH already -0.1 ; with CO₂ doubling -0.4 . Can phytoplankton cope?
 - Vegetation takes up and releases on a grand scale annually
 - Atmospheric CO₂ typically falls 4 to 6 ppm between May and August
 - But net changes are small
 - Only real escape is to deep ocean
 - Some as detritus rain
 - A few special sinks
 - 1000-year circulation
- > 100-year residence in our habitat





IPCC Projections of CO₂ Concentrations





Efficiency and more

- Enhanced efficiency is necessary, but ...
 - we have problems even with the status quo
 - in the 30 years ending in 2020, expect:
 - developed world: 4 \Rightarrow 5 billion tonnes CO₂/a
 - developing world: 1.6 \Rightarrow 5 billion tonnes CO₂/a
- ... Need CO₂ avoidance too
 - Determine the niches where CO₂-avoiding technologies can begin to take over
 - Rail, especially for freight, offers an alluring niche
 - It could pioneer



The Concept was Not Invented Here

- Foster & Escher, ERDA, 1976
- English *et al.*, Canadian Institute of Guided Ground Transport, 1978
- Transport Canada, 1983
- Scott & Rogner, *Int. J. Hydrogen Energy*, 1993
- Stehley, Taylor & Peters, US Transportation Research Board, 1994

However, sometimes the obvious bears repeating



Outline

- **Trains are somewhat out of fashion but:**
 - **would be relatively easy to convert to LH₂ as fuel**
 - LH₂ must come from a non-GHG emitting source
 - SMR hydrogen is only effective if CO₂ sequestered and are minimal losses of CH₄
 - far more cheaply and flexibly than electrifying track
 - **adapt readily to fuel cells**
 - **GHG reduction could be amplified by encouraging switch from trucks to rail**
 - trucks use 2.5 to 4 times more diesel than rail
 - cutting road freight would enjoy popular public support



Ideal Features for an LH₂-Powered System

Feature	truck	plane	train	ship
● Few operators	2	4	5	3
● High utilization factor	4	4	4-5	5
● Steady load	3	2-4	3	5
● Not too dispersed	2-4	4	5	3-4
● LH ₂ volume unimportant	3	3	5	5
● Weight important	3	5	1	1
● Good control of LH ₂	2	5	5	5
● Minimal public anxiety	4	1	5	5





Trains first; other modes can follow

- Overall:
 - rail is obvious place to launch LH₂ fuel cells
 - ships are not bad but they wander
 - apart from the (very real) weight advantage, planes come out poorer than ships (but have potential for reduced drag)
 - trucks are in last place
- Trains are an easy niche to start with





Evolutionary Opportunities

- **Begin in high-use corridors**
- **Only 4% of GHG transport emissions are from rail but 23% from commercial trucks**
- **Could even start with H₂-fueled diesels if fuel cells are not sufficiently developed**
- **Trains usually use at least two locomotives so have important natural redundancy**



What about the Cost?

- Diesel at ~~27~~¢/L ♦ 45 ¢/L (before taxes:
EIA, Central Atlantic, 2005 March)
- Energy equivalent to LH₂ at about 3.9 ¢/kW.h for electricity
- Before credit of 2.4 to 19 ¢/L for CO₂ avoidance
 - (10 to 80 \$/tonne CO₂: trading range → realistic real cost)
= 4.1 to 5.9 ¢/kW.h
- If displacing road transport, credit is x 3 or 4
= up to 9 ¢/kW.h
- New nuclear electricity costs 3 to 4 ¢/kW.h
 - H₂ production and liquefaction capital will add less than 1 ¢/kW.h
- Encouraging economics
 - Fuel cell cost still need to come down



Why not Electrify the Tracks?

- Backers of GHG-abatement projects will want high profiles ⇒ electrified track?
- In 1998, Caltrain costed electrification of an existing 124-km commuter line at 376 M\$US
- Pro-rated, the 32 km from Charlotte to Mooresville is 100 M\$US
 - Should easily buy enough fuel-cell locomotives and an LH₂ facility



Incidental Advantages over Electric Trains

- Fuel cell/LH₂-powered locomotives can roam
 - the system can grow without major commitments to new lines
 - unlike electrification, needs no critical traffic density to justify
 - Avoids either a totally new track or much interference with existing traffic while electrifying
 - Can begin with a few prototypes
- Power demand can avoid peak periods



Off ³: a Practical Technical Way Forward

- **Off rhetoric**
 - saying “conserve” a 1000 times is not working
- **Off road**
 - wider highways and bigger trucks only slow the rate of increase
- **Off carbon**
 - rail is a practical starting place to start deploying non-GHG technology



Interesting progression if this were to evolve from ...



Taken by John Foyl/BC Rail

BC Rail



The Ultimate in Unobtrusive Transport

- ✓ With LH₂ fuel cells:
no more
than a murmur
of sound and
almost zero
GHG emissions
- ✓ A legacy we could
be proud of



BC Rail



Future Possibilities

- With planes, LH_2 can be used to reduce drag by 30% at cruising altitudes (See Scott, D.S., Int J Hydrogen Energy, **29**, (2004), 1317-1325)
- With trains, one could envisage using the cold for superconducting MagLev

If we switch to H_2 , the last person around won't need to switch off the last light

With the sweep of its vision, the Mooresville Initiative can really switch the H_2 light on



