Simulation of the “e-highway” technology for the decarbonization of heavy transport on the A20-H401 highway corridor in Eastern Canada

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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.

The e-highway: a new concept based on century-old technology

Truck + **Pantograph** + **Overhead line**

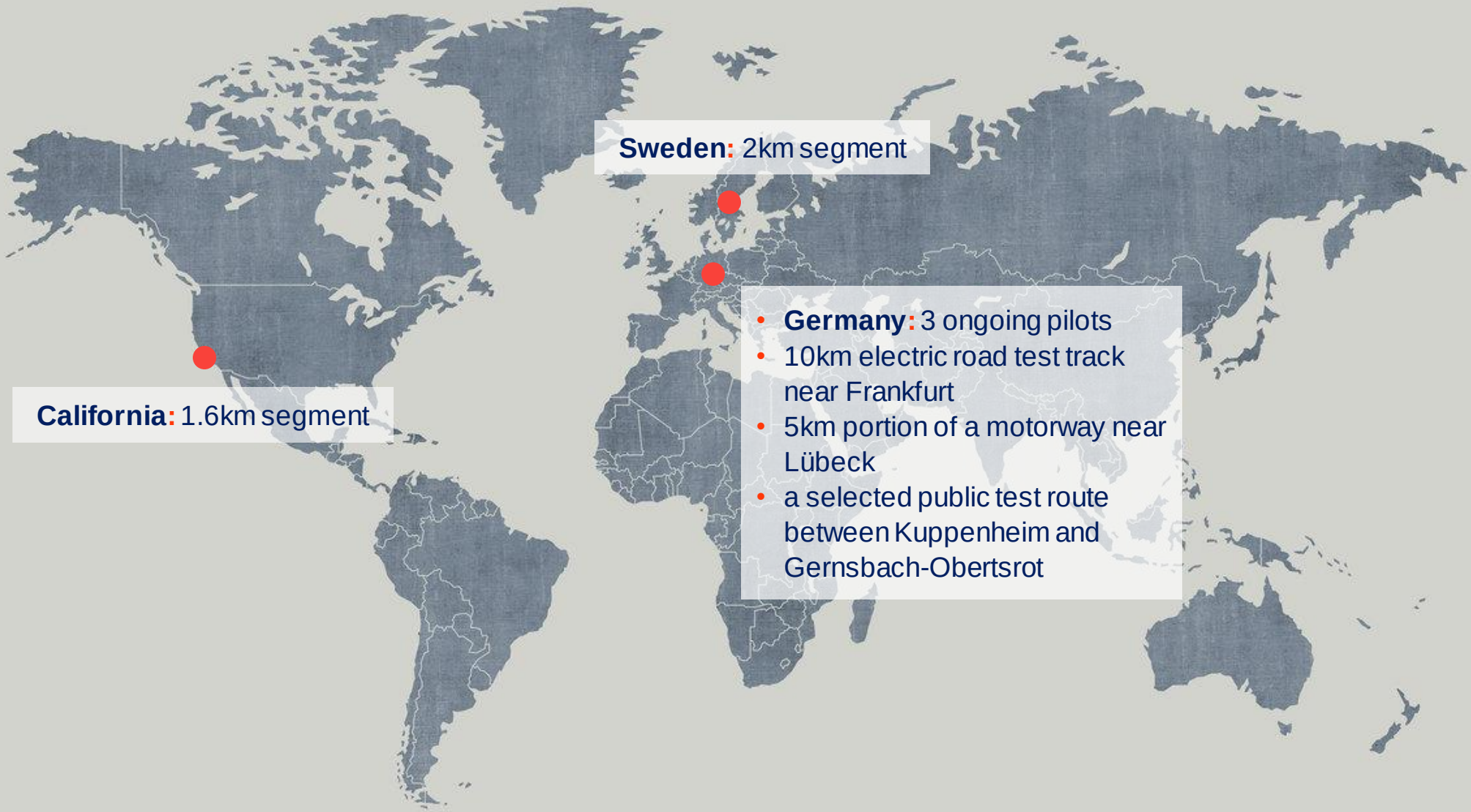
- A supporting structure built outside the road boundary holds two overhead catenaries, supplying the positive and negative electrical circuit.
- Electricity is transferred to the trucks through a pantograph installed on the roof.
- A secondary source of energy is used outside of electrified roads. This 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

