DECARBONIZATION OF LONG-HAUL TRUCKING IN EASTERN CANADA

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

cpcs solutions for growing economies

Chair in Energy Sector Management
HEC MONTRÉAL

PROJECT COLLABORATOR

IET INSTITUT DE L'ÉNERGIE TROTTIER

PREPARED FOR

Energy Modelling Initiative
Bringing the Tools to Support Canada's Energy Transition

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- **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

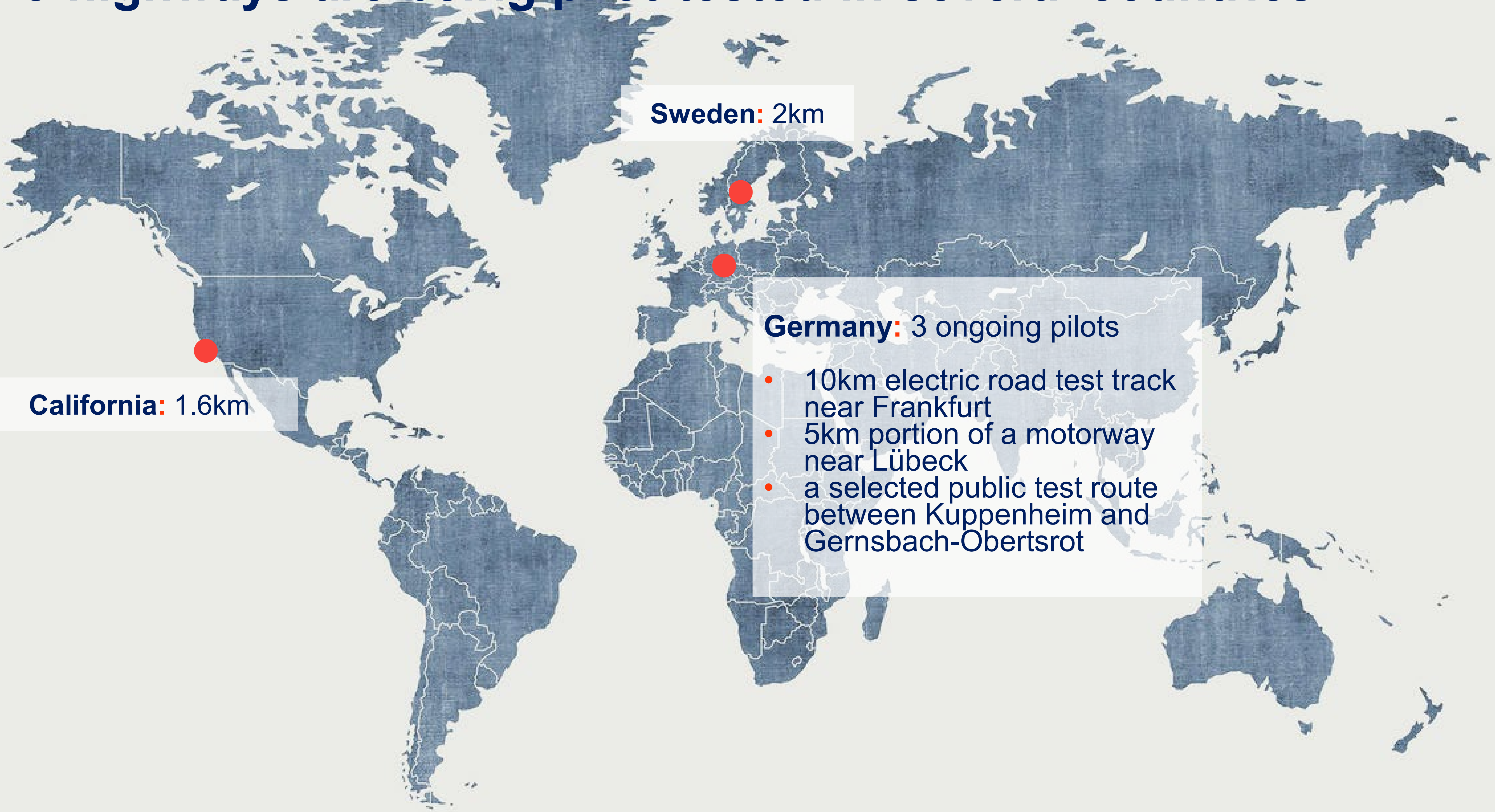
Zero emission trucks are possible, but efficiency varies

