

DECARBONIZATION OF LONG-HAUL TRUCKING IN EASTERN CANADA

SIMULATION OF THE e-HIGHWAY TECHNOLOGY
ON THE A20-H401 HIGHWAY CORRIDOR



Chair in Energy Sector
Management
HEC MONTRÉAL



PROJECT COLLABORATOR



PREPARED FOR





We are CPCS.

A global management consulting firm specializing in infrastructure.

50 years of global infrastructure leadership

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

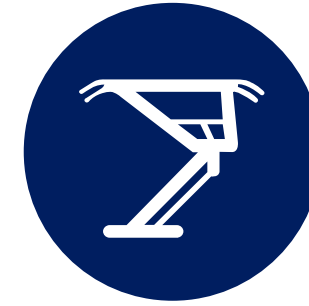
- Simulate the potential of e-highway technology for the decarbonization of heavy freight transport on a 1,300 km of the A20-H401 highway corridor connecting Quebec, Montreal and Toronto, up to the U.S. border
- Based on a GIS analysis of current flows of heavy vehicles, according to the present road 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



Trucks



Pantograph



Overhead lines

- 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



Pathway	Range Cost per km	Efficiency WTW	Example vehicle
Electric Road Systems 	60 km 19 ct/km	77%	
Battery 	48 km 20 ct/km	62%	
Hydrogen 	24 km 55 ct/km	29%	
Power-to-Gas 	17 km 70 ct/km	20%	

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

UK: White paper on
e-highway (2020)

Germany: 4,000 km
of e-highway by 2030

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

Techno-economic parameters of the e-highway

Scenario for deployment and adoption by the industry

Segment 3 - Quebec - Montreal (without city areas) - Both ways		0%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Deployment scenario of hybrid trucks		0%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Average yearly distance covered by hybrid heavy trucks		km/truck/yr	68,155,536	72,699,240	77,242,943	81,786,645	86,330,348	90,874,050	95,417,753	99,961,455	104,505,158	109,048,860	113,592,563	113,592,563	113,592,563	113,592,563	113,592,563	113,592,563	113,592,563
Data																			
Nighttime CAPEX of e-highway infrastructure		CAD	774,000,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EX of e-highway infrastructure		CAD/year	-	15,480,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of hybrid heavy trucks active on the segment		hybrid heavy trucks	-	897	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional cost of truck hybridization		CAD/truck/year	-	7,846,855	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electric consumption of hybrid trucks on e-highway		Wh/year	-	102,233,306	109,048,860	115,864,414	122,679,968	129,495,521	136,311,075	143,126,629	149,942,183	156,757,736	163,573,290	170,388,844	170,388,844	170,388,844	170,388,844	170,388,844	170,388,844
Cost of electricity		CAD/year	-	2,159,331	7,833,420	8,110,559	8,387,698	8,664,837	8,941,975	9,219,113	9,496,251	9,773,389	10,050,527	10,327,665	10,327,665	10,327,665	10,327,665	10,327,665	10,327,665
Total yearly operating costs (excluding CAPEX of e-highway)		CAD/year	-	30,483,186	31,483,398	32,483,610	33,483,822	34,484,034	35,484,246	36,484,458	37,484,670	38,484,882	39,485,094	40,485,306	40,485,310	40,485,310	40,485,310	40,485,310	40,485,310
Benefits																			
Avoided diesel consumption		l/year	-	153,009,182	163,209,794	173,410,406	183,611,018	193,811,630	204,012,242	214,212,854	224,413,466	234,614,078	244,814,690	255,015,302	255,015,303	255,015,303	255,015,303	255,015,303	255,015,303