e-highways are being pilot-tested in several countries



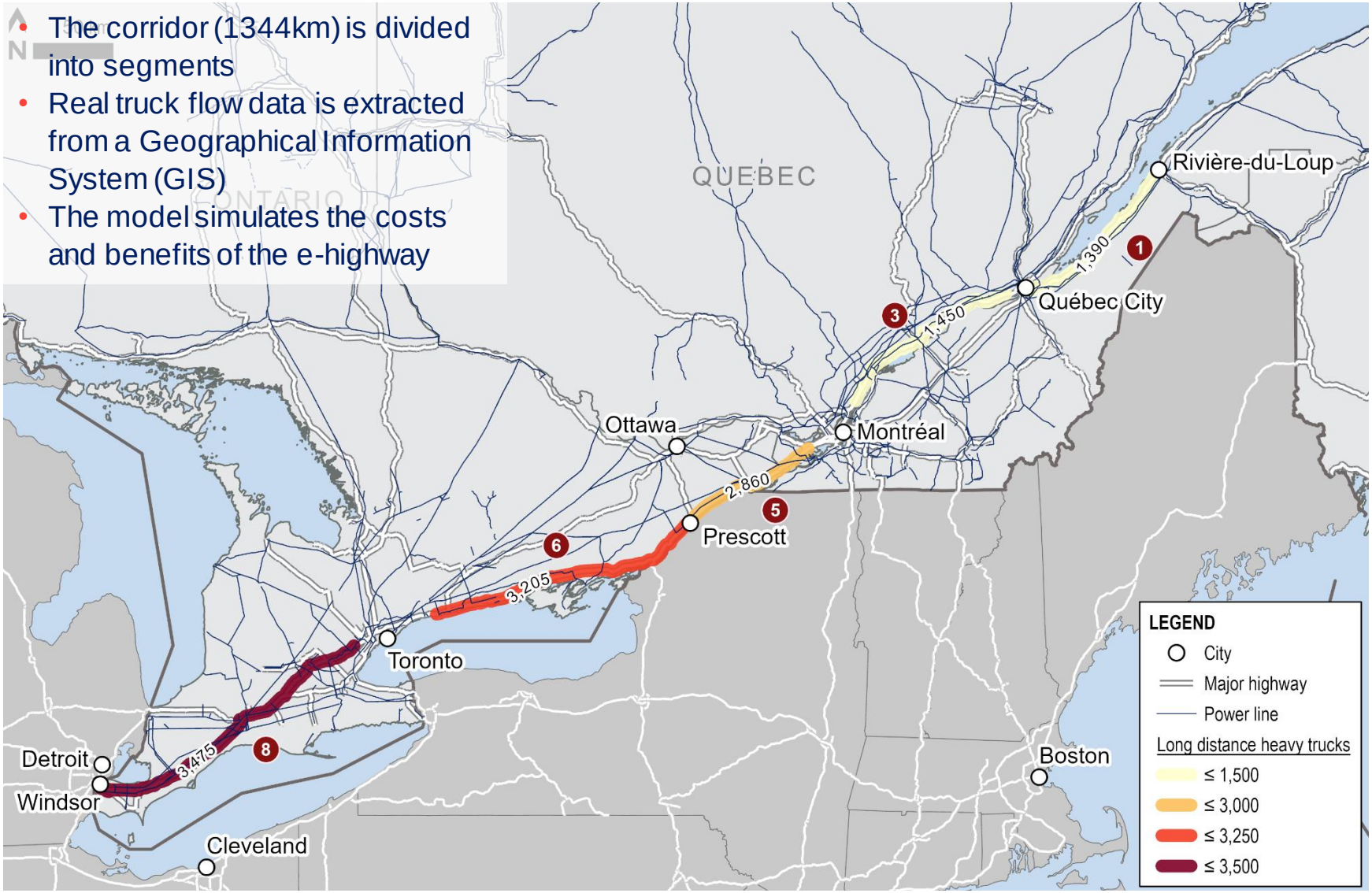
Sweden: 2km segment

California: 1.6km segment

- **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

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

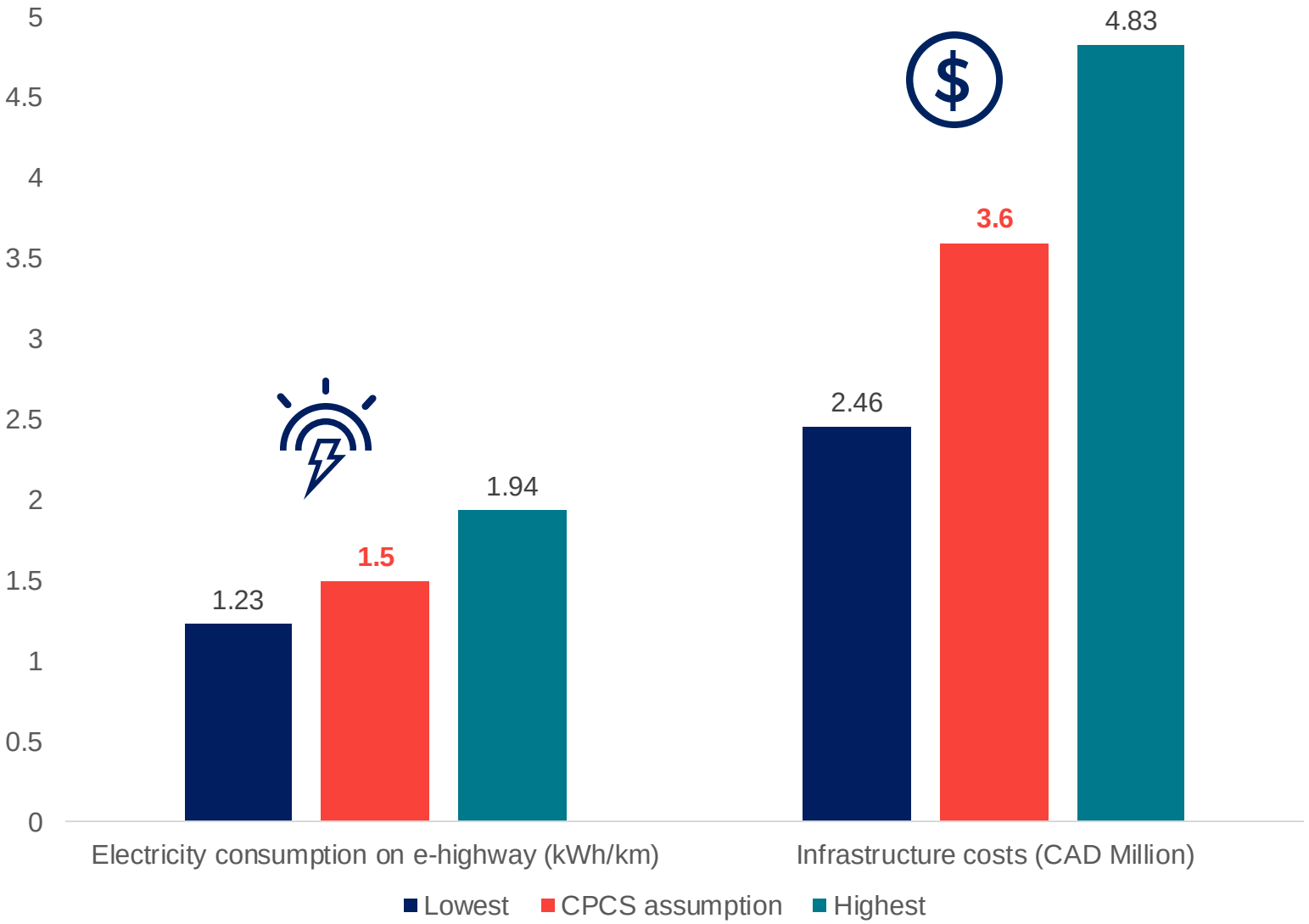
Costs

- Investment cost
- O&M cost, incl electricity

Benefits

- Savings on fuel
- Avoided CO_2

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



Assumptions *(continued)*

Parameter	Value	Basis
Extra capital cost per individual truck	**50,000 CAD/truck**	Extra investment per truck, covering the pantograph, the electric drive train, and a buffer battery.
Electricity consumption on e-highway	**1.5 kWh/km**	Value available in the literature range from 1.23 to 1.94
Diesel consumption on highway	**0.45 liters/km**	Average of 5.25 mpg (Ontario) and 5.35 mpg (Quebec)
Carbon contents of electricity	**QC: 1.2 g CO2eq/kWh** **ON: 40 g CO2eq/kWh**	Natural Resources Canada's 2017 National Inventory Report
Carbon contents of diesel	**2.6 kgCO2eq/l**	Natural Resources Canada's 2017 National Inventory Report
Cost of diesel	**0.78 CAD/liter**	Natural Resources Canada, 17 Feb. 2021. Taxes are excluded (0.389 CAD/liter)
Value of 1 ton of avoided CO2	**50 to 170 CAD**	

