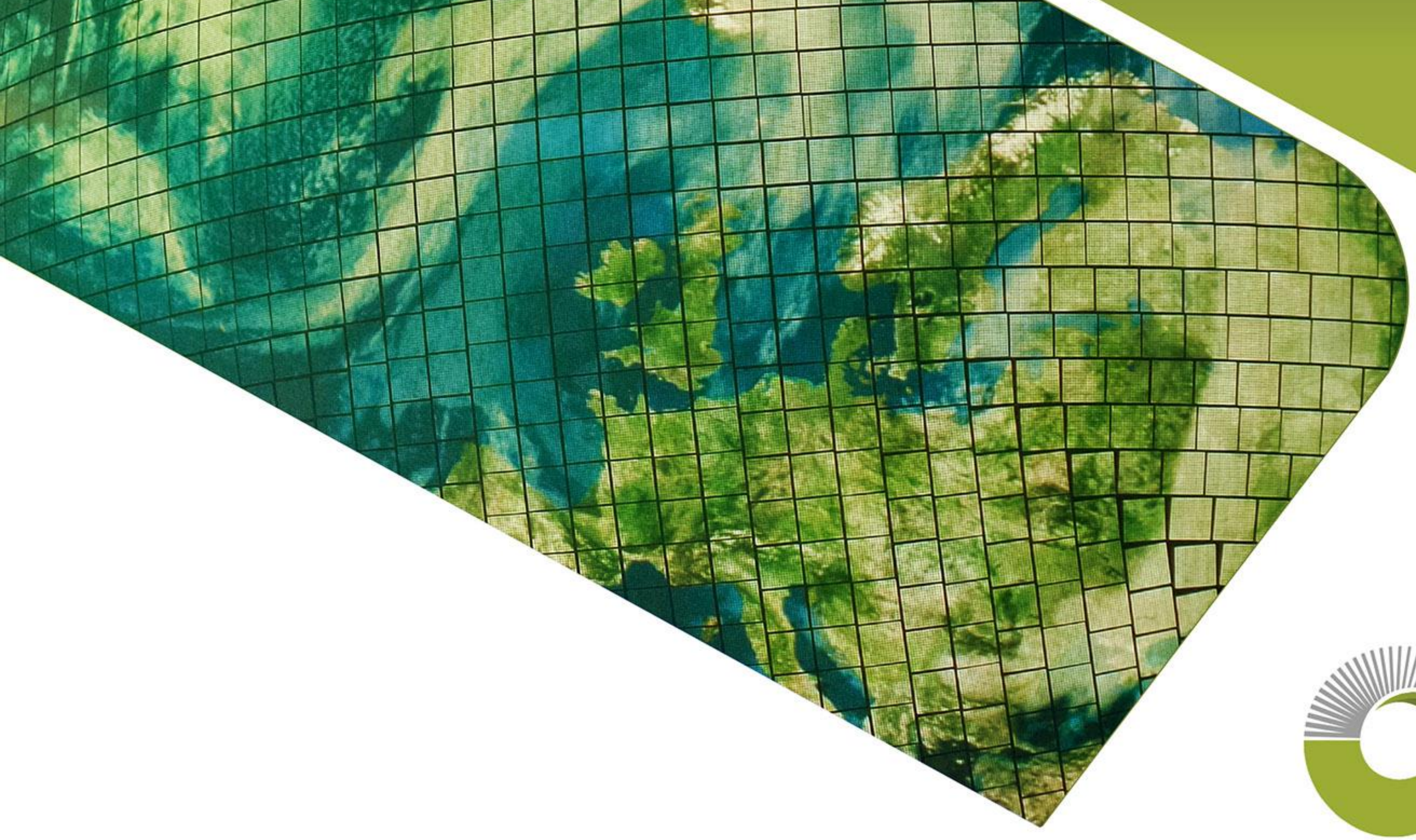

SYSTRA

PARIS REINFORCE

Net-zero scenarios for Canada

K. Vaillancourt, M. Pied (ESMIA), J. Wachsmuth (Fraunhofer ISI), A. Gambhir (Imperial), K. Koasidis, A. Nikas, H. Doukas (NTUA)

09/05/2022, Canada Stakeholder Workshop

The NATEM Model : North American TIMES Energy model

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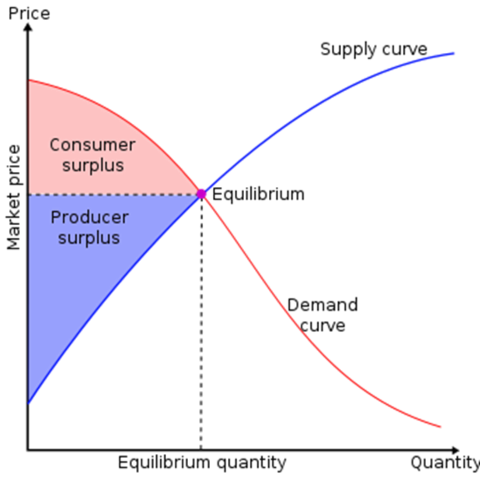
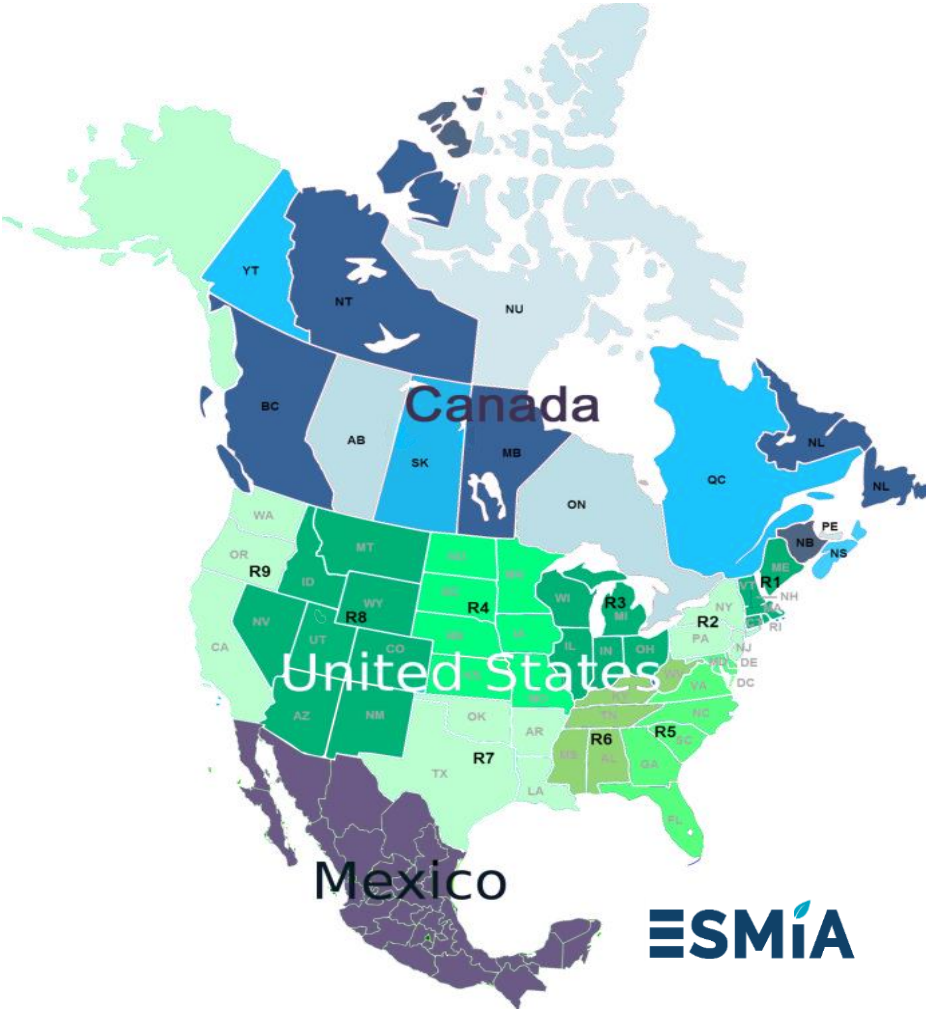
A TIMES energy system optimization model (ETSAP-IEA):

- Demand driven – energy services
- Price-elasticities of demands
- Integrated energy systems
- Dynamic model over + 40 years
- Simulates market competitions
- Computes a partial equilibrium



→ minimize the total net discounted cost
→ compute the marginal reduction cost



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The NATEM Model :
North American TIMES Energy model

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Geo coverage:

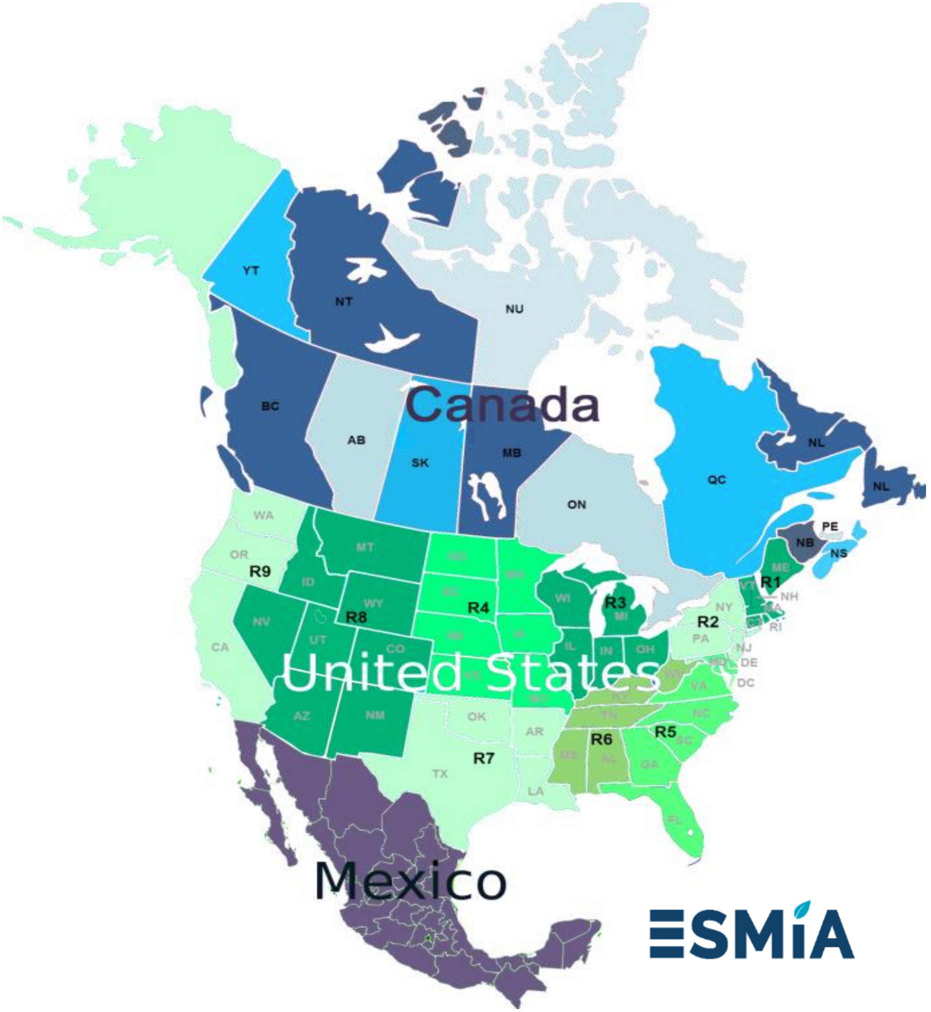
- Canada: **13 Provinces/Territories**
- USA: **9 Regions + California, Texas & New York**
- Mexico: **1 Region**