Savings related to avoided diesel consumption		CAD/year	-	119,347,162	127,303,639	135,260,117	143,216,594	151,173,072	159,129,549	167,086,026	175,042,504	182,998,981	190,955,459	198,911,936	198,911,936	198,911,936	198,911,936	198,911,936	198,911,936
Avoided GHG emissions related to avoided diesel consumption		CO2eq/yr	-	397,624	424,345	450,867	477,389	503,910	530,432	556,953	583,475	609,997	636,519	663,040	663,040	663,040	663,040	663,040	663,040
GHG emissions from electricity consumption		CO2eq/yr	-	51	55	58	61	65	68	72	75	78	82	85	85	85	85	85	85
It avoided GHG emissions		CO2eq/yr	-	397,773	424,291	450,809	477,327	503,845	530,364	556,882	583,400	609,918	636,436	662,955	662,955	662,955	662,955	662,955	662,955
Economic value of avoided GHG		CAD/year	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Financial revenue from avoided GHG (sales of carbon credits)		CAD/year	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net-Benefit calculation																			
Economic flows, including economic value of avoided GHG		CAD/year	(774,000,000)	88,863,976	95,820,241	102,776,506	109,732,771	116,689,036	123,645,301	130,601,566	137,557,831	144,514,096	151,470,361	158,426,626	158,426,626	158,426,626	158,426,626	158,426,626	158,426,626
Total savings + revenues from sales of carbon credits		CAD/year	-	119,347,162	127,303,639	135,260,117	143,216,594	151,173,072	159,129,549	167,086,026	175,042,504	182,998,981	190,955,459	198,911,936	198,911,936	198,911,936	198,911,936	198,911,936	198,911,936
Initial flows, excluding economic value of avoided GHG		CAD/year	(774,000,000)	88,863,976	95,820,241	102,776,506	109,732,771	116,689,036	123,645,301	130,601,566	137,557,831	144,514,096	151,470,361	158,426,626	158,426,626	158,426,626	158,426,626	158,426,626	158,426,626
Cumulative flows, excluding economic value of avoided GHG		CAD/year	(774,000,000)	(685,136,024)	(589,315,784)	(486,539,278)	(378,806,507)	(260,117,471)	(136,472,171)	(5,870,605)	131,687,228	276,201,322	421,716,416	568,098,309	744,524,935	902,951,561	1,061,378,187	1,219,804,813	1,378,231,439
Economic rate of return %		%	-	16%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simple payback period, excluding economic value of avoided GHG		years	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Segment 5 - Montreal - Prescott (without city area) - Both ways																			
Deployment scenario of hybrid trucks		% of heavy trucks	0%	10%	12%	14%	16%	18%	20%	22%	24%	26%	28%	30%	32%	34%	36%	38%	40%
Average yearly distance covered by hybrid heavy trucks		km/truck/yr	-	30,472,131	36,566,557	42,660,983	48,755,409	54,849,836	60,944,262	67,038,688	73,133,114	79,227,540	85,321,966	91,416,392	97,510,819	103,605,245	109,699,671	115,794,097	121,888,523
Data																			
Nighttime CAPEX of e-highway infrastructure		CAD	525,600,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EX of e-highway infrastructure		CAD/year	-	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000	10,512,000
Number of hybrid heavy trucks active on the segment		hybrid heavy trucks	-	401	481	561	642	722	802	882	962	1,042	1,123	1,203	1,283	1,363	1,443	1,523	1,603