Test #1: under maximum adoption assumptions, the infrastructure pays back in 10-20 years

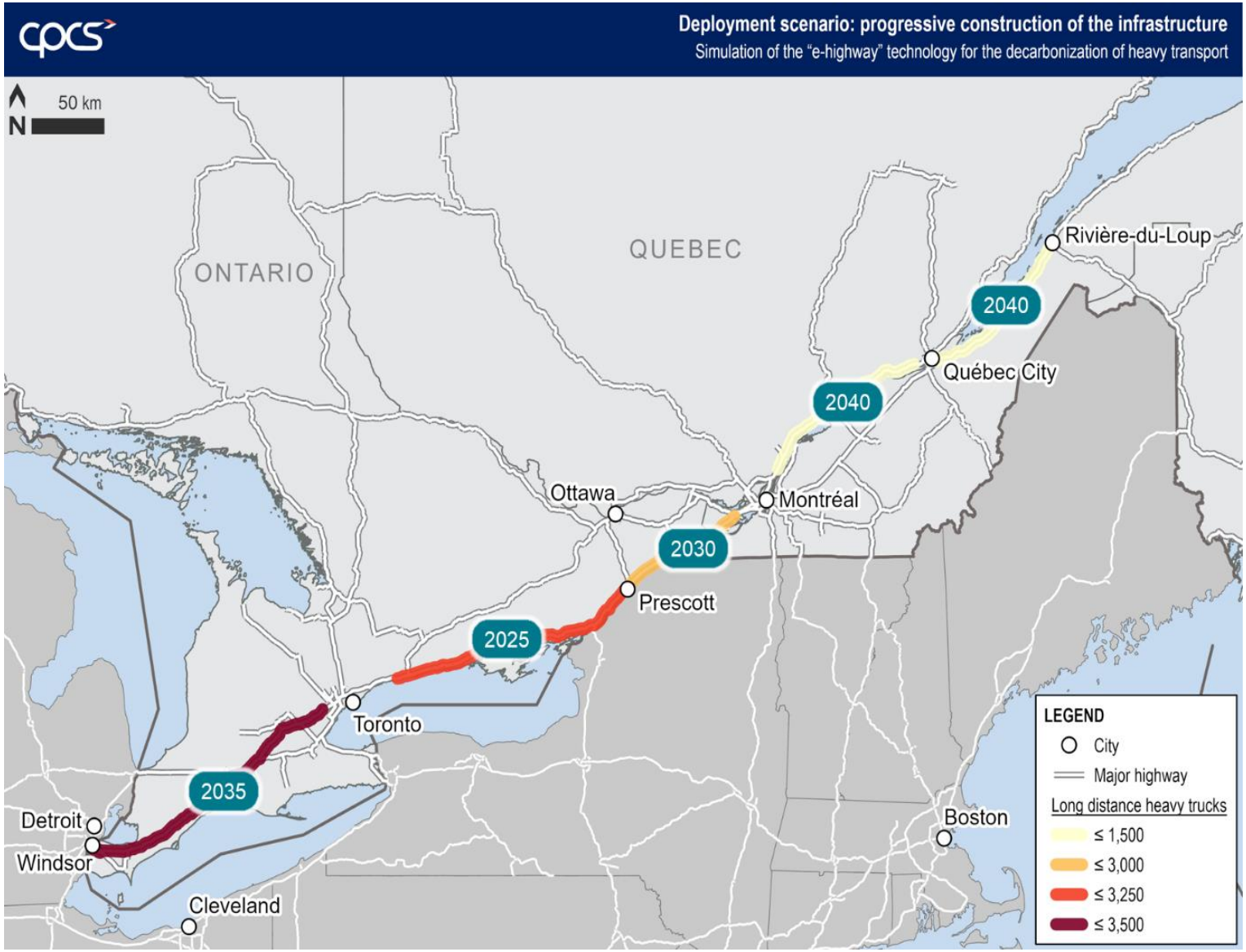
	Highway segments	Simple payback period @$50/tCO2	Simple payback period @$170/tCO2
1.	**Rivière du Loup – Quebec** (without city areas)	25	13
3.	**Quebec – Montreal** (without city areas)	23	12
5.	**Montreal – Prescott** (without city area)	23	9
6.	**Prescott – Toronto** (without city area)	20	8
8.	**Toronto – Windsor** (without city area)	17	7
Total	**A20 – H401**	20	9