Time dimension:

- Time horizon: 2016-**2060 horizon**
- Annual time slice (16): **4 seasons, 4 intradays (Peak)**

Energy system:

- **75 end-use demands** for energy services
- **5000 technologies** in all demand & supply sectors + trade
- **All greenhouse gases** (replicate the NIR except for LULUCF)



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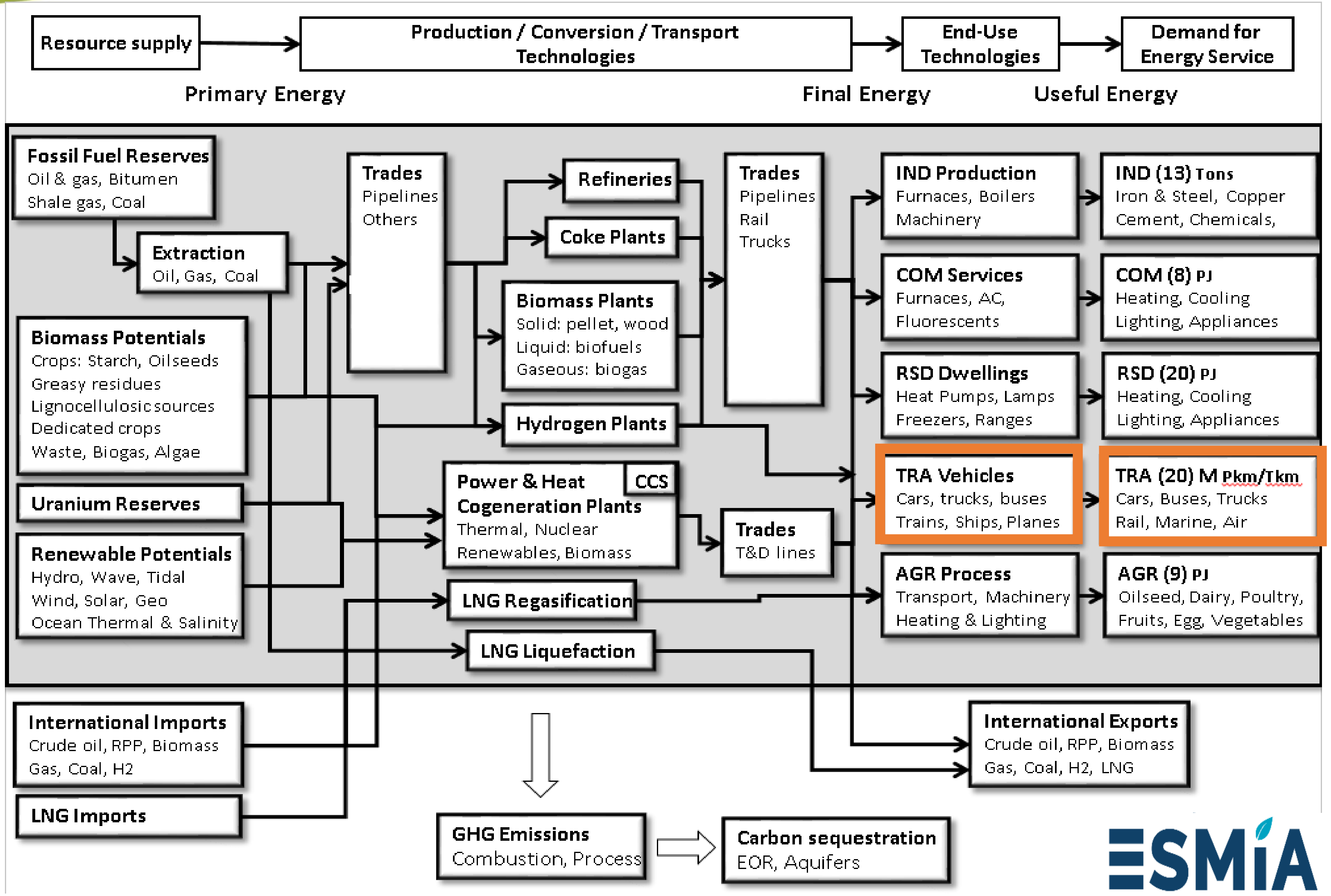

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The NATEM Model :
North American TIMES Energy model

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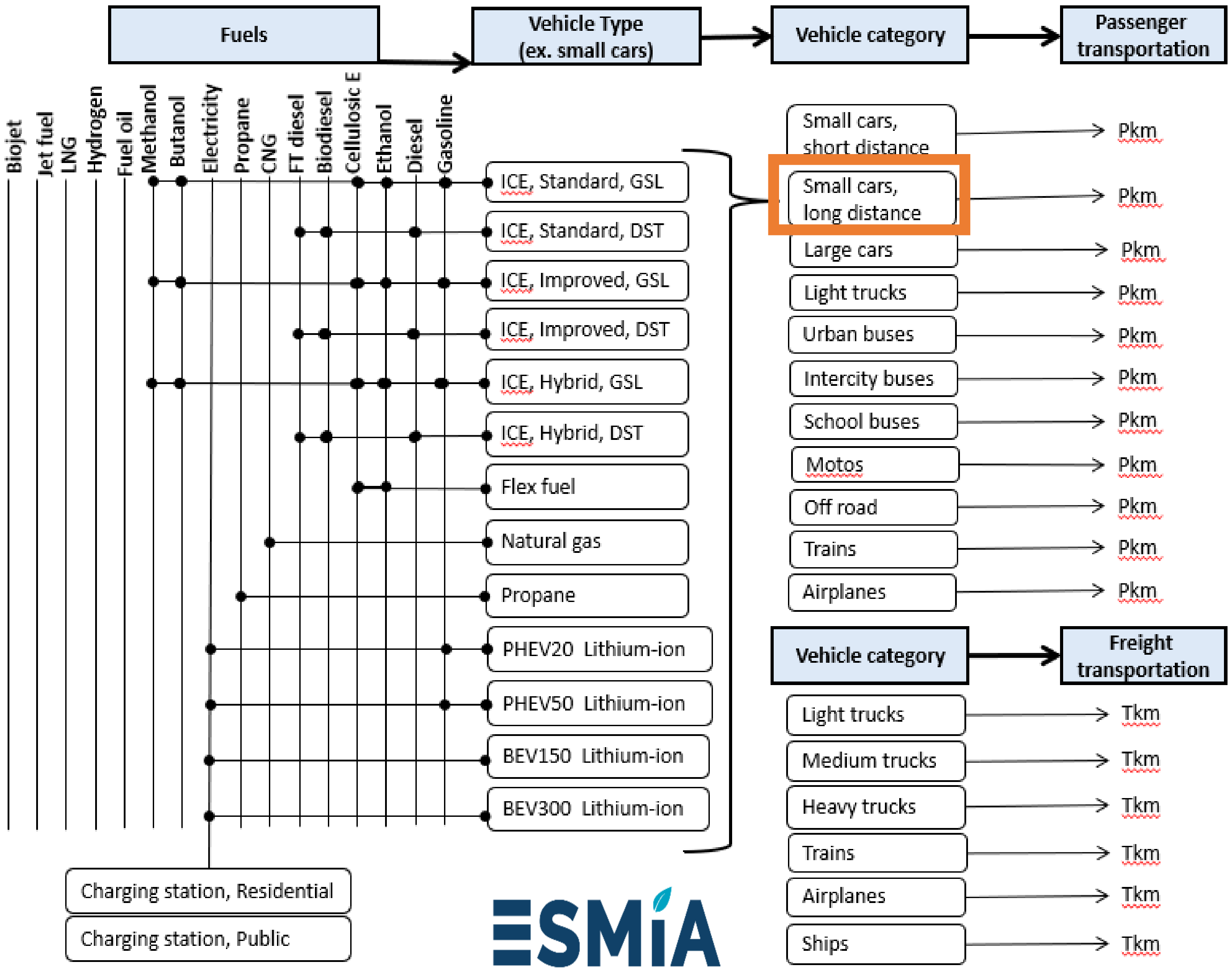

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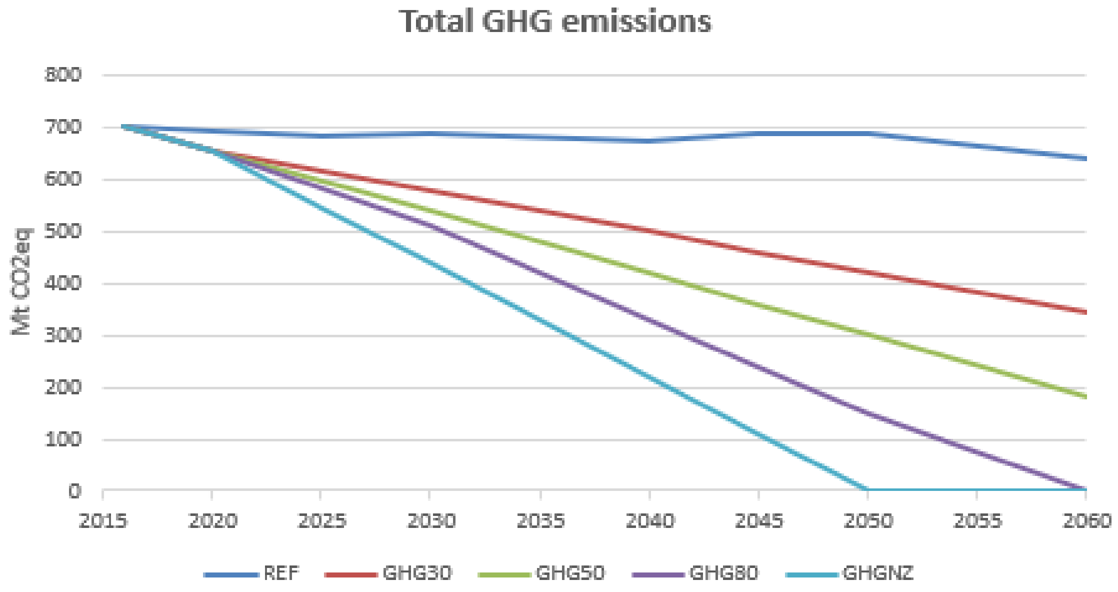
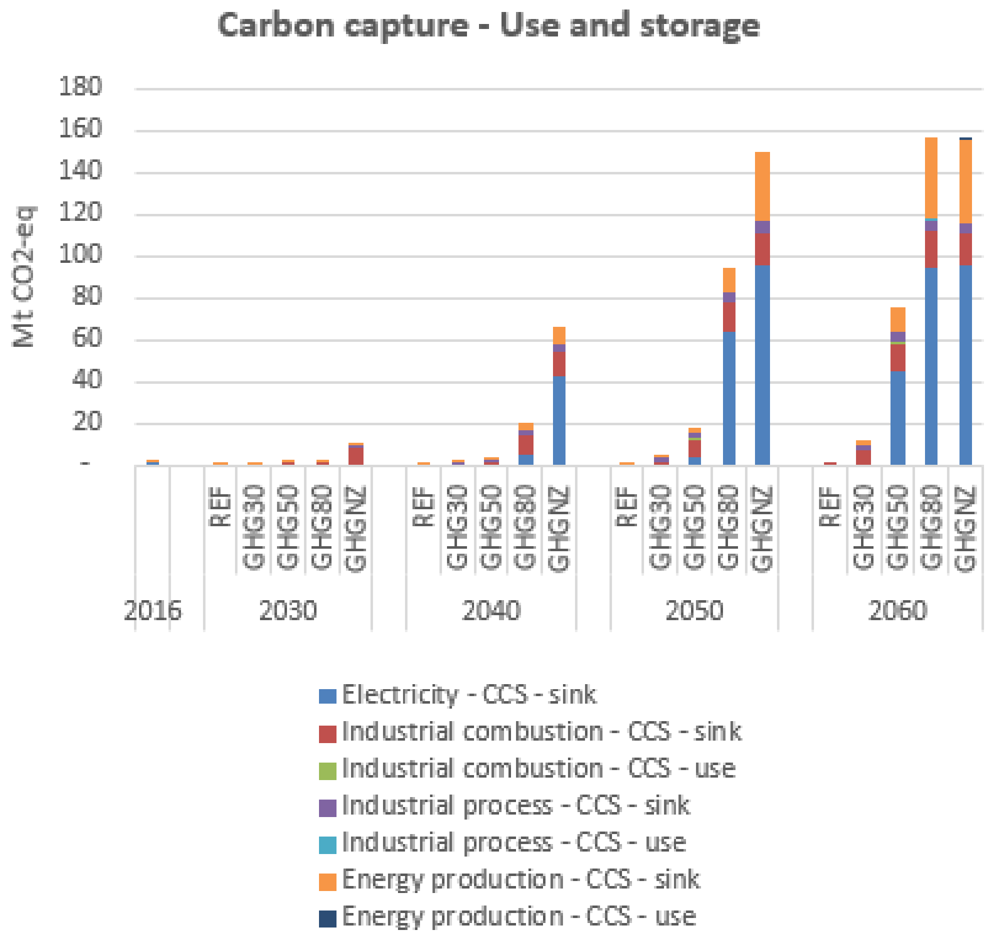
NATEM Canada : Scenarios definitions