Costs

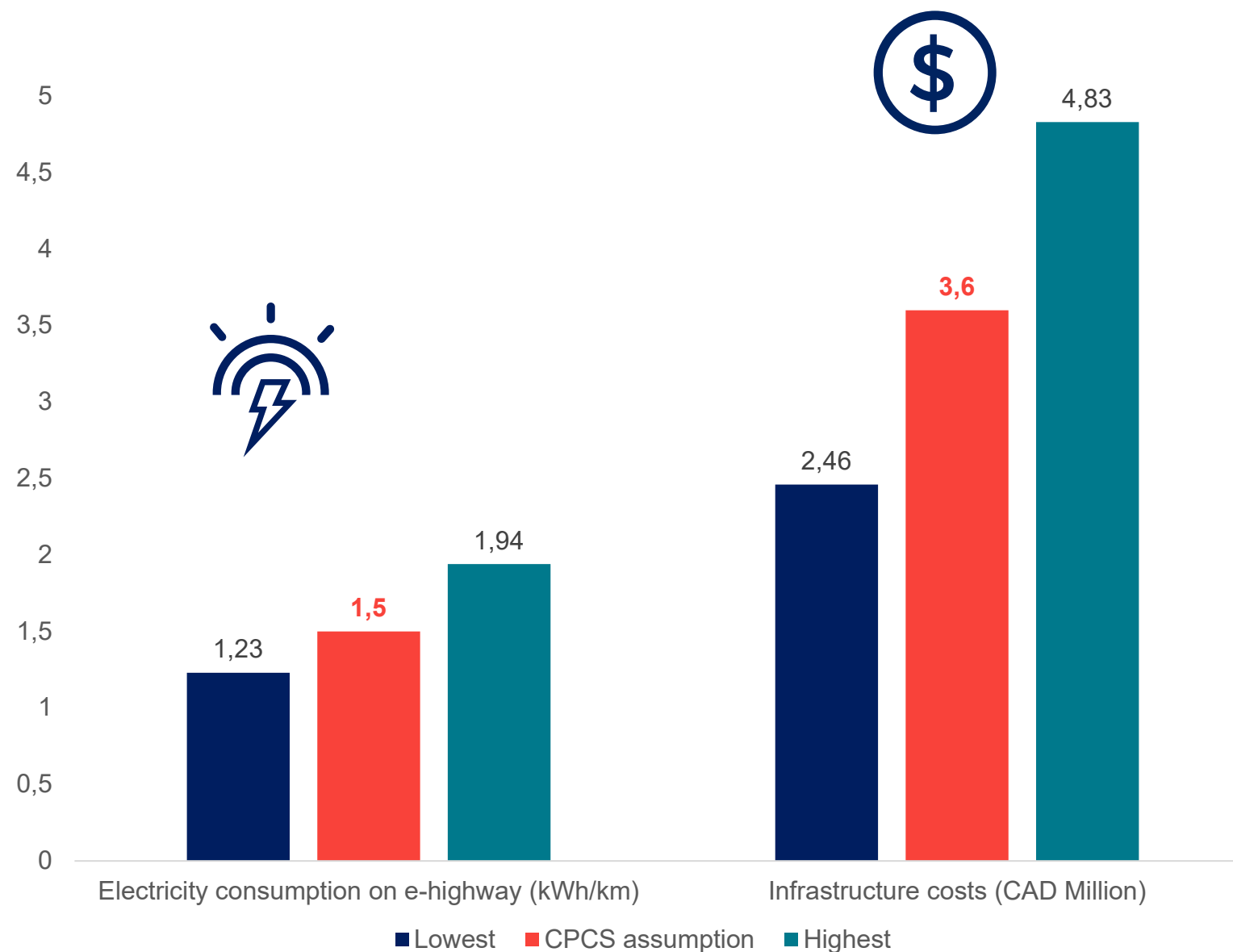
- Investment cost
- O&M cost, incl electricity

Benefits

- Savings on fuel
- Avoided CO₂





Techno-economic parameters of the e-highway come from a review of the literature



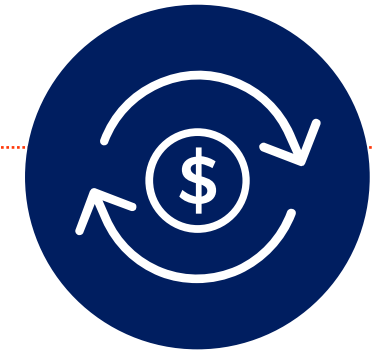
Assumptions

Parameter	Value	Comment
Extra capital cost per individual truck	From \$70,000/truck today to \$20,000/truck in 2040	Extra investment per truck, covering the pantograph, the electric drive train, and a buffer battery.
Diesel consumption on highway (baseline)	0.45 liters/km	Average 5.25 mpg (Ontario) Average 5.35 mpg (Quebec)
Carbon contents of electricity	QC: 1.2 g CO ₂ e/kWh ON: 40 g CO ₂ e/kWh	NRCan National Inventory Report 2017
Carbon contents of diesel	2.6 kg CO ₂ eq/liter	NRCan National Inventory Report 2017
Cost of diesel	\$0.78/liter	NRCan, 17 Feb. 2021. Taxes are excluded (\$0.389/liter)
Value of carbon	Increase from \$30/t CO ₂ e today to \$170/t in 2030	Federal carbon pricing policy

Test n°1: under maximum adoption assumption, the infrastructure pays back in 10 years

\$ 		
\$ 		
Highway segments	Simple payback period	Avoided GHG, MtCO2/year
Rivière du Loup – Quebec (without city areas)	12	0.3
Quebec – Montreal (without city areas)	11	0.3
Montreal – Prescott (without city area)	8	0.4
Prescott – Toronto (without city area)	8	1.0
Toronto – Windsor (without city area)	7	1.2
A20 – H401	9	3.2