* **Payback period is shorter on segments with higher traffic**

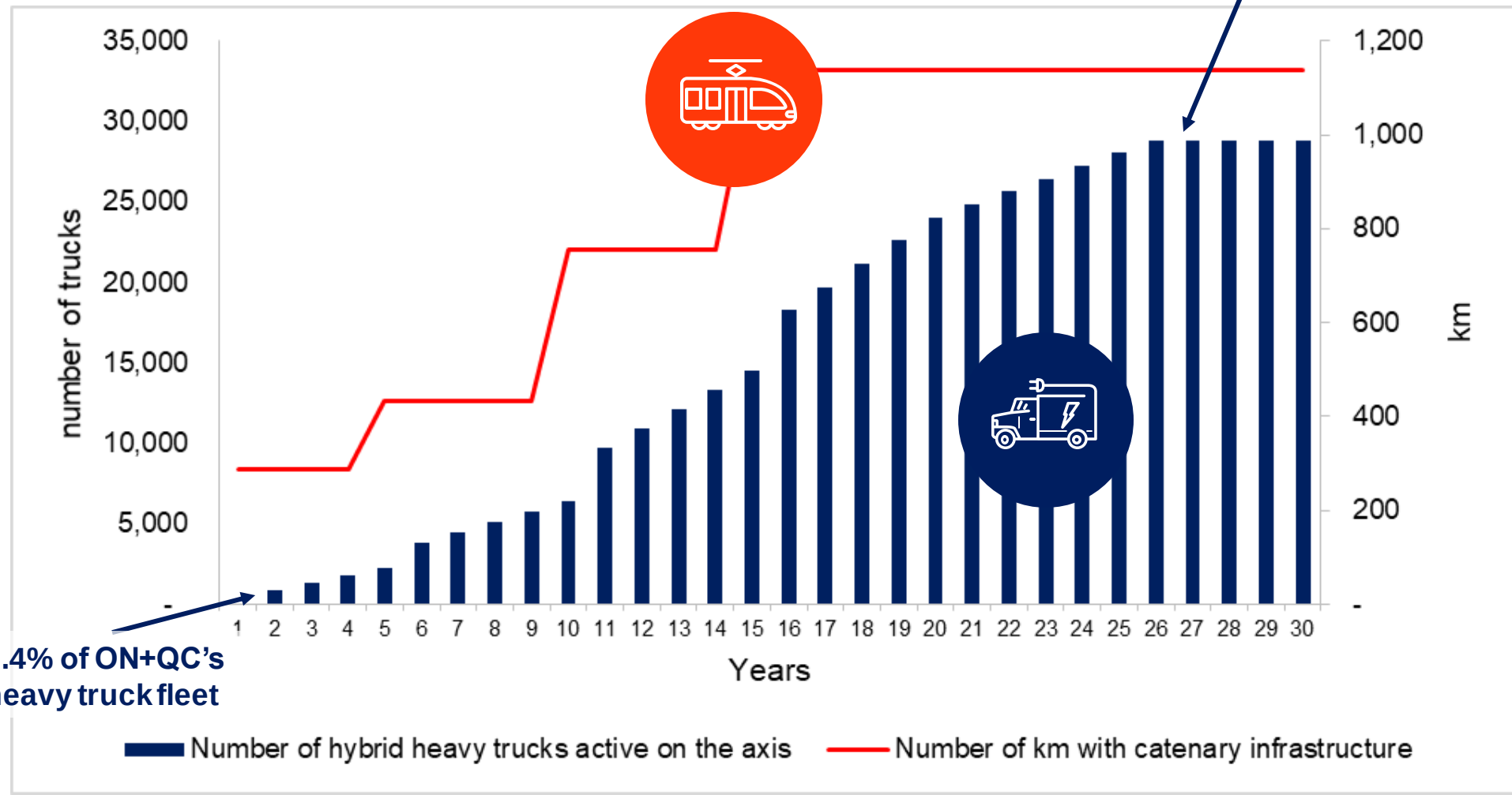
Simple payback period: number of years after initial investment costs would be completely offset by net savings from avoided diesel consumption.