REF Reference scenario including existing policies

GHG30 Scenario with a 30% target by 2050 (from 2005).

GHG50 Scenario with a 50% target by 2050 (from 2005).

GHG80 Scenario with an 80% target by 2050 (from 2005) and 100% by 2060

GHGNZ Scenario with a 100% target by 2050 and beyond, intermediate target of 30% by 2030 (base = 2005).

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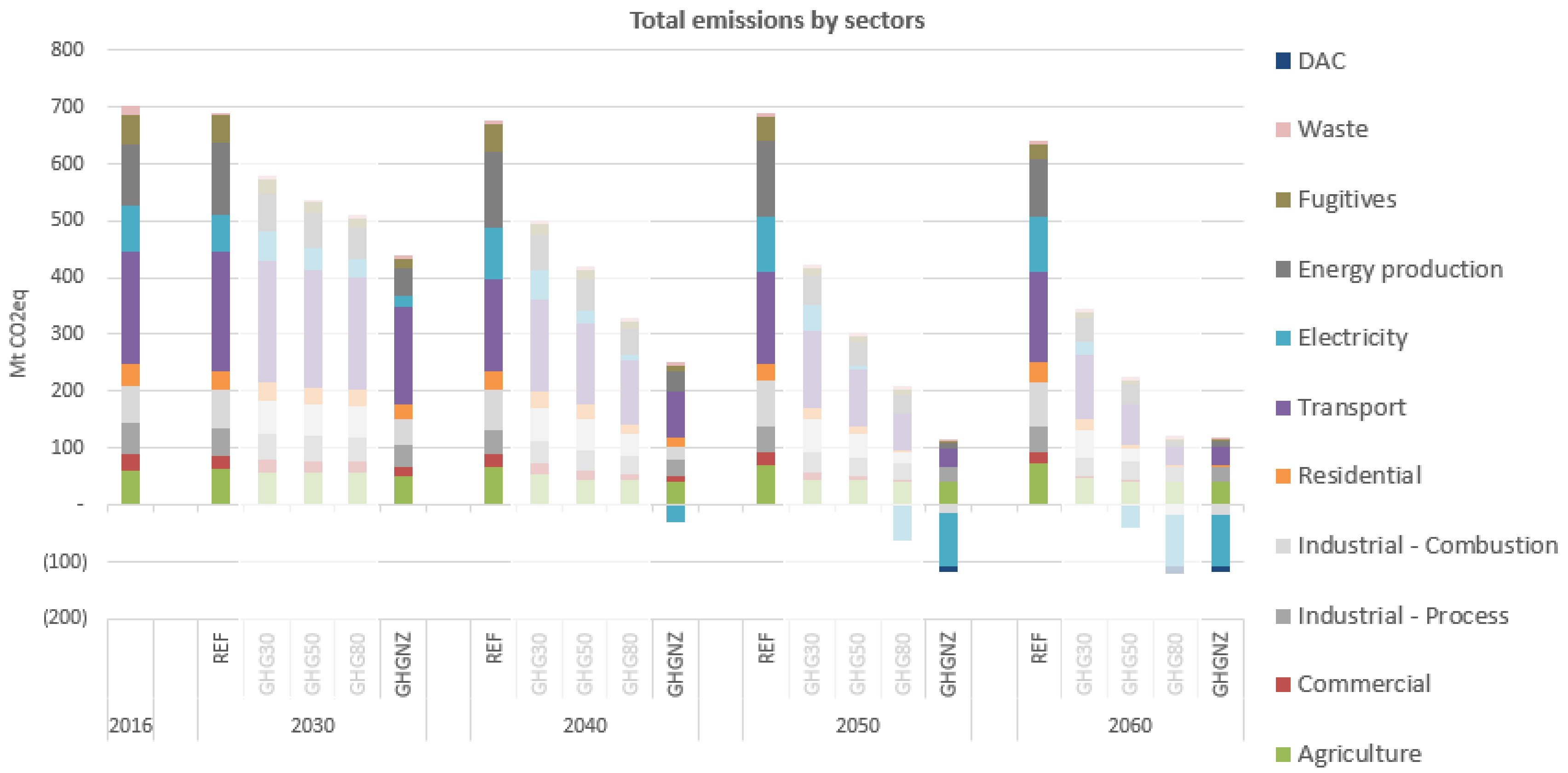
NATEM Canada : Main results



- Most challenging sectors : Agriculture (>40Mt), Industrial processes (25Mt), Some transport segments (30Mt).
- Rely on net-negative emission options (electricity generation from biomass + CCS, industrial biomass heat + CCS).
- DAC (Direct Air Capture) is used as a last-resort option.
- In transport, remaining GHG come from air and off-road segments with fewer mitigation options.

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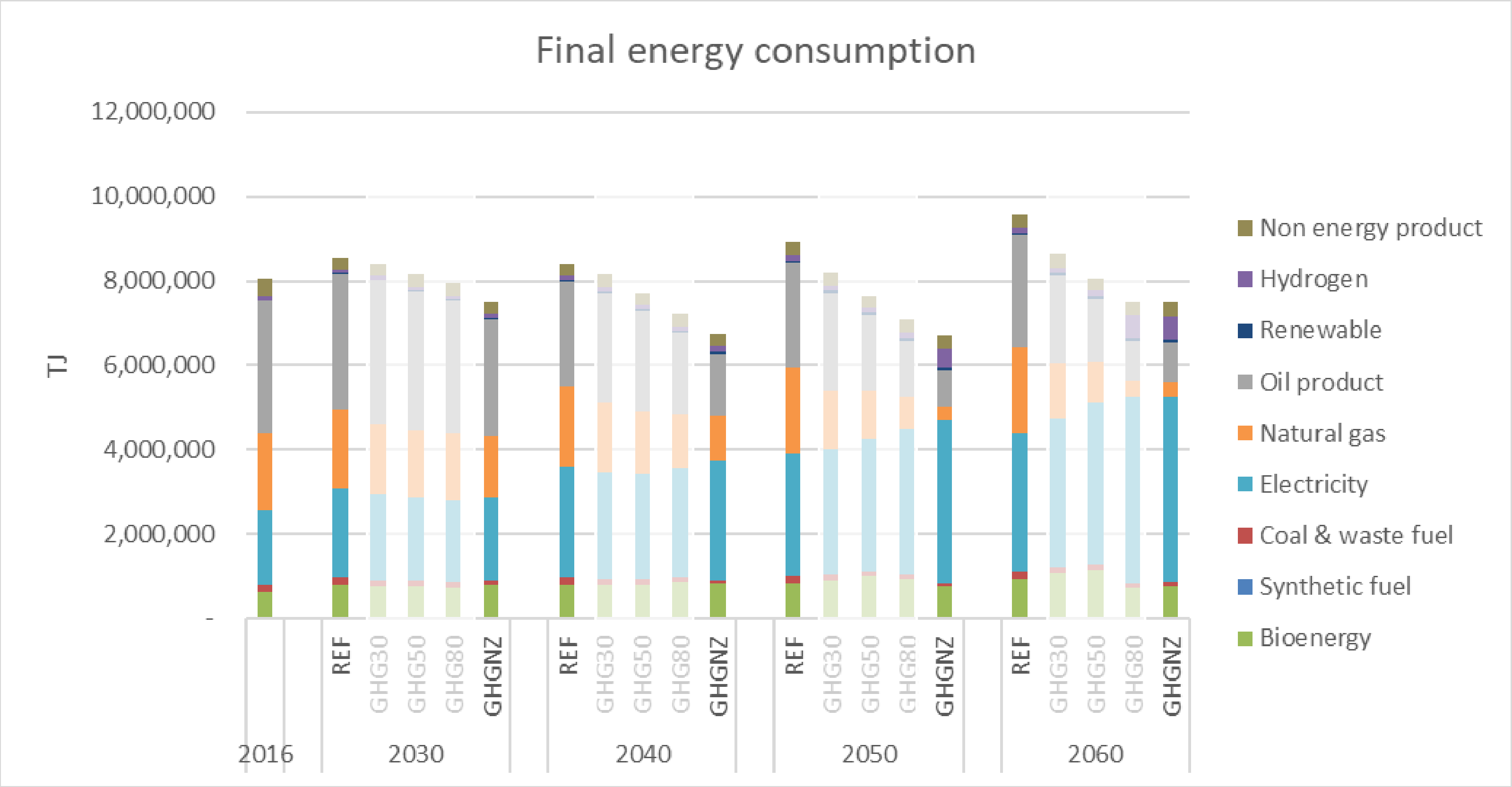

- In 2050, more than half of the final energy consumption is coming from electricity.
- Natural gas and petroleum product consumption is reduced drastically.
- Hydrogen remains a small portion of the final energy consumption mix.