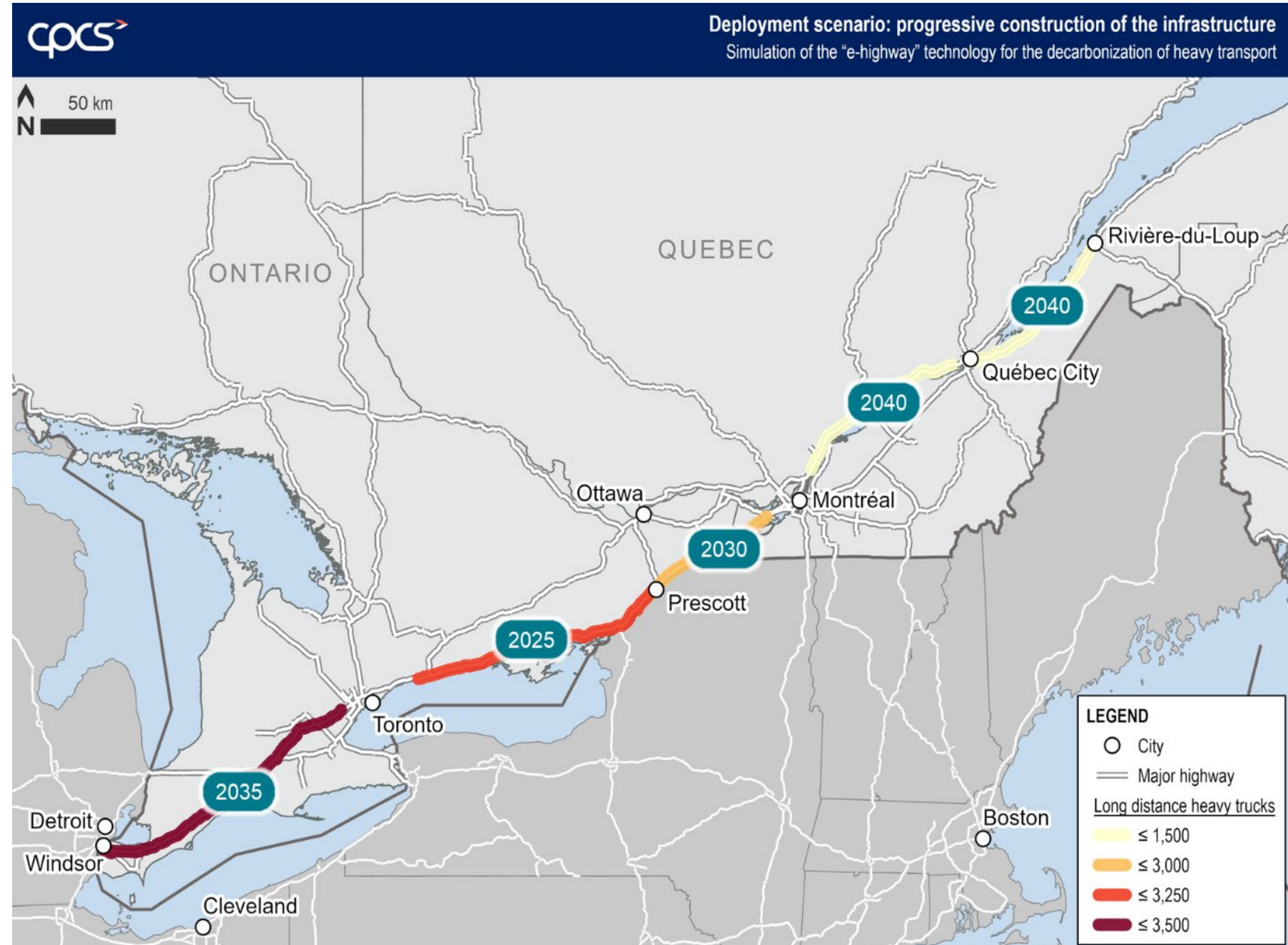
* Payback period is shorter on segments with higher traffic



