DECARBONIZATION OF LONG-HAUL TRUCKING IN EASTERN CANADA
SIMULATION OF THE e-HIGHWAY TECHNOLOGY ON THE A20-H401 HIGHWAY CORRIDOR
We solve infrastructure challenges specific to transportation, power and public-private partnerships.

We do it by providing end-to-end management consulting services, including analytics, technical, legal, regulatory as well as economics, policy, finance and governance.

Our work in action

• **Mobilize** public and private investments to start an initiative for coastal protection in Africa.
• **Help** a North American transport agency solve urban freight challenges.
• **Guide** a South Asian government revitalize its power sector to meet growing energy demands.
Presentation plan

- Introduction
- Presentation of the e-highway concept
- Model and Methodology
- Assumptions
- Results
- Conclusion
Introduction

Freight transportation is one of the most challenging sector to decarbonize
- Heavy truck sector = 8% of national emissions and tripled since 1990
- Complex (logistics chains, regulations and cross-border traffic…)
- Supports daily economic activities

Achieving Canada’s net zero emissions goals by 2050 will require decisive action in this sector, both technologically and logistically

Current initiatives are insufficient to place Canada on a clear path towards zero-emission road freight
- Carbon tax; improving standards for heavy-duty trucks; subsidizing alternative truck technologies and fuels; Clean fuel standard for regulating minimum levels of biofuels in diesel.

Limits of the current approach has led to considering new option: e-highways
- Overhead catenary system to directly power heavy truck engines equipped with pantographs, on dedicated highway corridors
Objective of the study

- Simulate the potential of e-highway technology for the decarbonization of heavy freight transport on a 1,300 km of the A20-H401 highway corridor connecting Quebec, Montreal and Toronto, up to the U.S. border

- Based on a GIS analysis of current flows of heavy vehicles, according to the present road capacity of the A20-H401

- Study considers hybrid diesel-catenary electric trucks (class 8 and above)

- First step in a proposal developed by HEC Montréal and CPCS, in collaboration with government, university and private partners, to compare the costs and potential of different decarbonization technologies along the A20-H401 axis.
e-highway : a new concept based on century-old technology

- A supporting structure built outside the road boundary holds two overhead catenaries, supplying the positive and negative electrical circuit.
- Electricity is transferred to the trucks through a pantograph installed on the roof.
- A secondary source of energy is used outside of electrified roads. This secondary source can be diesel or electricity (with a long-range battery), as well as hydrogen, bio-gas, etc.
- The technology is extremely flexible, as trucks equipped with the technology remain able to circulate on any road. The catenary system does not prevent other vehicles from using the electrified highway.
Relevance in the Canadian context and benefits

- Linear transportation network
- Clean and affordable electricity
- Use of existing road infrastructure
- Flexibility (transfer from hybrid system to battery over time)
- Tested in cold climate (Sweden)

- Known technology
- Efficiency given direct use of electricity
- No downtime for recharging batteries (for 100% electric trucks)
- Low maintenance and repair costs
- Significant potential for GHG emissions reductions
Zero emission trucks are possible, but efficiency varies

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Range Cost per km</th>
<th>Efficiency WTW</th>
<th>Example vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Road Systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eTruck (Grid)</td>
<td>60 km 19 ct/km</td>
<td>77%</td>
<td></td>
</tr>
<tr>
<td>eTruck (Solar)</td>
<td>95 kWh 12 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eTruck (Grid)</td>
<td>48 km 20 ct/km</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>eTruck (Battery)</td>
<td>95 kWh 10 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eTruck (Electric)</td>
<td>24 km 55 ct/km</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>eTruck (Hydrogen)</td>
<td>93 kWh 16 ct/kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power-to-Gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eTruck (Electric)</td>
<td>17 km 70 ct/km</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>eTruck (Methane)</td>
<td>56 kWh 15 ct/kWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Including storage
Source: German Ministry of Environment
e-highways are being pilot-tested in several countries...

Sweden: 2km

California: 1.6km

Germany: 3 ongoing pilots
- 10km electric road test track near Frankfurt
- 5km portion of a motorway near Lübeck
- a selected public test route between Kuppenheim and Gernsbach-Obertsrot
... and plans are being made for further deployment

- **Sweden**: 2,000 km of ERS by 2030
- **Germany**: 4,000 km of e-highway by 2030
- **UK**: White paper on e-highway (2020)
- **France**: Under study
- **Italy**: 6km pilot under consideration
Our model simulates the deployment of an e-highway on the A20-H401 corridor

- The corridor (1344km) is divided into segments
- Real truck flow data is extracted from a Geographical Information System (GIS)
- The model simulates the costs and benefits of the e-highway
The model compares the costs and benefits with a business-as-usual baseline.