100 kWh
6.0 ct/kWh

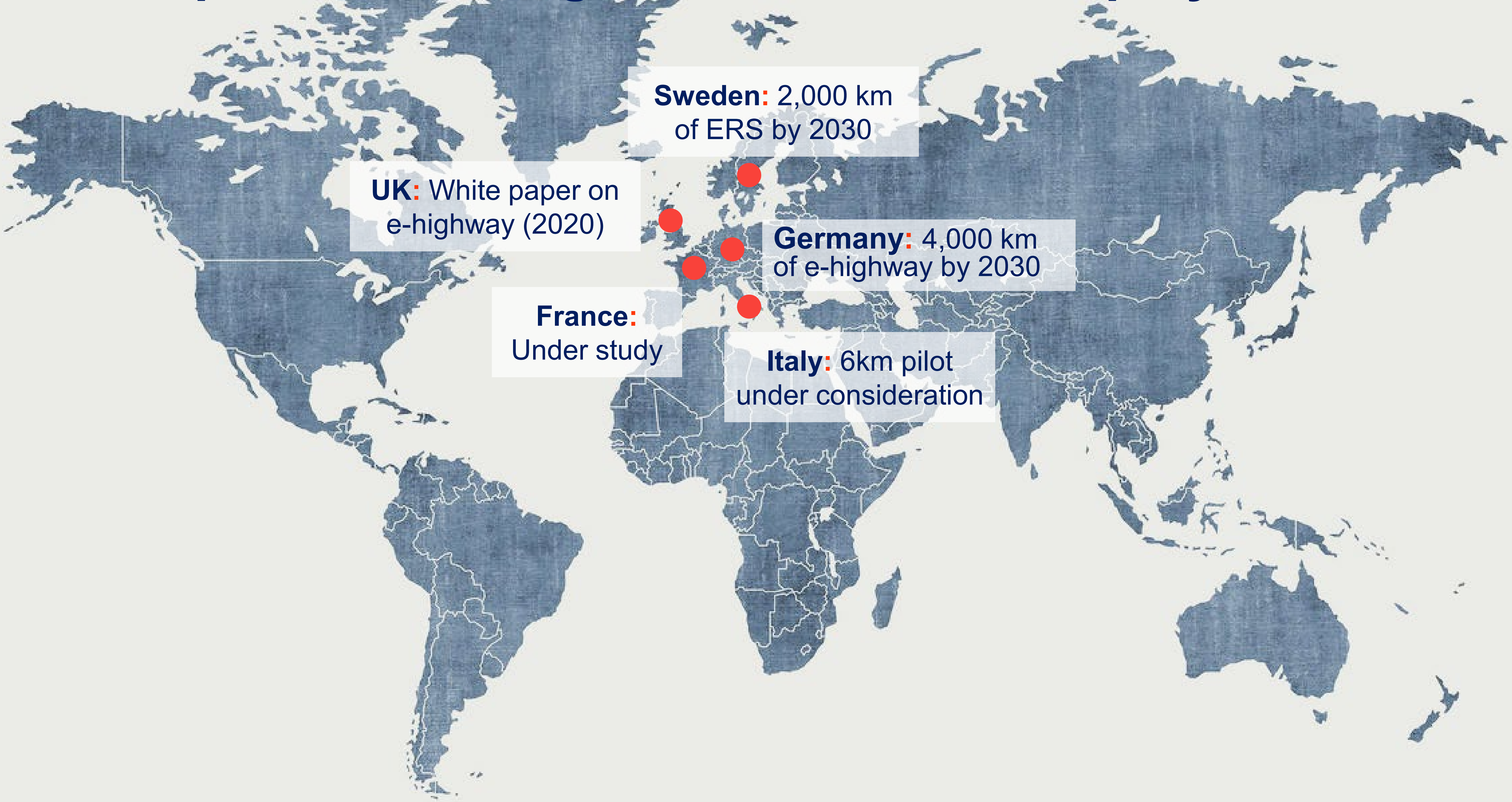
Pathway	Range Cost per km	Efficiency WTW	Example vehicle
Electric Road Systems: e^- → Grid (incl. catenary) → e^- → eTruck (Catenary-Hybrid); 96 kWh, 12 ct/kWh; 1,6 kWh/km	**60 km** 19 ct/km	77%	
Battery: e^- → Grid → e^- → eTruck (Battery); 96 kWh, 10 ct/kWh; 2 kWh/km	**48 km** 20 ct/km	62%	
Hydrogen: e^- (93 kWh) → Electrolysis η = 70% → H_2 (65 kWh, 15 ct/kWh) → H_2-network[1] (2 kWh) → H_2 (65 kWh, 18 ct/kWh) → CH_2- fuel station (5 kWh) → $C.H_2$ (65 kWh, 20 ct/kWh) → Fuel cell truck; 2.7 kWh/km	**24 km** 55 ct/km	29%	
Power-to-Gas: e^- (98 kWh) → Electrolysis η = 70% → H_2 (69 kWh, 15 ct/kWh) → Methanation η = 80% → CH_4 (55 kWh, 19 ct/kWh) → NG-network[1] → NG (55 kWh, 20 ct/kWh) → CNG-fuel station (2 kWh) → CNG (55 kWh, 22 ct/kWh) → Gas-truck; 3.2 kWh/km	**17 km** 70 ct/km	20%	

