Seasonal Hydrogen Storage for Trucks

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CNL Hydrogen Strategic Initiative
Hydrogen cogeneration, safety & applied research for three markets

Transport Sector Decarbonisation
- Hydrogen production,
- Safety,
- Process design,
- Concepts validation

Small Modular Reactor Cogeneration
- Hydrogen production,
- Safety,
- Process design,
- Materials research

Off-grid Community
- Energy storage,
- Safety,
- Process design,
- Feasibility and sustainability
Hydrogen R&D for Energy Sector

CNL’s expertise in yellow filled boxes with end-to-end assessment

- Clean Electricity
- Hydrogen Storage
- Distribution
- Production

Water

Time shift

P2P: Grid
P2G: Storage
P2X: Feedstock

Water

Clean Electricity
Hydrogen Storage
Production
Distribution
P2P: Grid
P2G: Storage
P2X: Feedstock
Hydrogen R&D for Transport Sector

CNL’s expertise in yellow filled boxes with end-to-end assessment

Water -> Clean Electricity -> Hydrogen Storage -> Production -> Storage Fuel Cells Batteries -> Vehicle -> Distribution -> Water

Time shift
GHG Reduction Ambitions for Trucks

Global push for change in fueling trucks, are we ready to support that

- Anheuser-Busch orders 800 hydrogen-powered semi trucks from Tesla rival Nikola (May 2018, CNN)
- Hydrogen-fueled truck maker announces $1 billion Arizona plant (Jan. 2018, Reuters)
- Toyota’s hydrogen fuel cell trucks are now moving goods around the Port of LA (Oct. 2017, The Verge)
- Toyota fuel cell trucks to be used by Seven-Eleven stores in Japan from 2019 (June 2018, Mainichi)
- Kenworth showcases its Hybrid Electric Cargo Transport truck (Jan. 2018, Truck News)
- Daimler Adds Two Electric Trucks in Race Against Tesla, VW (June 2018, Bloomberg)
Hydrogen Meets On-Road Trucks

CNL’s project on large-scale energy storage provides part of the solution.

- Green Electricity
- Production
- Storage
- Tanks
- Geologic
- Storage Fuel Cells
- Batteries

TRUCKS

Canada has 1 million on-road trucks registered.
Hydrogen for Trucks

CNL’s energy storage model used to assess grid, hydrogen and trucks

- Trucks classified:
  - Canada - Category 1 to 7 for heavy trucks.
  - Europe - Class A to G for semi-trailers.
  - US - Class 1 to 9 (pick-up to super-heavy).
- CNL took the full range of weights of trucks - from 5 tonnes to 65 tonnes allowed in Canada
- This provides a substantial range of comparison that any truck operator could use
CNL Energy Storage Model

Key assumptions used in the model

Trucks assumptions:
- 200 km/day or 58,400 km/year
- Operating 292 days/year
- Average speed 70 km/h
- 30% energy penalty for stop/start
- Current focus on operating cost only
- Carbon cost at 20 $/tonne of CO₂

Electrical grid assumptions:
- Surplus during <=0 $/MWh periods
- Transmission, distribution and regulation charges included

Hydrogen assumptions:
- PEM electrolyser at 500 $/kWe
- Mid-pressure tanks at 100 $/kg
- Geologic storage at 3 to 30 $/kg
- Storage pressure at 13 Mpa
- Hydrogen production from 20% of surplus electricity and when HOEP is below or equal to 0 $/MWh

Acronyms:
- HOEP – Hourly Ontario Electricity Price
- GHG – Greenhouse Gas
Diesel as Truck Fuel Needs Replacing

Preliminary results from CNL model - carbon costs are significant
Grid Surplus for Hydrogen Production

Preliminary results from CNL model - a need for large-scale storage
Hydrogen Production Planning

Preliminary results from CNL model - when electricity price is the lowest

Electrolyser operating characteristics:
For the same installed size, could increase hydrogen production capacity by increasing current density

![Graph showing the relationship between Electrolyser current density (A/cm²) and Hydrogen Production Characteristics such as Duration for 50 tpd plant (hours) and Rate for 50 tpd plant (tonne/h).]
Large-scale Seasonal Storage

Preliminary results from CNL model - cost of tanks scale with size

![Graph showing the cost of tanks vs. seasonal storage size. The graph compares tank storage and geologic storage, with tank storage showing a significant increase in cost with increasing storage size, while geologic storage remains relatively constant.](image-url)
Operating Costs for Trucks

Preliminary results from CNL model - fuel costs vary with storage option

Fuel cost for trucks (k$/year)

All truck categories - based on total weight (tonnes)

Hydrogen cost - tank storage
Hydrogen cost - geologic storage
Diesel cost

Levelised hydrogen cost, geologic = 1.9 $/kg
Levelised hydrogen cost, tanks = 6.8 $/kg
Potential for Deployment of H$_2$-Trucks

Preliminary results from CNL model - Ontario surplus has potential

125,000 of these trucks in Ontario in 2016

125,000 of these trucks in Ontario in 2016

No. of trucks 20% surplus could support

All truck categories - based on total weight (tonnes)
Next Steps

CNL is assessing geologic storage potential, starting with Ontario

• Geologic storage is economical for seasonal storage
• Current CNL project to assess geologic sites suitable to store hydrogen
  • Begin with sites in Ontario, then expand to rest of Canada
Summary

Hydrogen powered trucks are getting real and they need hydrogen

Storage:

- Hydrogen produced using electricity from the grid needs viable large-scale storage (such as geologic) to improve economics
- Geologic storage could become a necessity for storing large quantities of hydrogen produced from other clean production processes as well

Trucks and vehicles:

- CNL has developed models to assess vehicle fleets powered by hydrogen to support long-term policies for GHG reduction
- We could provide case-specific hydrogen from grid assessments for different truck fleets or other vehicle fleets
Thank You