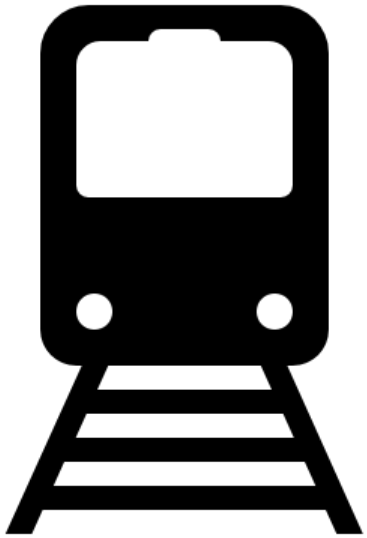

Hydrogen, the end-to-end solution for rail

Nirmal Gnanapragasam, Ph.D., P.Eng.

Process/modeling Scientist, CNL

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Hydrogen on the move

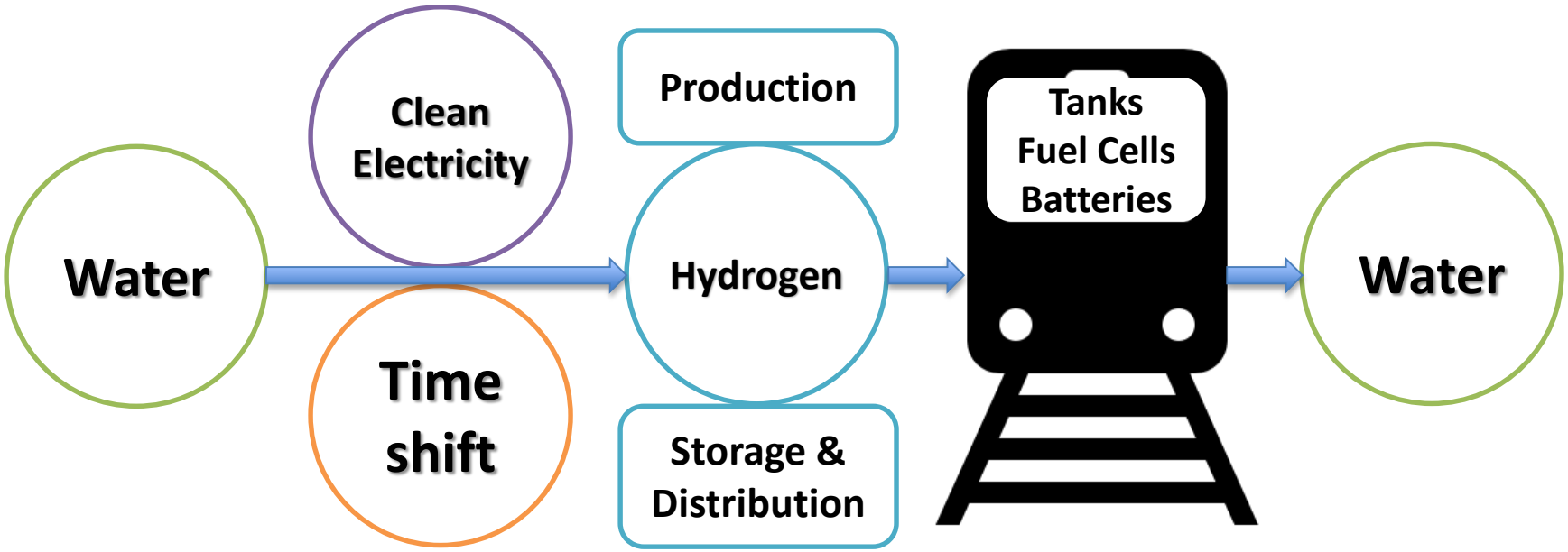
Why rail needs hydrogen as fuel?

Enables opportunities beyond the railways

- **Multi-sectoral leverage**: interlinks three economic sectors – energy, transport and environmental protection
- **Lowers economic risk**: upfront capital is the lowest among clean-propulsion systems, future cost-reduction is happening
- **Shares infrastructure**: hydrogen as a fuel is useful beyond rail transport for cars, buses, trucks, forklifts, ships, etc.
- **Cleans the air**: enables acceleration of emissions reduction per-capita better than other modes of transport
- **Localises the economy**: has potential to make Canada the hub for advanced manufacturing and clean-tech solutions

What entails hydrogen-rail (hydrail)?

Water-to-water, with some engineering in the middle



Where hydrogen fits for rail?

Flexible enough to serve light to heavy-duty rail applications

- Passenger trains:
  - Trams (inner city service)
  - Light-rail (commuter rail service)
  - Heavy-rail (suburban rail service)
- Freight trains:
  - Regional (short-haul)
  - National (long-haul)
  - International (as large as the US-Canada freight rail network)

Where is hydrail currently?

Global update on planned and proposed commercial deployments

- Canada
  - Metrolinx continues hydrogen fuel cell study to power trains (Urban Toronto)
- China
  - China rolls out world's first hydrogen-powered tram (Shangaiist)
- Germany
  - 14 hydrogen-powered trains to run on German rails from 2021 (phys.org)
- Netherlands
  - First hydrogen-powered train set for northern Netherlands in 2018 (DutchNews)
- United Kingdom
  - Proposal for UK use of Alstom's hydrogen trains (PressReader)

What challenges still exists

Hindering the progress for large-scale deployment

- **Fixed infrastructure** is required but is cheaper than wired electrification
- End-to-end energy conversion **efficiency lower – 30 to 40%** at the most, compared to wired electrification – **80 to 90%**
- **Not** an **established** technology for rail, yet
- Rail **vehicle manufacturers** are **slower to adapt** to the hydrogen based propulsion technology
- **Battery technology growth** seems to catch-up to heavy-duty application like rail, but range is still an issue

What Canada offers to hydrail?

Deeper and wider technology capabilities and expertise on hydrogen

- Hydrogen system and end-to-end assessments
- Regulation, codes and standards
- Hydrogen production
- Hydrogen storage and distribution
- Hydrogen refueling
- Hydrogen fuel cells
- Batteries
- Engineering and design
- Academic and industrial research

Does Canada have the market?

Canadian energy, transport and environmental landscape

- British Columbia has the combination of the three
- Manitoba has both energy and transport landscape
- Ontario has both energy and environmental landscape
- Quebec has the environmental landscape

Summary

Hydrogen is an improved energy currency for rail

- Hydrail helps replace diesel-powered rail by being more:
  - Energy efficient
  - Environmentally friendly
  - Economic

Canada Federal Hydrogen Capabilities

We are here to help you succeed in the hydrogen business

- Eric Barker – Innovation, Science, Economic Development
- Francois Girard – National Research Council
- Nirmal Gnanapragasam – Canadian Nuclear Laboratories
- Aaron Hoskin – Natural Resource Canada
- Ryan Klomp – Transport Canada
- Ian Williams – Global Affairs Canada

Canadian Hydrogen and Fuel Cell Sector Profile 2016

English | French

Thank You