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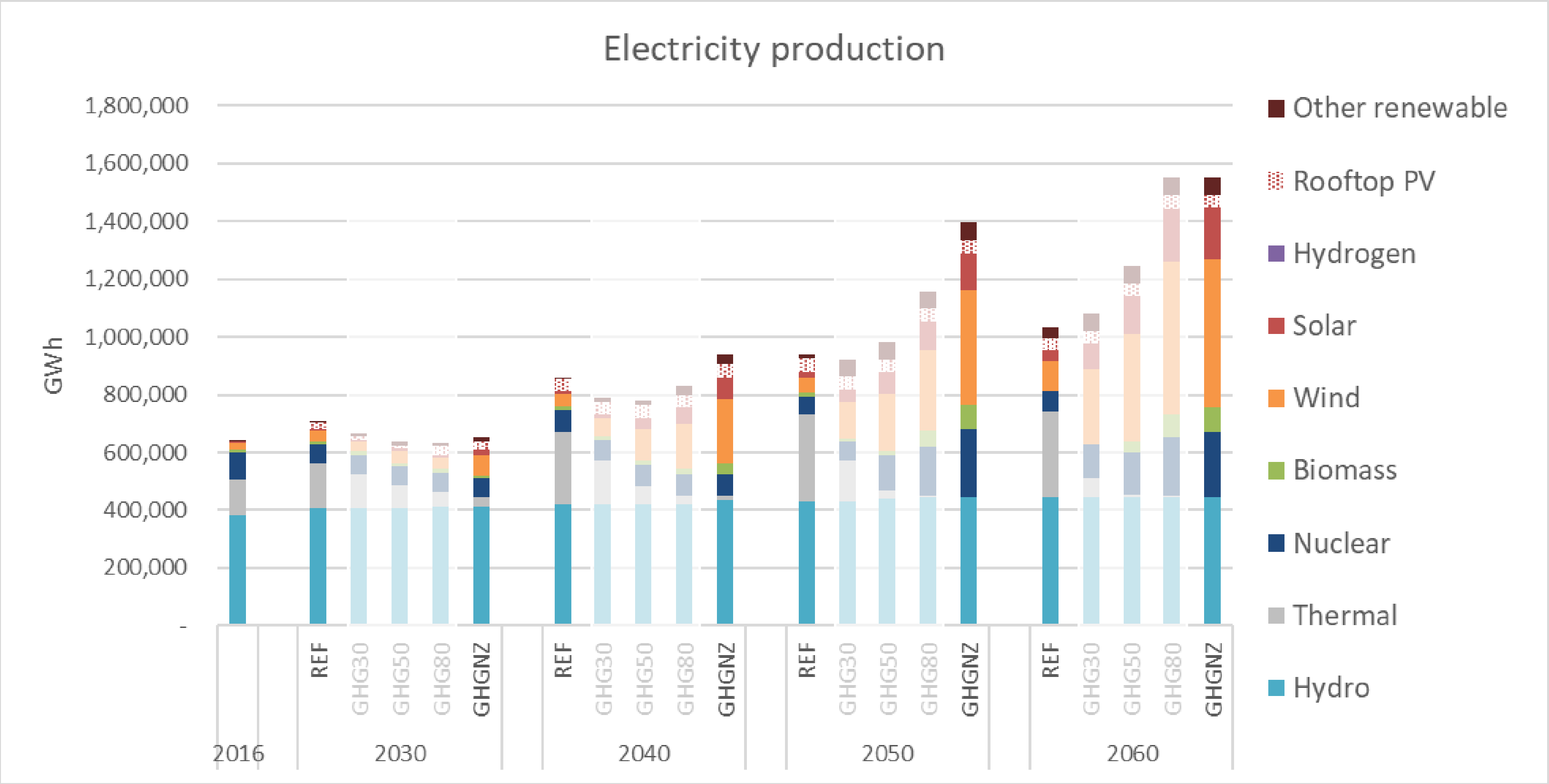
NATEM Canada : Main results



- Canada electric systems are very diversified; baseload production remains hydro for regions with the best potential.
- Additional demands is met with some nuclear (refurbishment of existing plants + SMR) and a large share of intermittent/storage.
- Electricity generation with biomass+CCS appears in deep decarbonization scenarios as a net-negative mitigation options.

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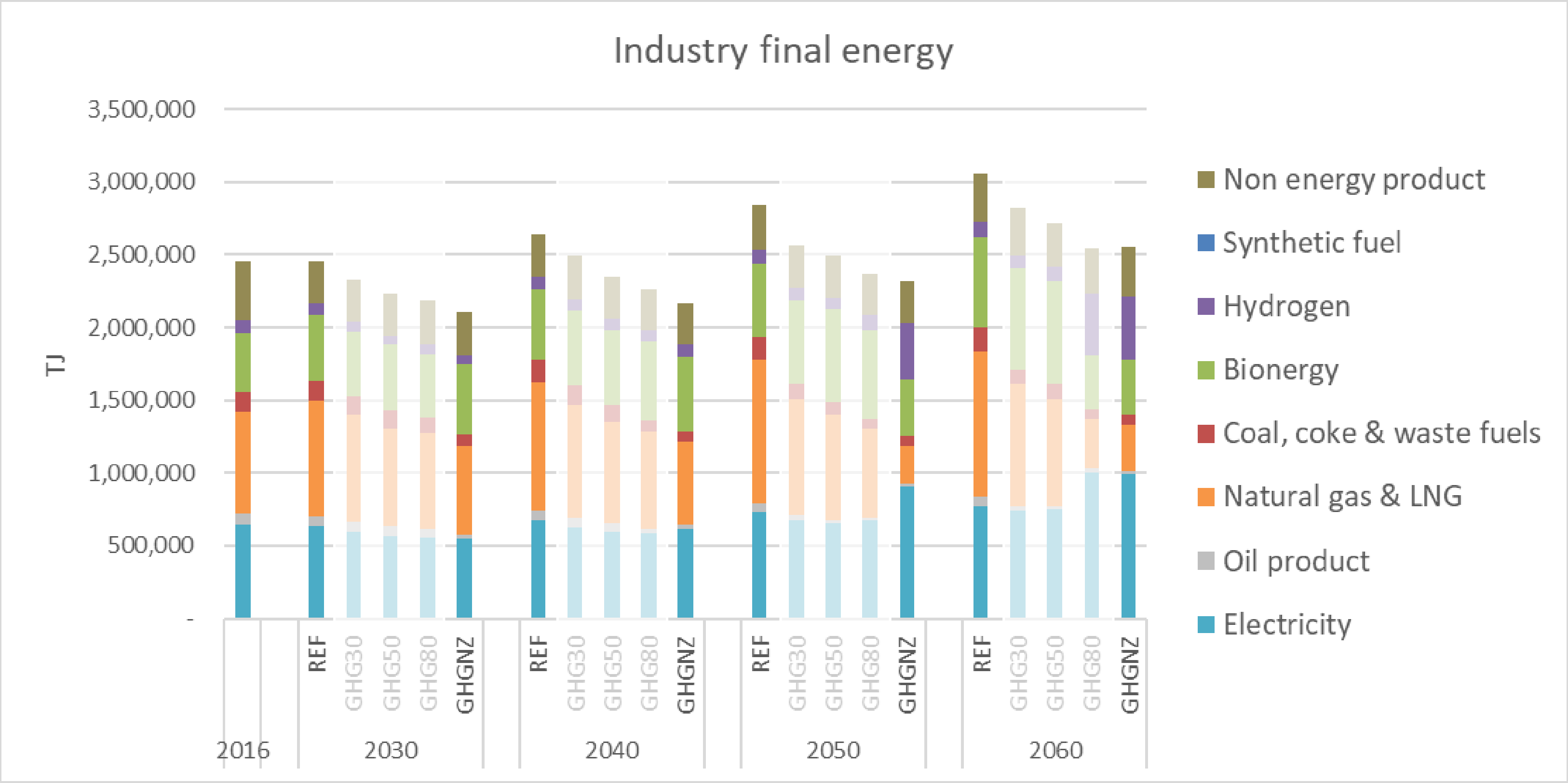
NATEM Canada : Main results



- Natural gas and coal are gradually replaced with electricity (reaching 40% of the total in 2050).
- Hydrogen have a role in net-zero scenarios for heat production and as feedstock in key sectors.
- Process emissions are hard to eliminate. Reduction can come from process changes such as inert anodes for aluminum production. Otherwise, CCS and DAC are essential options for the decarbonization of the industrial sectors.

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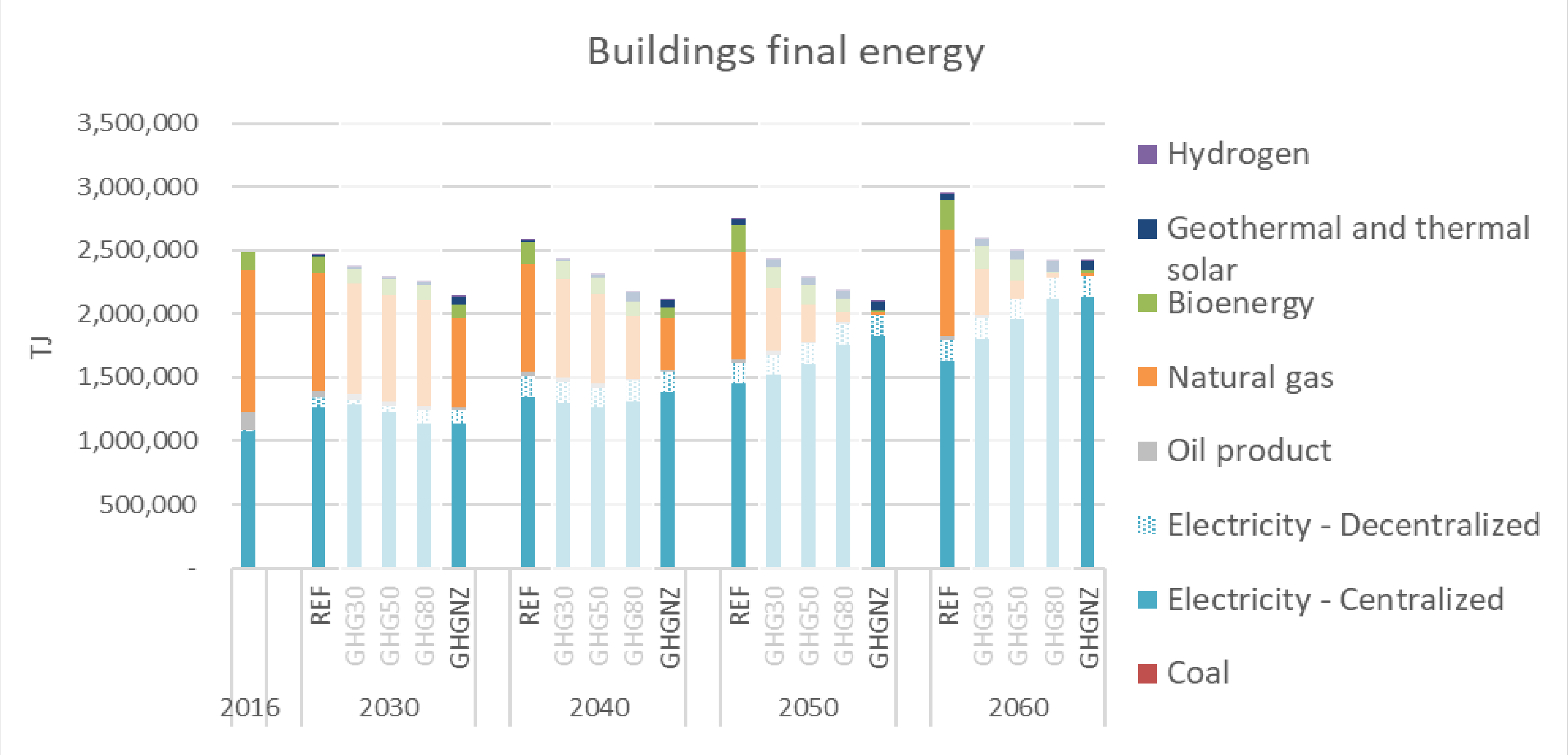
NATEM Canada : Main results



- Electricity is a clear path forward for building decarbonization, combine with energy efficiency & conservation.
- Electric heat pumps become rapidly the predominant space heating technology.