<table>
<thead>
<tr>
<th>Costs</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Investment cost</td>
<td>• Savings on fuel</td>
</tr>
<tr>
<td>• O&amp;M cost, incl electricity</td>
<td>• Avoided CO₂</td>
</tr>
</tbody>
</table>

Techno-economic parameters of the e-highway

Scenario for deployment and adoption by the industry

Excel based model
Techno-economic parameters of the e-highway come from a review of the literature.
## Assumptions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra capital cost per individual truck</td>
<td>From $70,000/truck today to $20,000/truck in 2040</td>
<td>Extra investment per truck, covering the pantograph, the electric drive train, and a buffer battery.</td>
</tr>
<tr>
<td>Diesel consumption on highway (baseline)</td>
<td>0.45 liters/km</td>
<td>Average 5.25 mpg (Ontario) Average 5.35 mpg (Quebec)</td>
</tr>
<tr>
<td>Carbon contents of electricity</td>
<td>QC: 1.2 g CO₂e/kWh ON: 40 g CO₂e/kWh</td>
<td>NRCan National Inventory Report 2017</td>
</tr>
<tr>
<td>Carbon contents of diesel</td>
<td>2.6 kg CO₂ eq/liter</td>
<td>NRCan National Inventory Report 2017</td>
</tr>
<tr>
<td>Cost of diesel</td>
<td>$0.78/liter</td>
<td>NRCan, 17 Feb. 2021. Taxes are excluded ($0.389/liter)</td>
</tr>
<tr>
<td>Value of carbon</td>
<td>Increase from $30/t CO₂e today to $170/t in 2030</td>
<td>Federal carbon pricing policy</td>
</tr>
</tbody>
</table>
**Test n°1: under maximum adoption assumption, the infrastructure pays back in 10 years**

<table>
<thead>
<tr>
<th>Highway segments</th>
<th>Simple payback period</th>
<th>Avoided GHG, MtCO2/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivière du Loup – Quebec (without city areas)</td>
<td>12</td>
<td>0.3</td>
</tr>
<tr>
<td>Quebec – Montreal (without city areas)</td>
<td>11</td>
<td>0.3</td>
</tr>
<tr>
<td>Montreal – Prescott (without city area)</td>
<td>8</td>
<td>0.4</td>
</tr>
<tr>
<td>Prescott – Toronto (without city area)</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Toronto – Windsor (without city area)</td>
<td>7</td>
<td>1.2</td>
</tr>
<tr>
<td>A20 – H401</td>
<td>9</td>
<td>3.2</td>
</tr>
</tbody>
</table>

* Payback period is shorter on segments with higher traffic.

**Simple payback period:** number of years after initial investment costs would be completely offset by net savings from avoided diesel consumption.
Test n°2: progressive deployment scenario

- **Start with South-West:** denser traffic
- **5-year increments** to allow for construction time
- **North East portion** of the route last to be electrified
Test n°2: adoption by the industry is assumed to progress slowly

- 0.2% of ON + QC heavy truck fleet
- 13% of ON + QC heavy truck fleet
Test n°2: Under the progressive scenario, the economic rate of return ranges from 7 to 10%.

- **Costs**
  - $4.1 billion investment in infrastructure
  - $0.7 billion extra cost for trucks

- **Benefits**
  - Yearly GHG reductions: 2.8 Mt CO$_2$e
  - $360 millions CAD d'économie de carburant

**ERR: 7%**
(10% for segments with highest traffic)

**Economic rate of return:**
Discounted economic benefits expressed as a % of initial investment. Similar to an interest rate.
Test n°3: Viability is sensitive to fuel and infrastructure costs, and adoption rate

Conclusion: at first sight, an interesting option...

- **Pays back in 7 years** on segments with highest traffic if 100% adoption
- **ERR of 7 to 10%** with a progressive, more realistic adoption scenario
- **Reasonable abatment costs** ranging from $65/t CO₂ (high traffic, high adoption) to $200/t CO₂ (entire range, progressive adoption) with an 8% discount rate
... While many questions remain open

➤ What is the trucking industry’s perception of the technology?

➤ Is it compatible with operational constraints and industry preferences?

➤ What is the optimal financing structure, how should costs and benefits be allocated among stakeholders?
... technical feasibility needs further investigation

- Can it withstand an ice storm?
- What about clearances?
... and alternative design options could be envisaged

- Full electrification of the highway
- Hybrid trucks (electric + diesel / biofuels / LNG etc)
- Short range battery (buffer)

Our simulation v. Alternative design

- Short electrified segments for on-the-go recharge
- Fully electric trucks
- Larger batteries
Proposal of the extended study

Preliminary list of freight decarbonization technologies to compare

A. Zero emission technologies
   - ERS trucks
   - Battery Electric Trucks
   - Hydrogen fuel cell trucks
   - Biofuels

B. Other technologies, incl. use of hydrocarbons
   - Battery-diesel hybrid trucks
   - LNG
   - Synthetic fuels

C. Complementary intermodal solutions
   - Rail
   - Maritime

Preliminary list of key parameters for technology analysis

- Carbon footprint
- Technology maturity
- Capital investment requirement
- Truck production costs
- Operating costs
- Feasibility in the Canadian context
- Stakeholder engagement/acceptability
- Flexibility
- Inter-jurisdictional issues
- Possible sources of funding
- …
Acknowledgements

**Funding:** EMI / NRCan

**Other coauthors**
- Ramata Ba, CPCS
- Ashok Kinjarapu, CPCS

**Collaborator**
- Normand Mousseau, IET – Polytechnique Montréal

**Reviewers**
- Peter Harrison, CPCS
- Joel Carlson, CPCS
- Patrik Åkerman, Siemens Mobility
- Pierre-Olivier Pineau, HEC Montréal
Download report
energie.hec.ca/canada-ehighway/

Clara Kayser-Bril : ckayserbril@cpcs.ca
Johanne Whitmore : johanne.whitmore@hec.ca

For technical info on the technology, contact Patrik Akerman
patrik.akerman@siemens.com