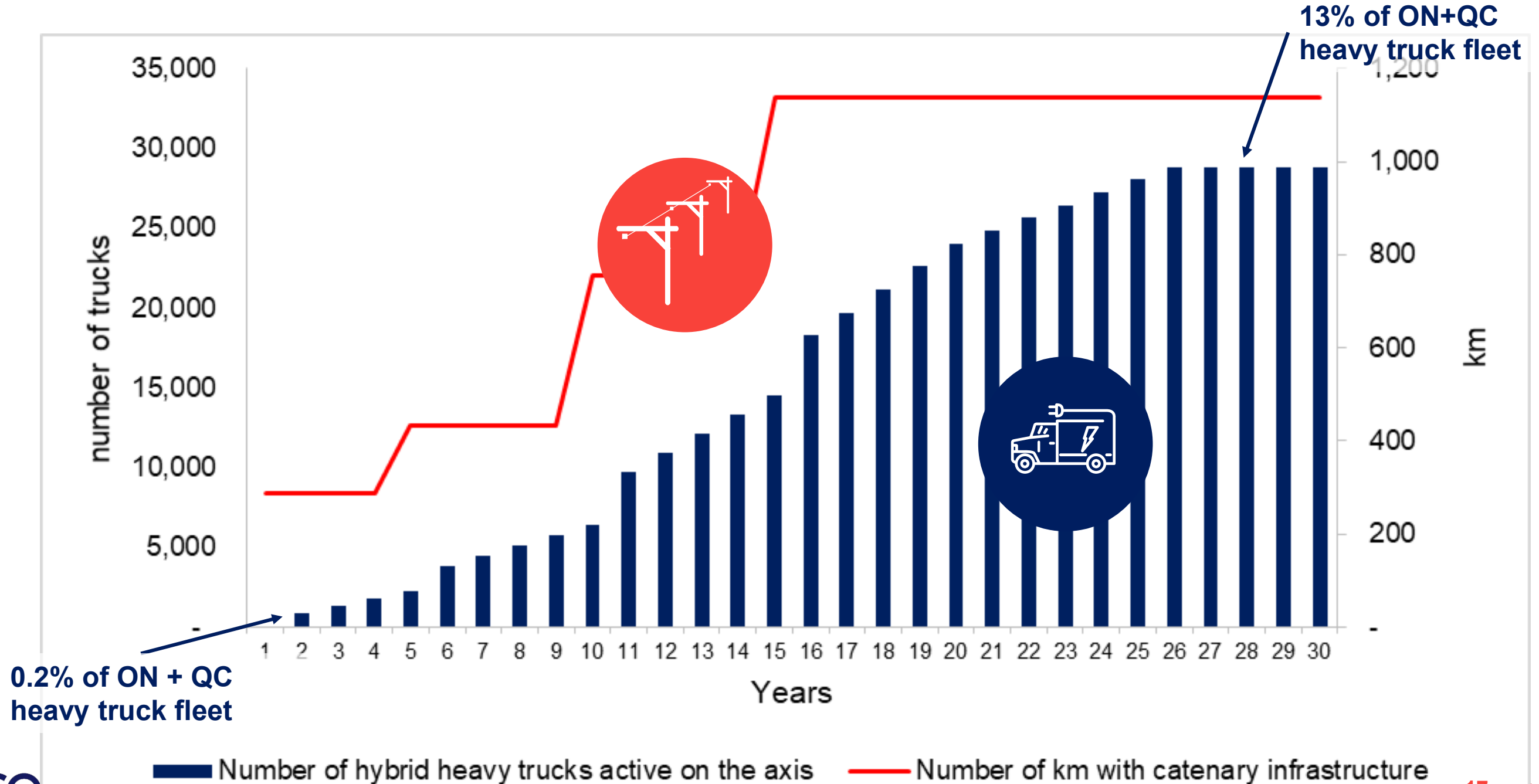
Simple payback period: number of years after initial investment costs would be completely offset by net savings from avoided diesel consumption.

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



Test n°2: Under the progressive scenario, the economic rate of return ranges from 7 to 10%