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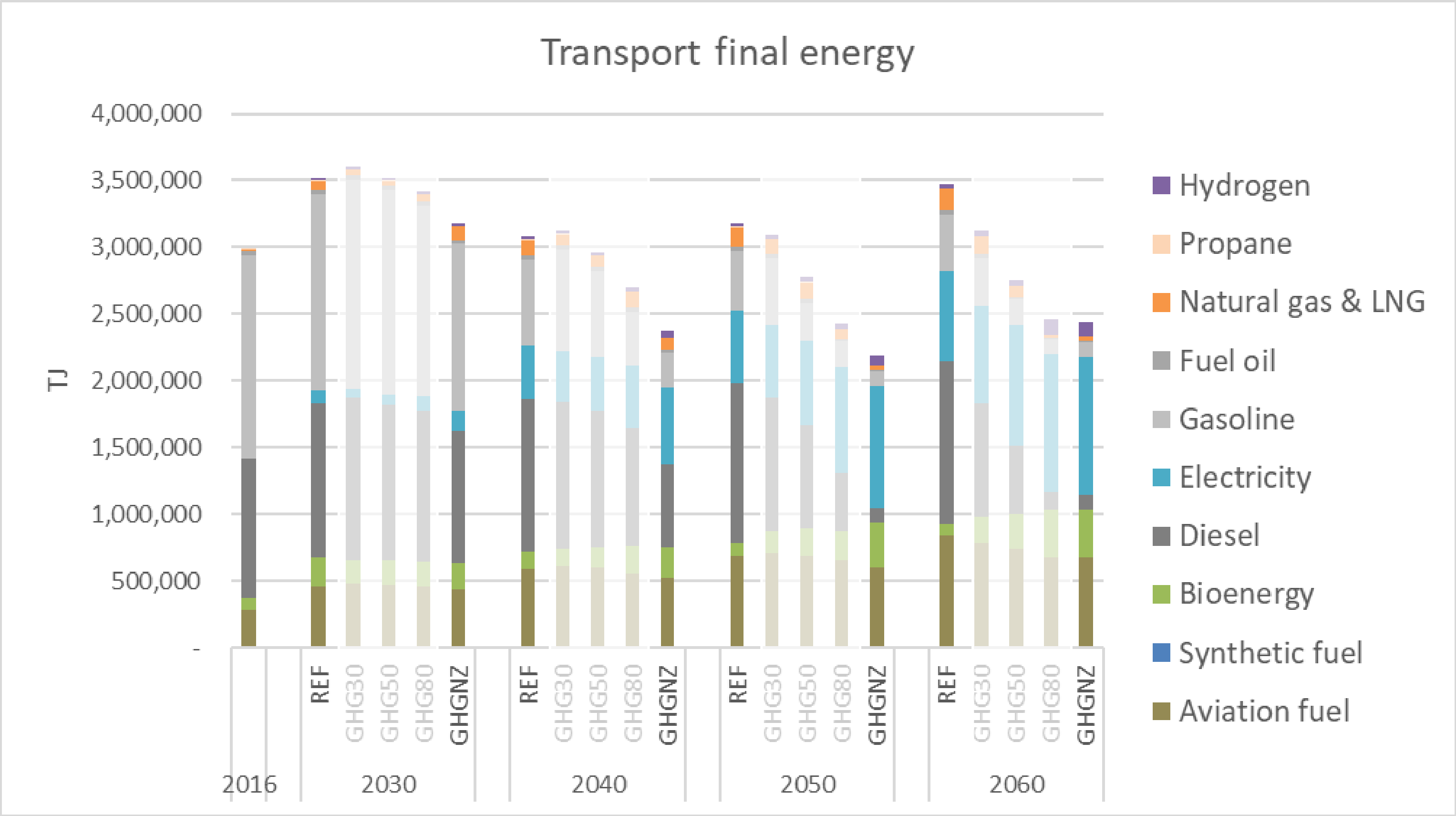
NATEM Canada : Main results



- Electric vehicles become the predominant technologies for road transport, especially the light duty vehicle segments.
- For other segments, such as heavy freight, the solution is more diverse and uncertain.
- Hydrogen share remains relatively low and appears in transport segments that are hard to decarbonize (rail, marine).

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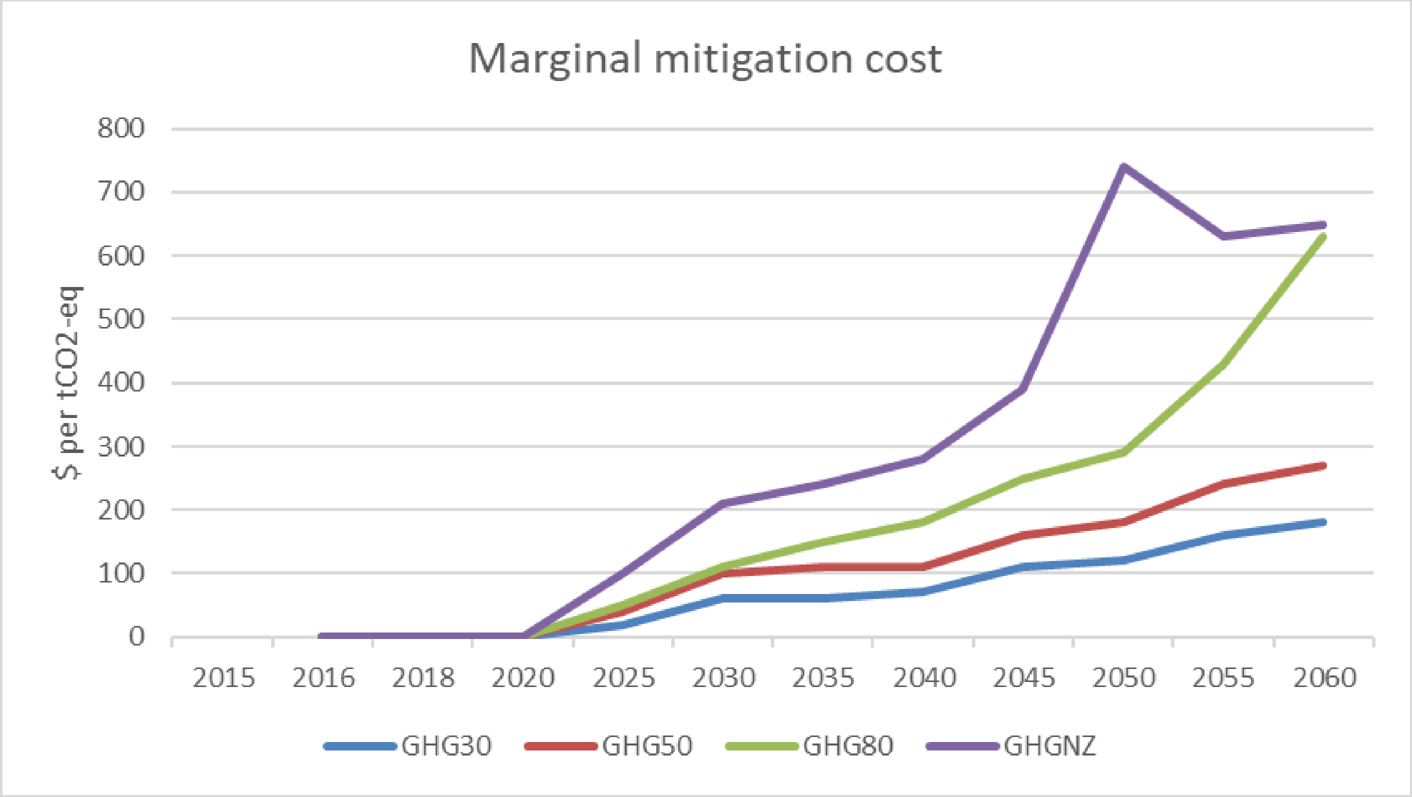

- Marginal mitigation costs are high but are decreasing overtime with the addition of emerging technologies and mitigation options.
- In all cases, the carbon price needed to achieve ambitious targets is higher than existing market prices.

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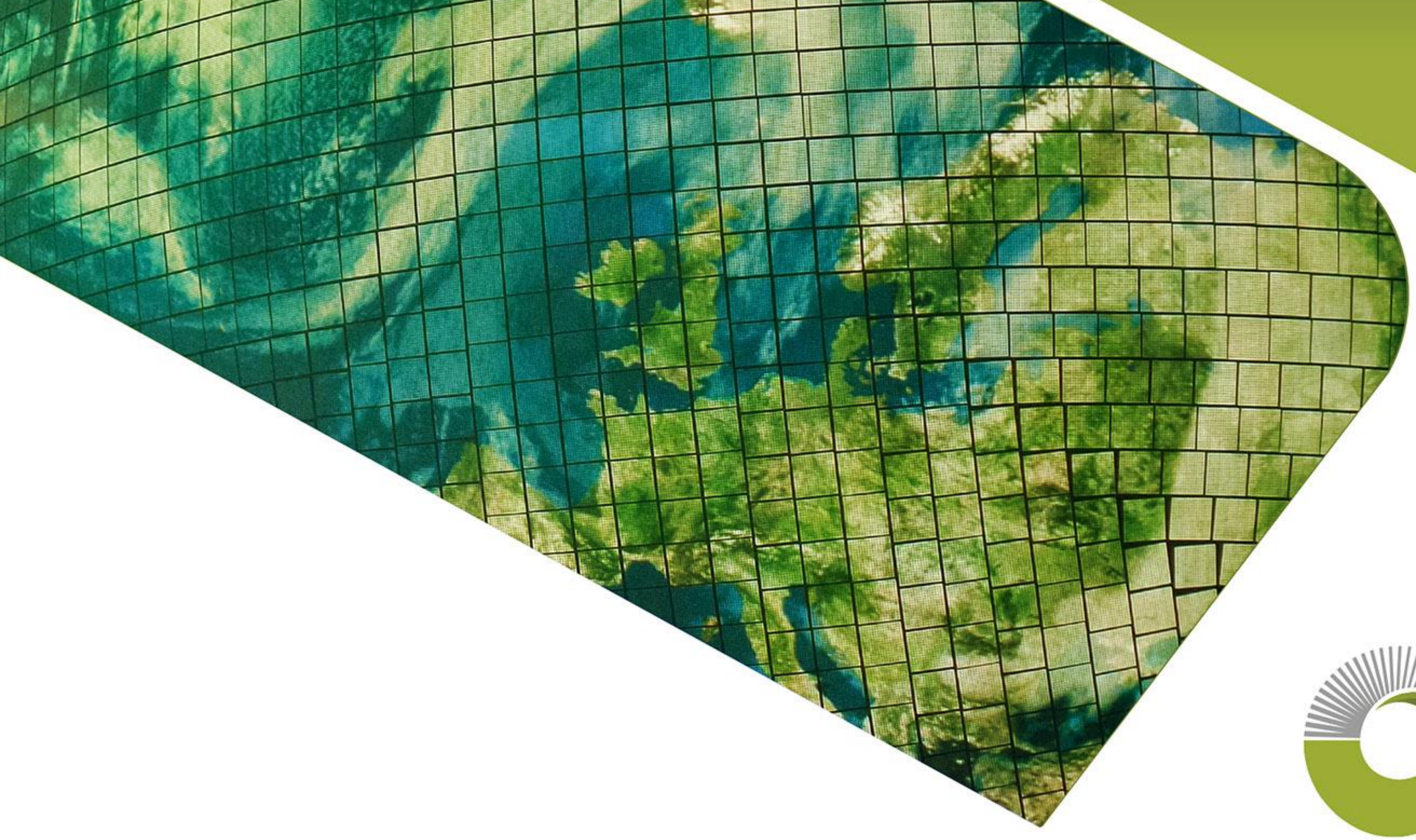