1) Including storage
Source: German Ministry of Environment

e-highways are being pilot-tested in several countries...

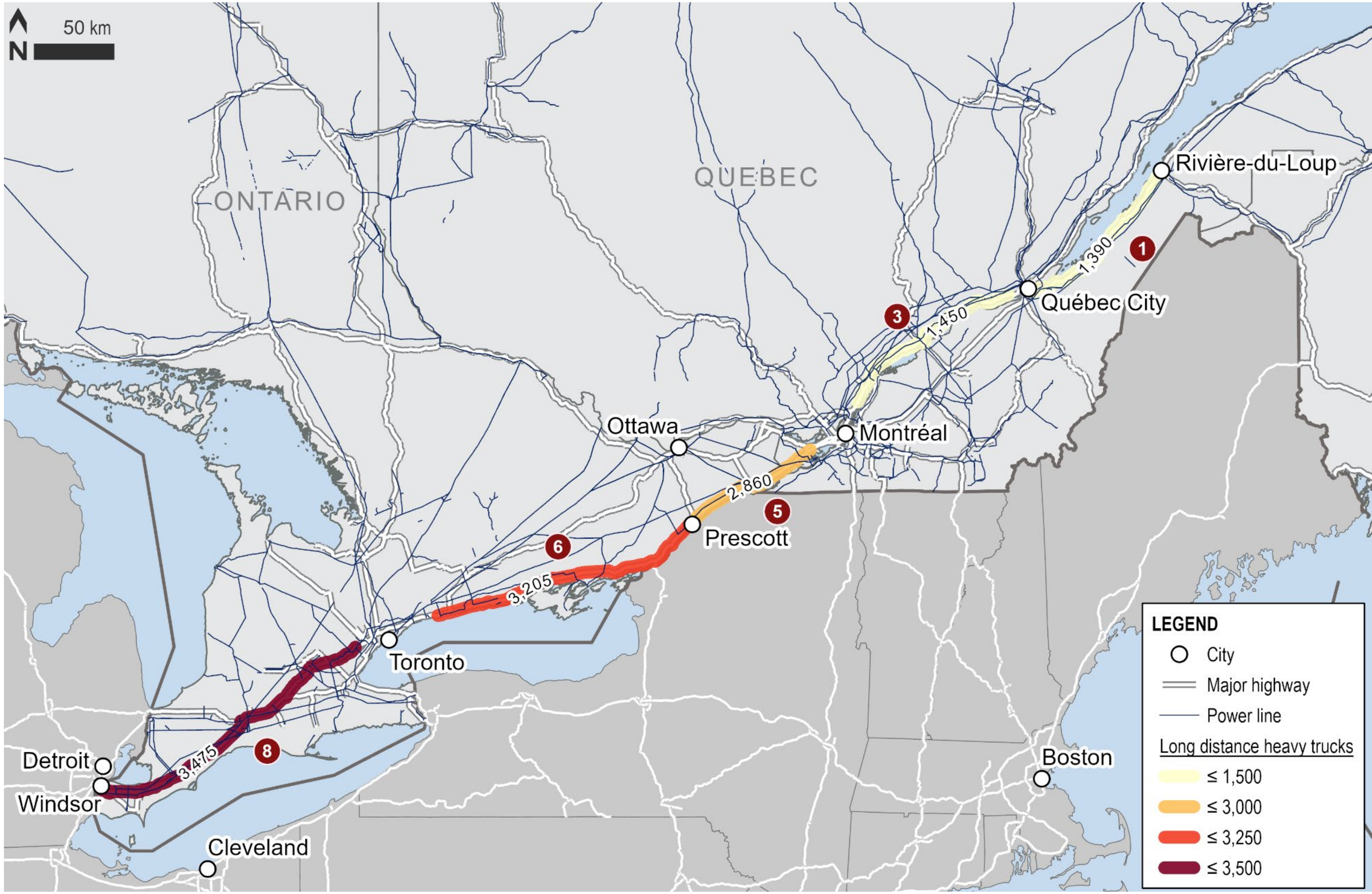


... and plans are being made for further deployment



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



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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