\$4.1 billion
investment in
infrastructure

\$0.7 billion extra
cost for trucks



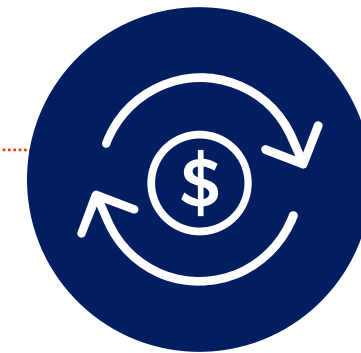
VS



Yearly GHG reductions:
2.8 Mt CO₂e

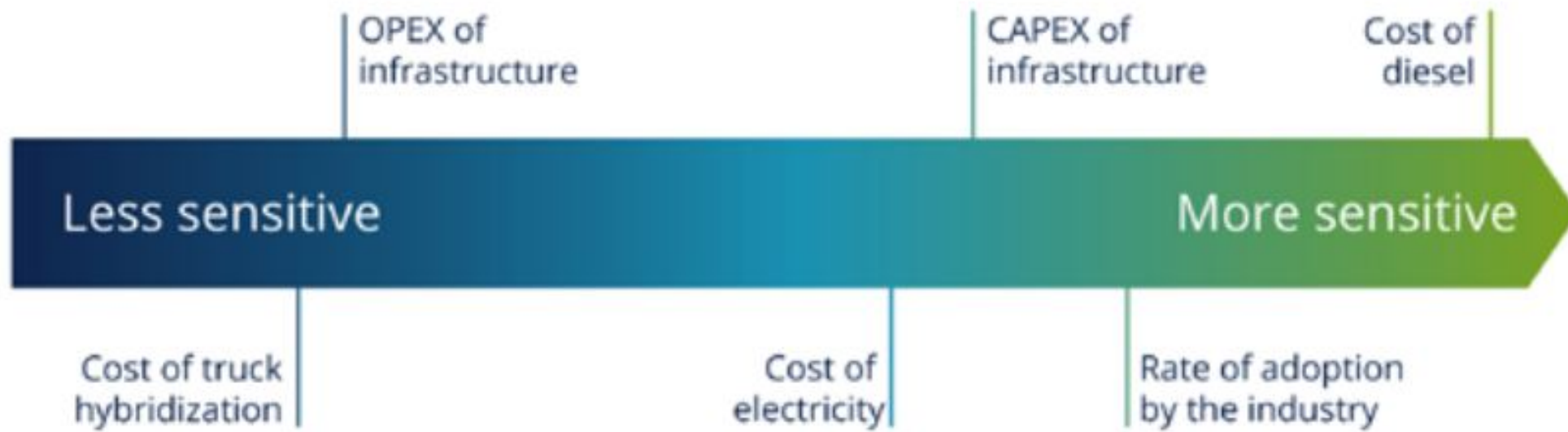
\$360 millions CAD
d'économie de carburant

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



Source CPCS, 2021.



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



Results for
discussion

- **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 abatement 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?

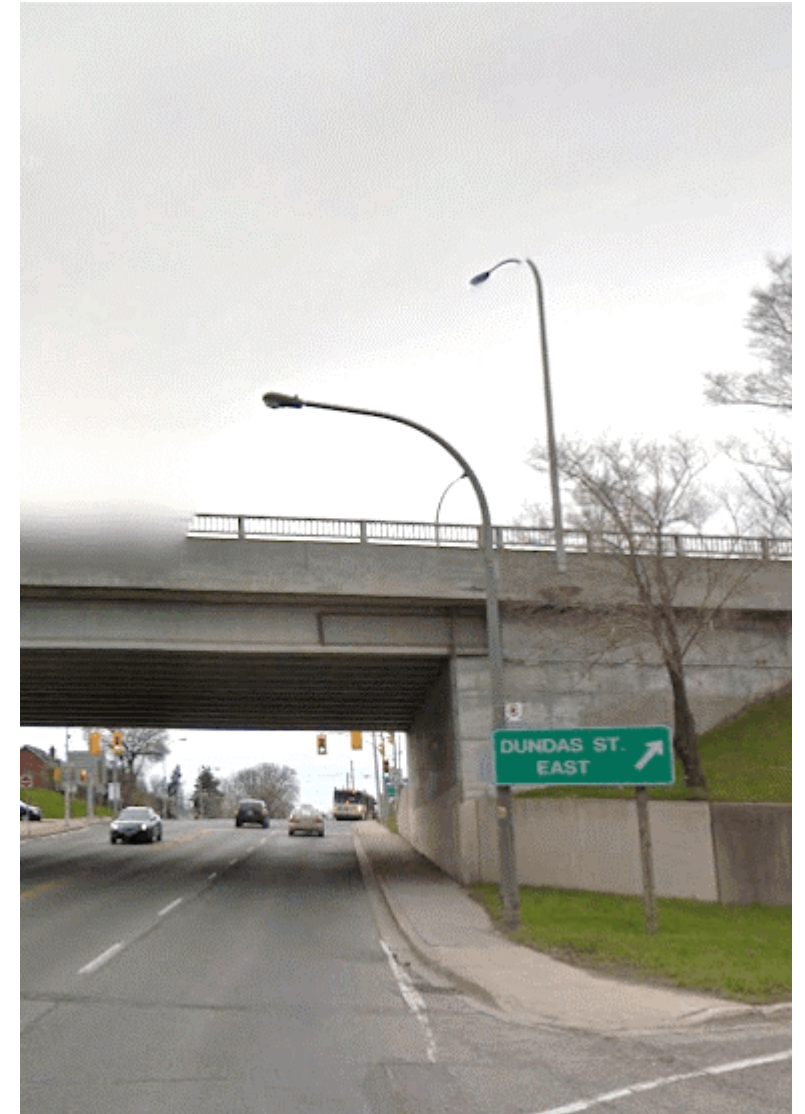


... technical feasibility needs further investigation

➤ 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
- ...





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