SYSTRA

PARIS REINFORCE

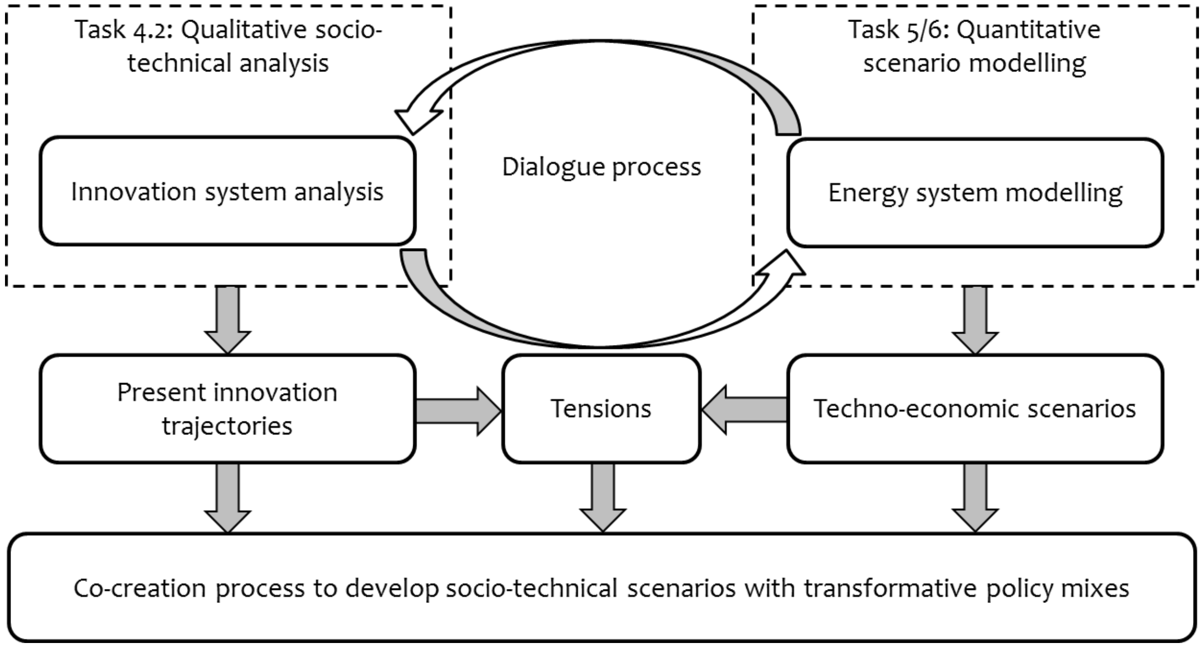
Sectoral Analysis: Decarbonisation of transport, role of oil, electricity, hydrogen and efficiency

J. Wachsmuth (Fraunhofer ISI), K. Vaillancourt, M. Pied (ESMIA), A. Gambhir (Imperial), K. Koasidis, A. Nikas, H. Doukas (NTUA)

09/05/2022, Canada Stakeholder Workshop

Our objective within PARIS REINFORCE:

To extend quantitative techno-economic scenarios in line with the Paris targets to socio-technical narratives by describing a transformative policy mix based on innovation system analyses



Sources: own representation

Transformative policy mixes:

- combine technology push and demand pull but address also systemic concerns
- pay attention to societal experimentation + phase-out of non-sustainable practices
- involve new institutional arrangements and governance structures

Case study for Canada: Sustainable transport

- Innovation system analysis for the transport sector in Canada
- Reference and Deep Mitigation Scenario based on the NATEM Canada model.

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Canadian transport sector: recent developments

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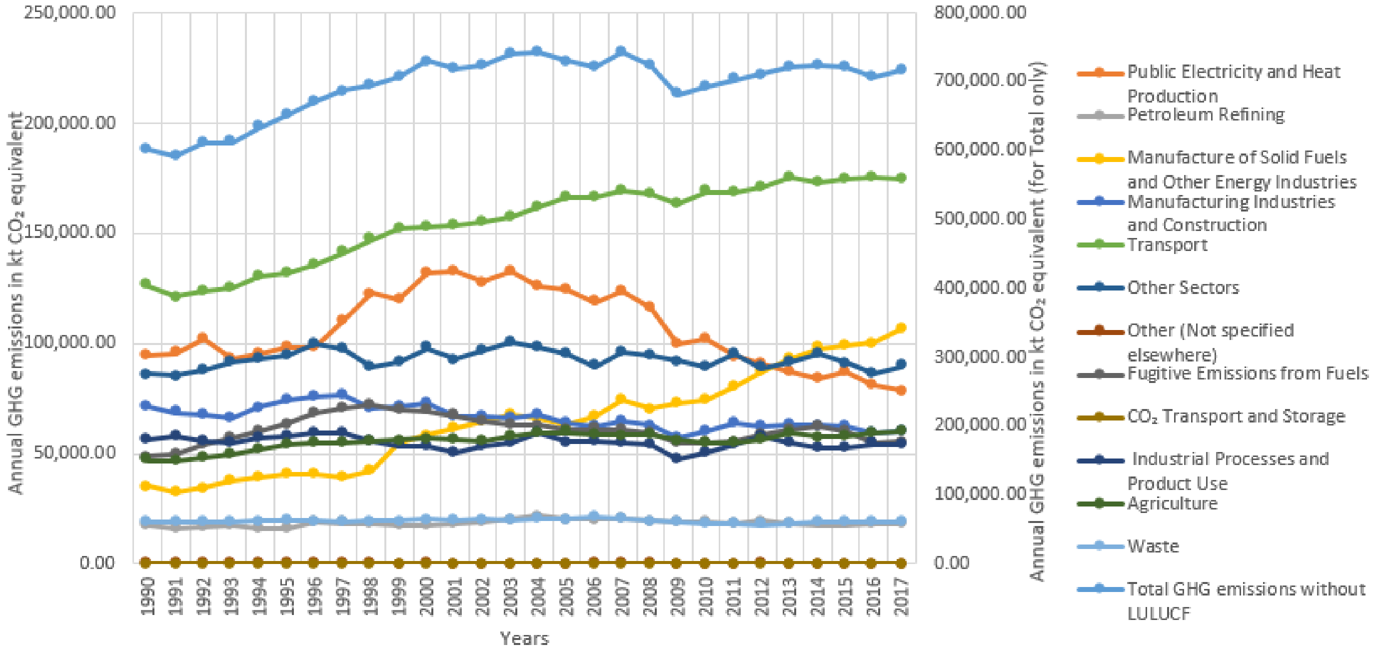
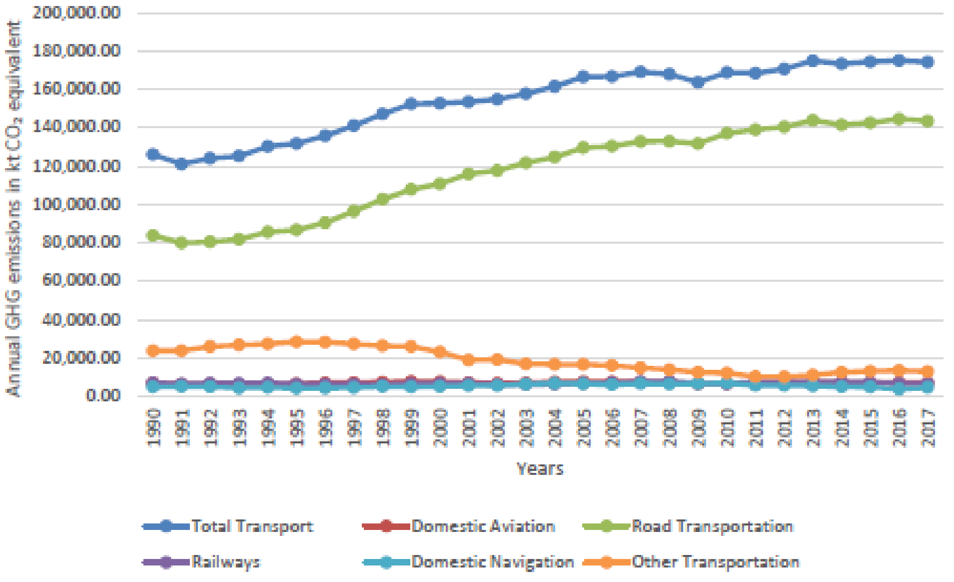
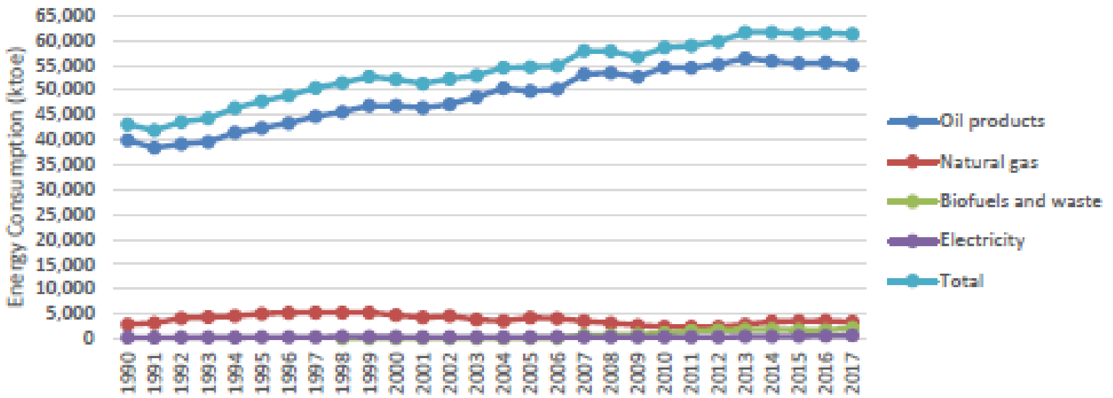
- Transport: major emitting sector in Canada, with emissions currently still increasing
- Road transportation dominant sub-sector
- Most transport means dominated by fossil fuels (~90%)