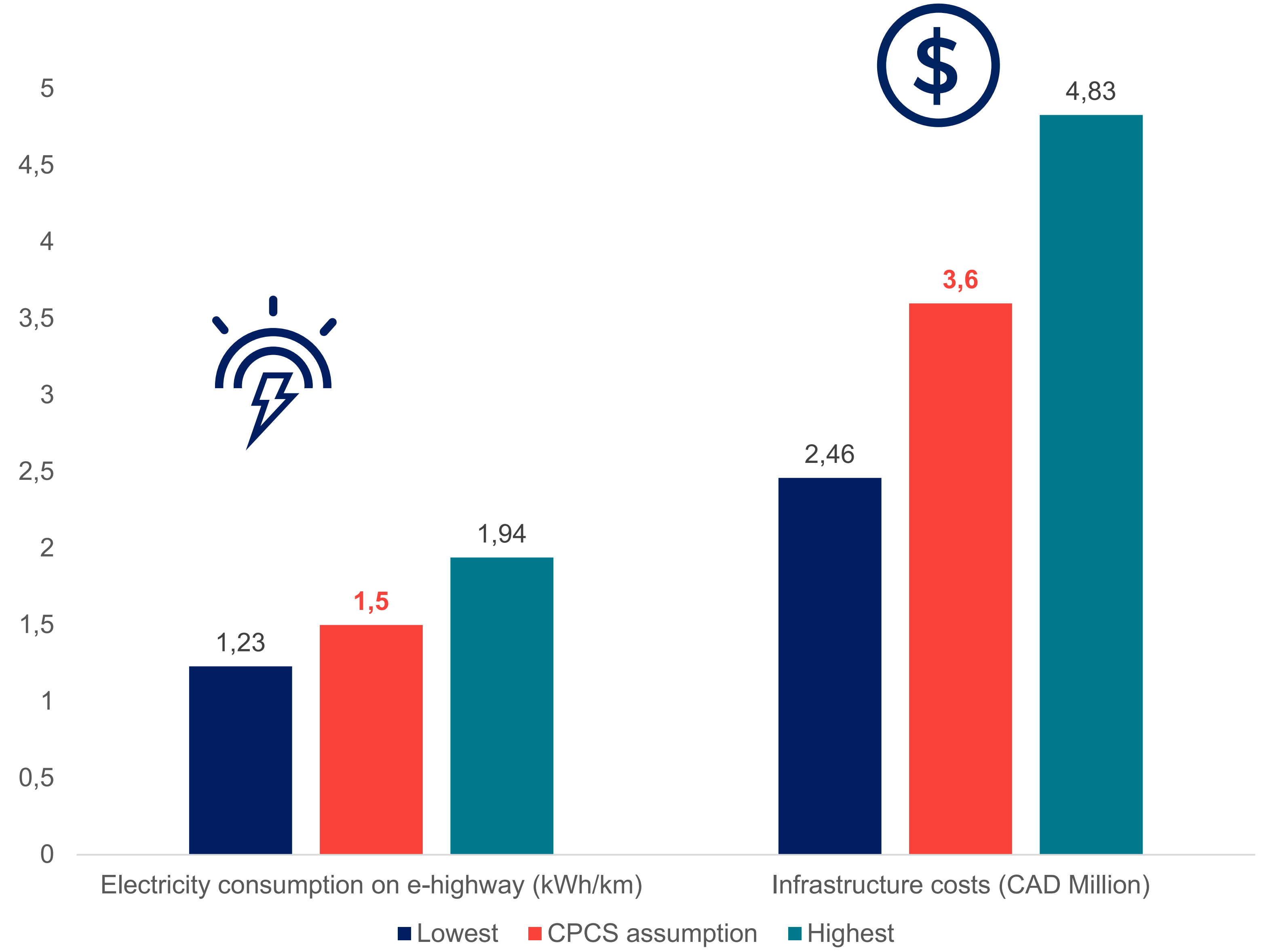
Costs

- 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

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_2e/kWh ON: 40 g CO_2e/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_2e today to $170/t in 2030	Federal carbon pricing policy