Test #2: simulates a realistic, step-by-step 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 #2: adoption by the industry is assumed to progress slowly



Test #2: under this “realistic” scenario, benefits outweigh the costs from $85/tCO2

Economic Internal Rate of Return

4.1 billion investment in infrastructure

1 billion investment in trucks

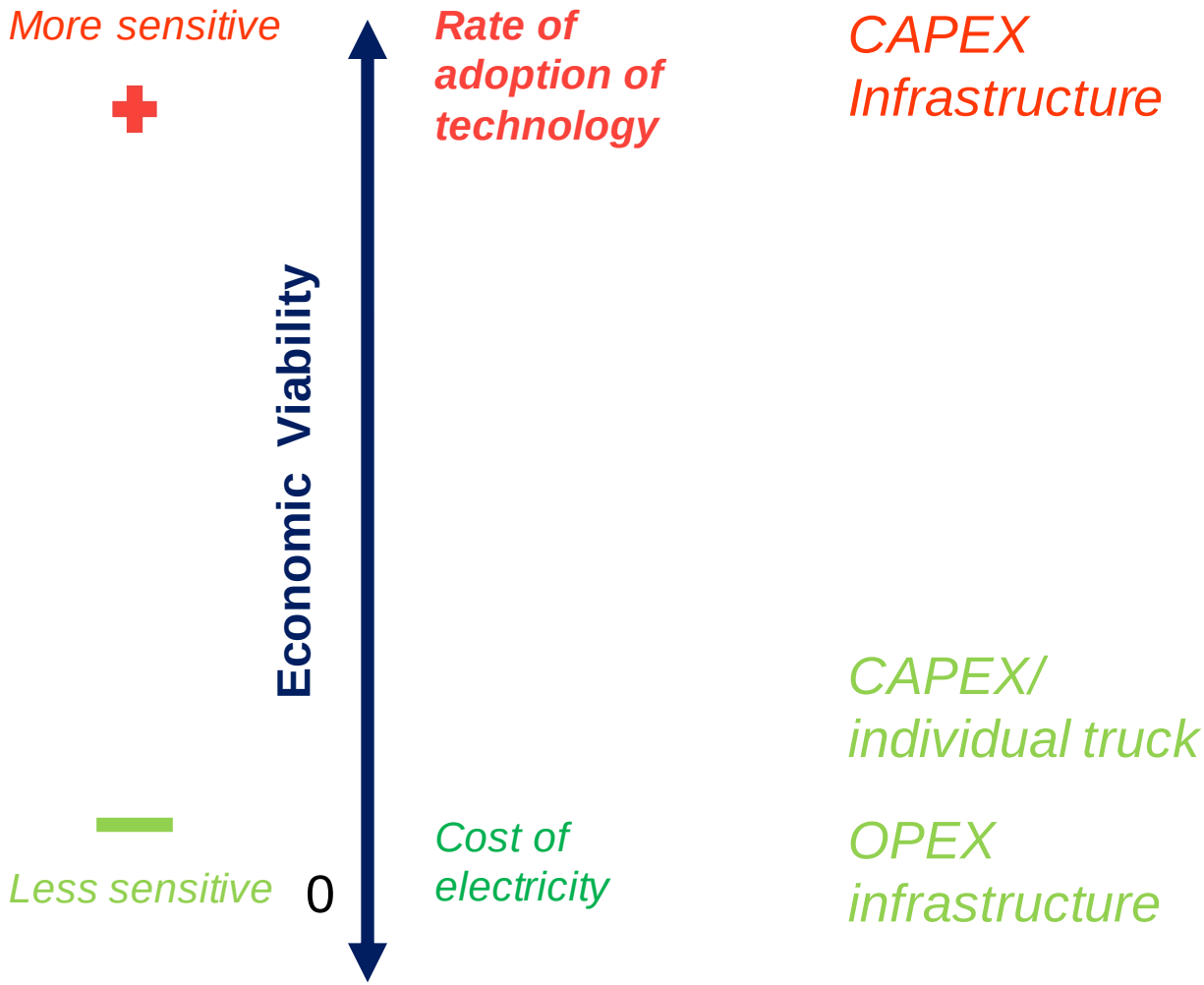
VS

Yearly GHG Emission reduction of 2.5 million tonnes of CO_2 eq
343 million annual savings on fuel

EIRR @ $100/tCO2
1.2%

EIRR @ $170/tCO2
5%

Test #3: Viability is sensitive to infrastructure cost and adoption rate



Conclusion

Limitations of the study and future research avenues

- Uncertainty on adoption rate of technology
- Relevance of technology for heavy truck industry (operational constraints) and better understanding of the preferences of the industry
- Financing structure and costs
- Benefits sharing allocation between different stakeholders
- Other feasibility considerations ex: overhead clearance issues
- Different configurations ex: alternative switching systems
- Different design for catenary trucks

Link to download report

- https://energie.hec.ca/e-highwaysimulationeastcanada/

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