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Source: Koasidis, K. et al. (2020a)

SIS blocks	Key results
Actors and Networks	• Mostly private firms operate in the sector • Fossil fuel powerhouses have significant influence • Increased localised elements. Western provinces are strongly involved in oil and natural gas production
Institutions	• Policy depends both on the federal and the regional governments • Some provinces resist federal legislation (e.g. GHGPPA) • No universal carbon pricing scheme. Some provinces participate in a scheme with the state of California (US)
Demand	• The vast area of Canada creates increased transportation needs for multiple means
Knowledge, learning processes and technologies	• The current regime is dominated by inefficient gasoline vehicles • EV share slowly increases • EV diffusion more influential in regions with high share of hydro-power generation (e.g. Quebec)

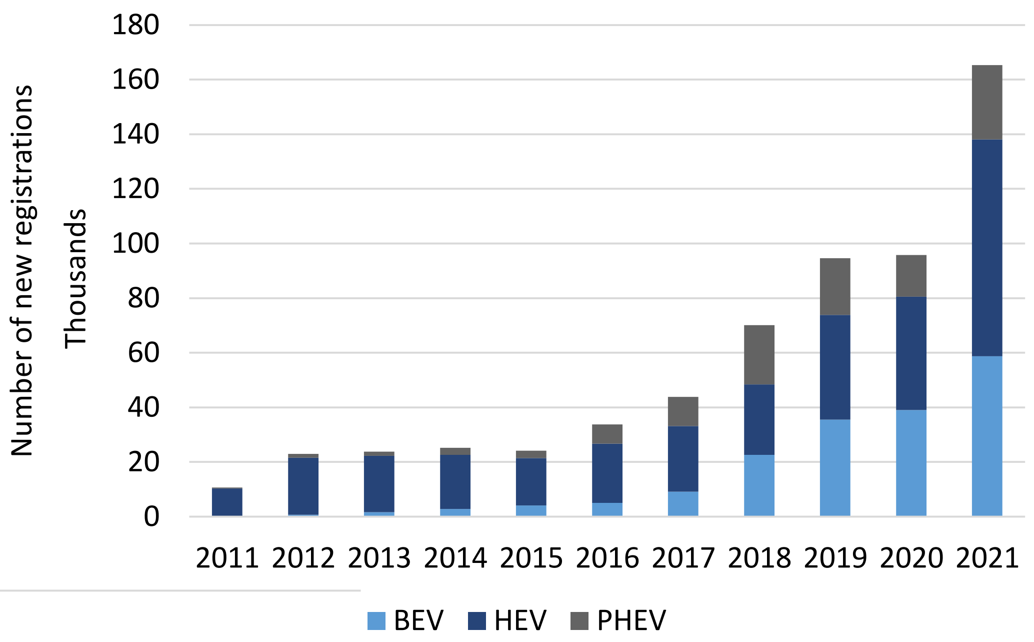
The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

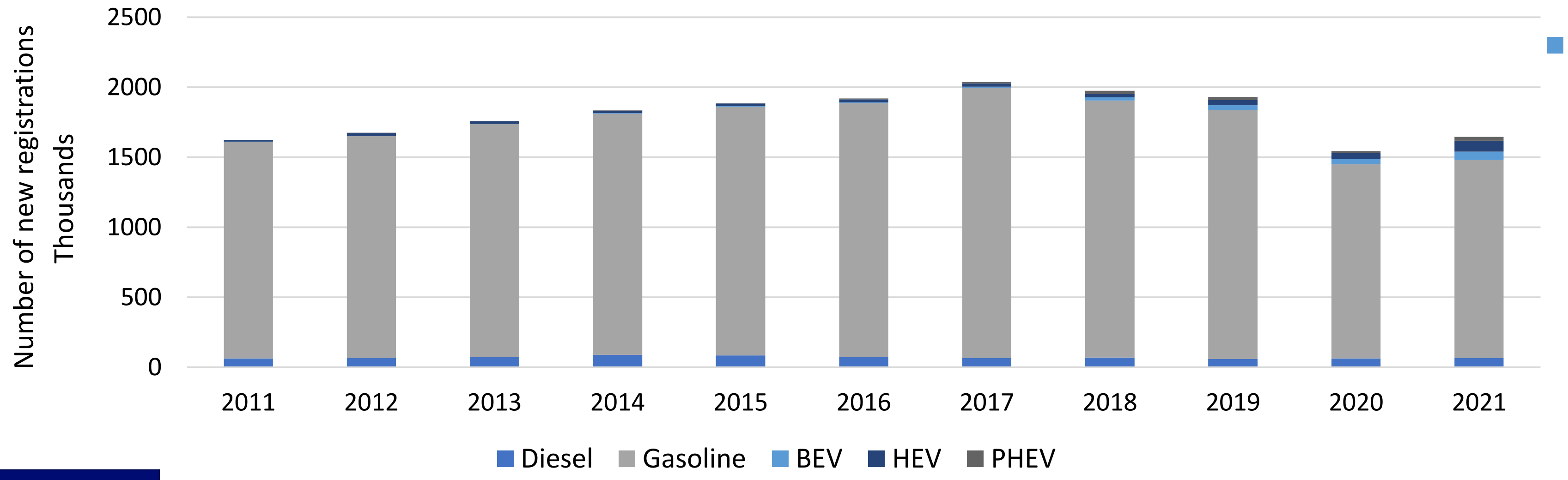
Source: Koasidis, K. et al. (2020a)

Canadian transport sector: current role of e-mobility

- Share of e-vehicles (battery and (plug-in) hybrid) increased from 1.3% in 2012 to 4.8% in 2019
- Within two years, the share of e-vehicles in total registrations doubled, reaching 10% in 2021.

- hybrid EV share in total e-vehicles fell from 90% in 2012 to less than half in 2021
- share of PHEVs still higher than the BEV share





Source: Statistics Canada (2022)

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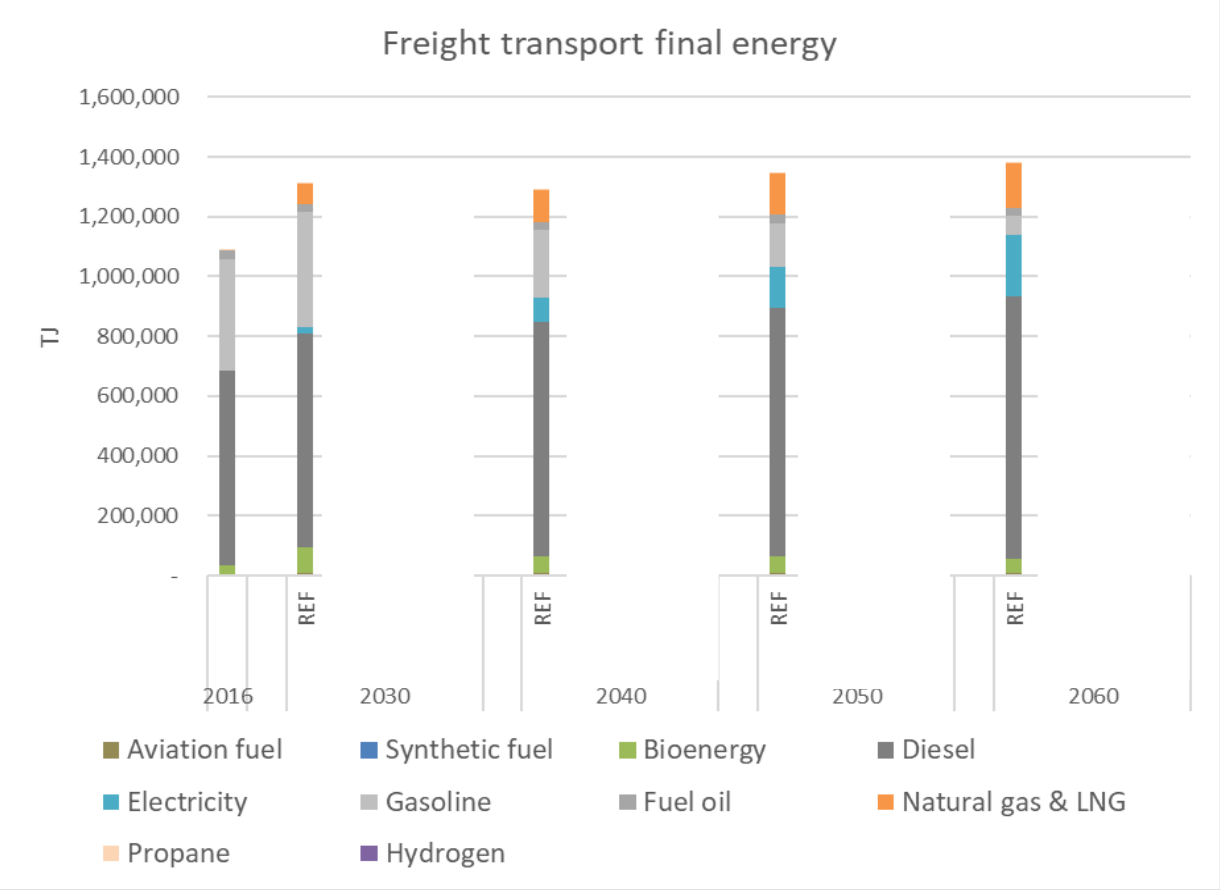
The reference scenario for the freight transport sector in Canada

Freight transport	Assumptions in the reference scenario	Key findings in the reference scenario
Overall	• No modal shift assumed. • Conservative demand elasticities (look at technology choices). • Uncertain assumptions for some technologies.	• Strong increase of energy demand until 2030 and plateau after 2030. • No contribution from hydrogen.
Road transport	• Electric vehicles for light and medium segments reach price parity around 2040.	• Substantial electrification of LDVs and MDVs. • Use of natural gas and oil products in HDVs.
Other modes	• Air and off-road transport have few decarbonization options	• Mainly oil products. • Natural gas and biofuels play a role.