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

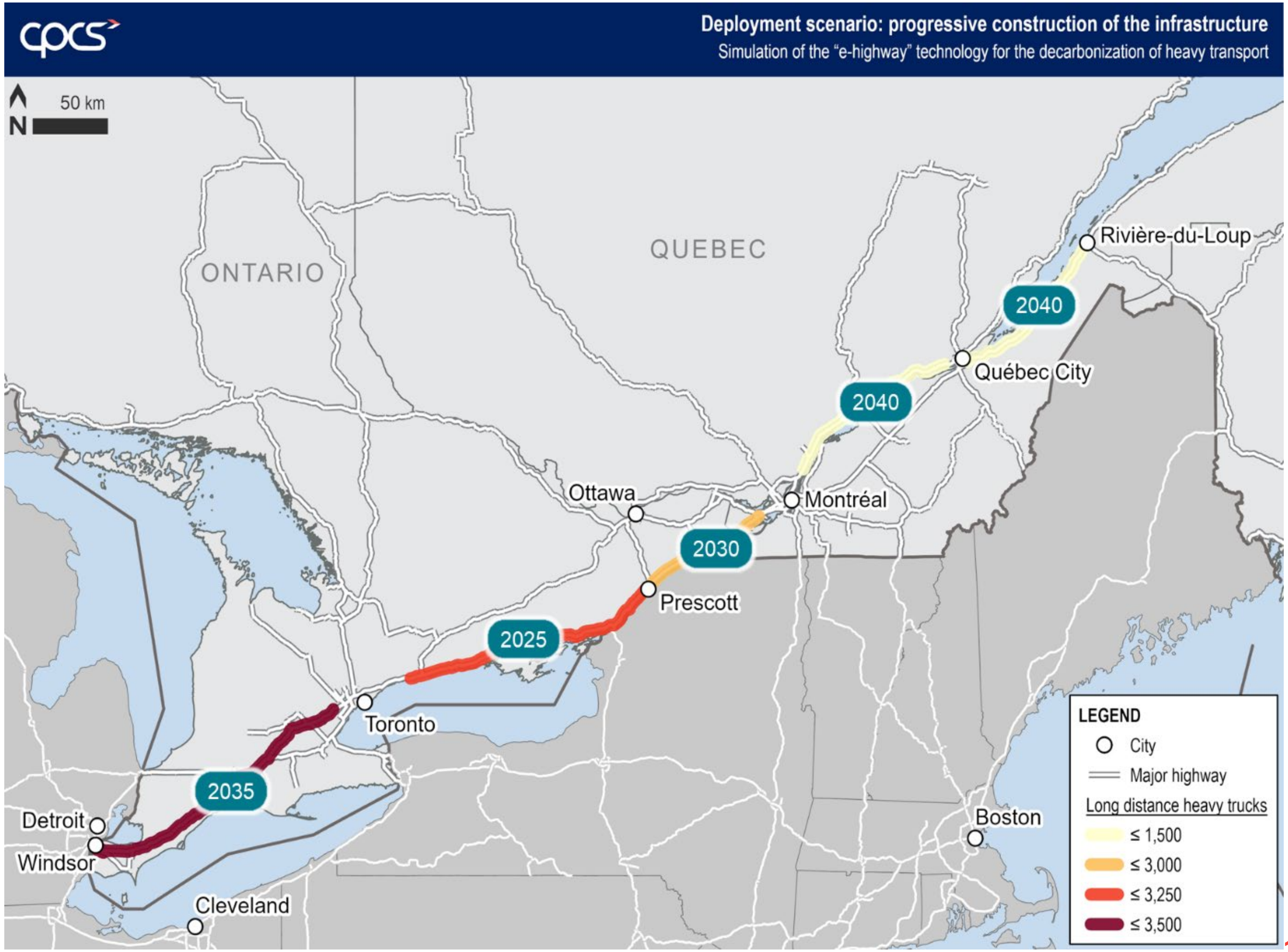
Highway segments	Simple payback period	Avoided GHG, MtCO2/year
Rivière du Loup – Quebec (without city areas)	12	0.3
Quebec – Montreal (without city areas)	11	0.3
Montreal – Prescott (without city area)	8	0.4
Prescott – Toronto (without city area)	8	1.0
Toronto – Windsor (without city area)	7	1.2
A20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

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

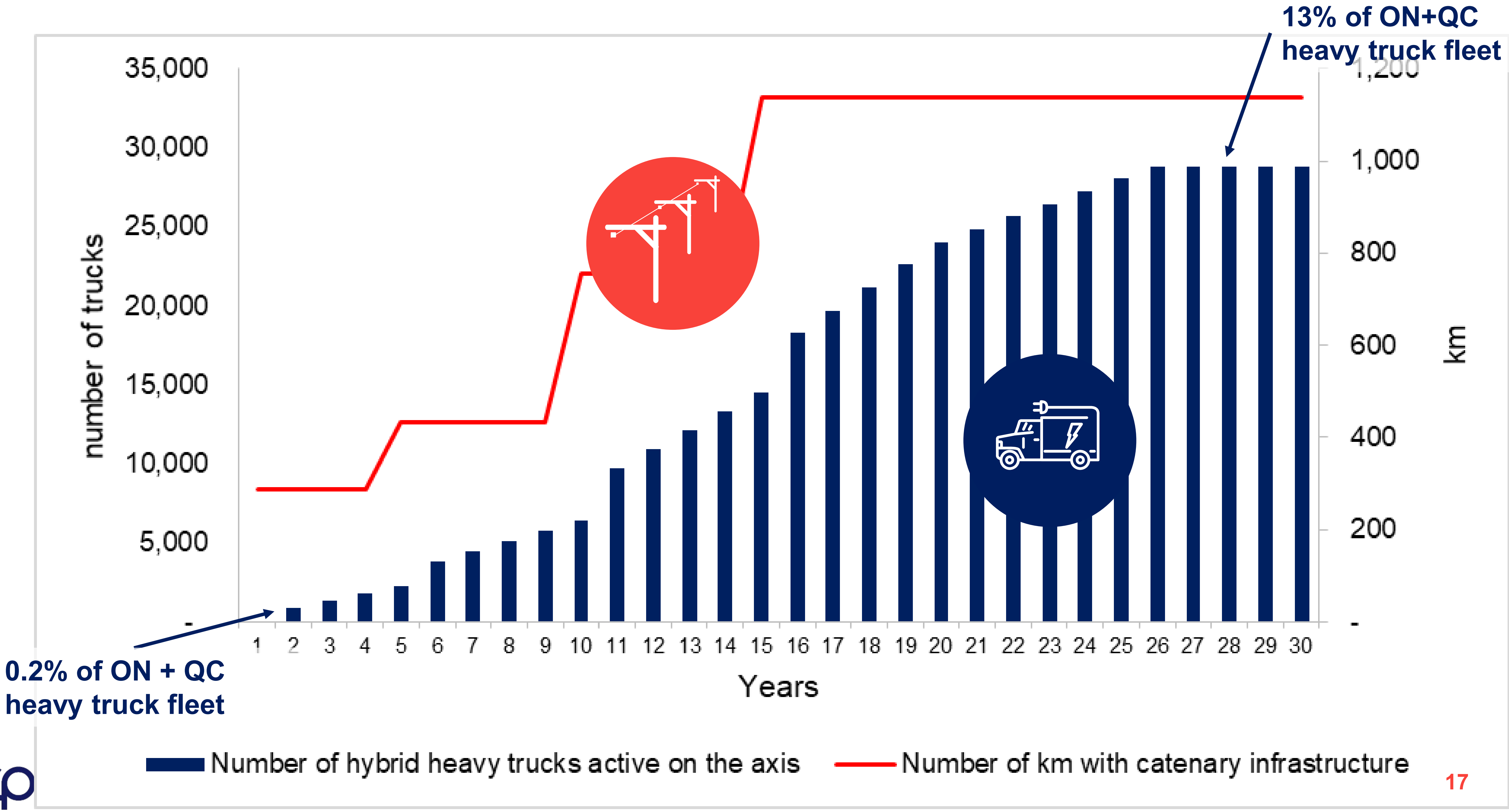
Simple payback period: number of years after initial investment costs would be completely offset by net savings from avoided diesel consumption.

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

Costs

VS

Benefits

Yearly GHG reductions: 2.8 Mt CO_2e

$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 nº3: Viability is sensitive to fuel and infrastructure costs, and adoption rate

Source CPCS, 2021.

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

Results for discussion

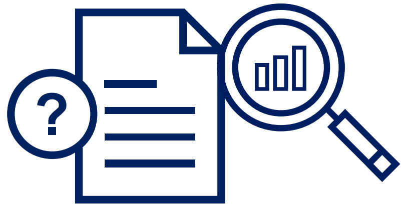
- **Pays back in 7 years** on segments with highest traffic if 100% adoption
- **ERR of 7 to 10%** with a progressive, more realistic adoption scenario
- **Reasonable abatment costs** ranging from \$65/t CO_2 (high traffic, high adoption) to \$200/t CO_2 (entire range, progressive adoption) with an 8% 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

Our simulation	v.	Alternative design
Full electrification of the highway		Short electrified segments for on-the-go recharge
Hybrid trucks (electric + diesel / biofuels / LNG etc)		Fully electric trucks
Short range battery (buffer)		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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