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The deep mitigation scenario for the freight transport sector in Canada

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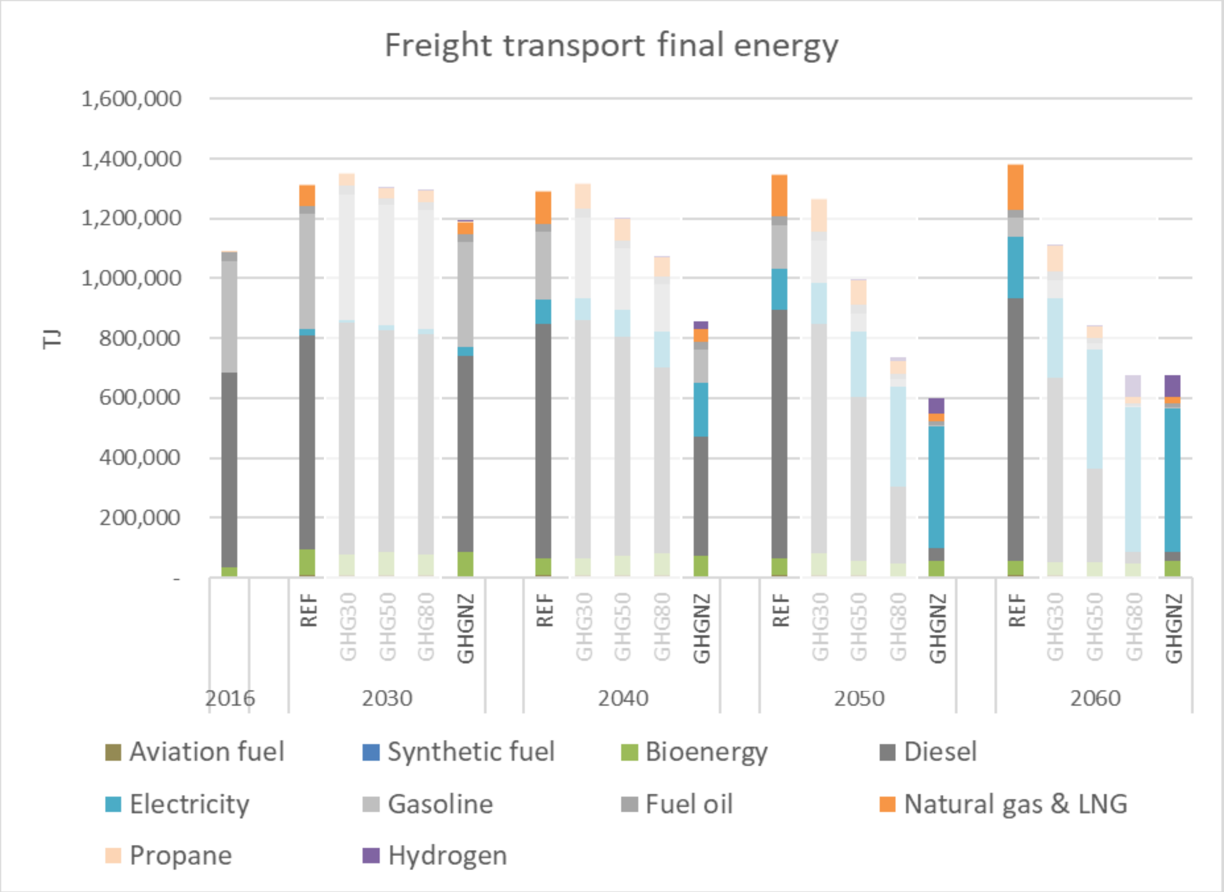
Freight transport	Assumptions in the deep mitigation scenario	Key findings in the deep mitigation scenario compared to the reference
Overall	• No changes apart from higher carbon price	• Sharp decline of energy use after 2030 (motor efficiency). • Most of the energy uses is electricity. • Limited contribution of hydrogen (but sensitivity analysis is required).
Road transport	• No changes	• Strong electrification of LDVs and MDVs. • HDVs technology mix is diverse and highly depends on assumptions. • Lower use of natural gas.
Other modes	• No changes	• Hydrogen for rail and marine transport. • Some amounts of biofuels.



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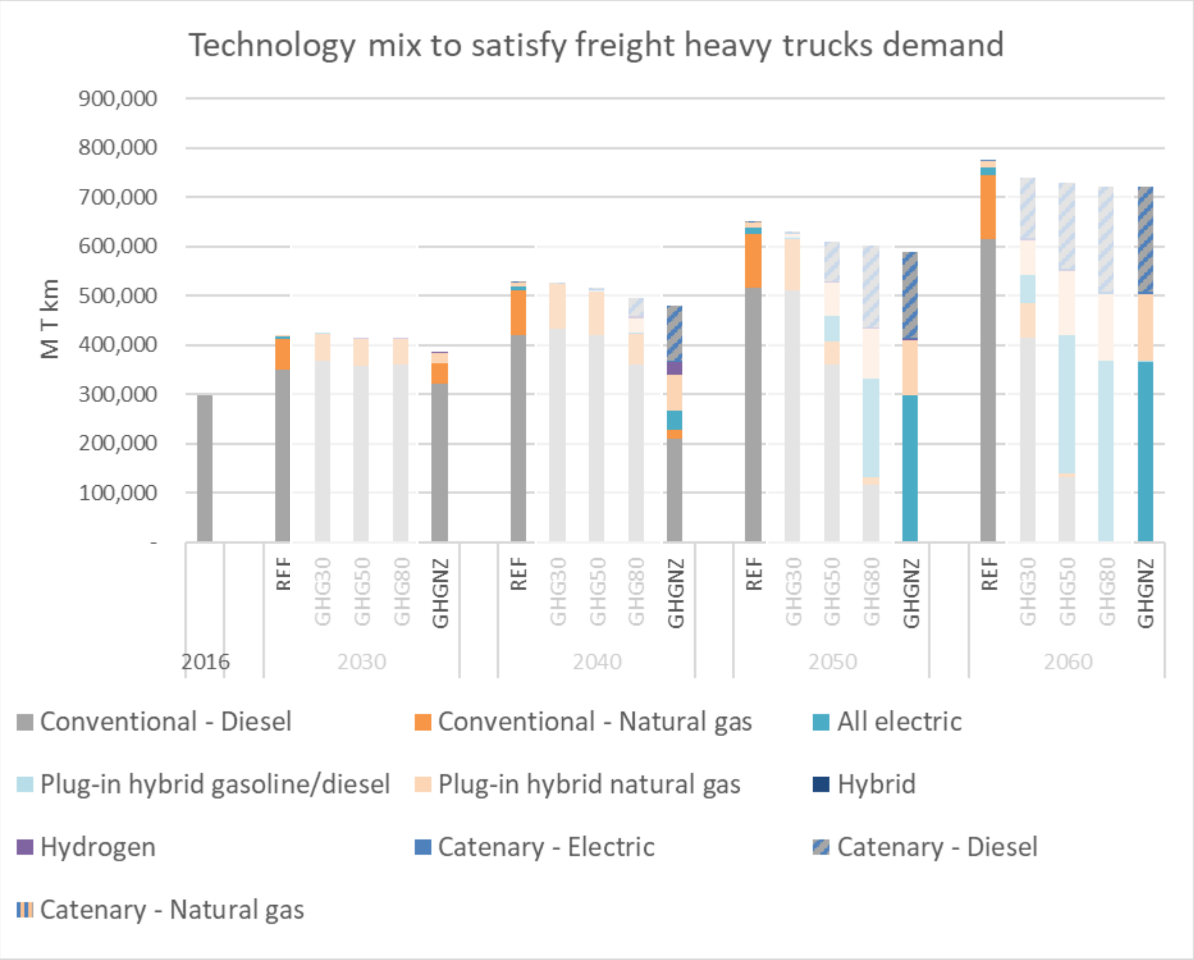

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The reference scenario for the passenger transport sector in Canada

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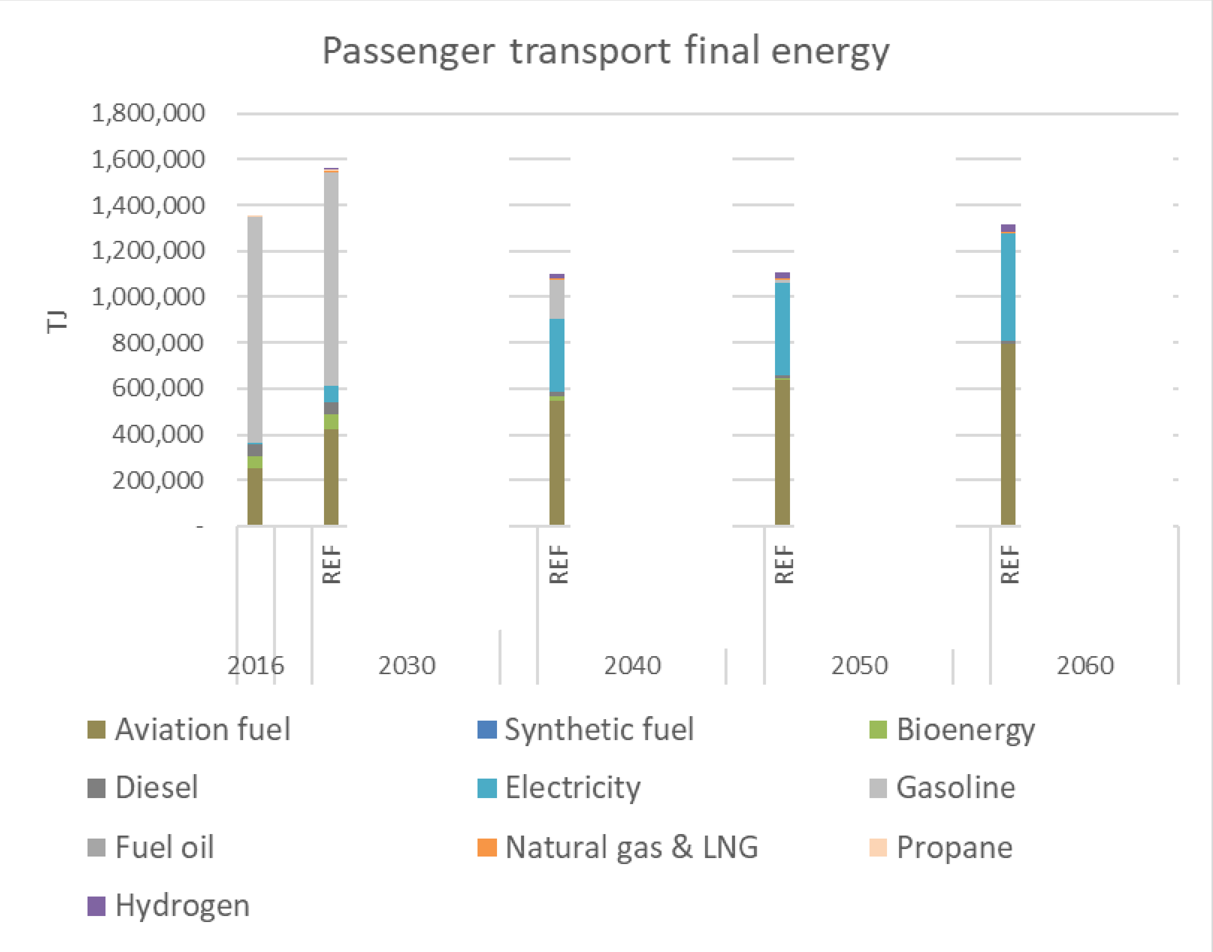
Transport sector in Brazil	Assumptions in the reference scenario	Key findings in the reference scenario
Overall	• No modal shift assumed. • Conservative demand elasticities (look at technology choices).	• Strong increase of energy demand until 2030 and decrease after 2030. • Limited contribution of hydrogen.
Road transport	• Electric vehicles for passenger cars and light trucks reach price parity around 2030.	• Strong electrification of passenger cars and light trucks • No use of natural gas. • Limited use of biofuels until 2030.
Other modes	• Air transport have few decarbonization options.	• Not much decarbonization in reference.



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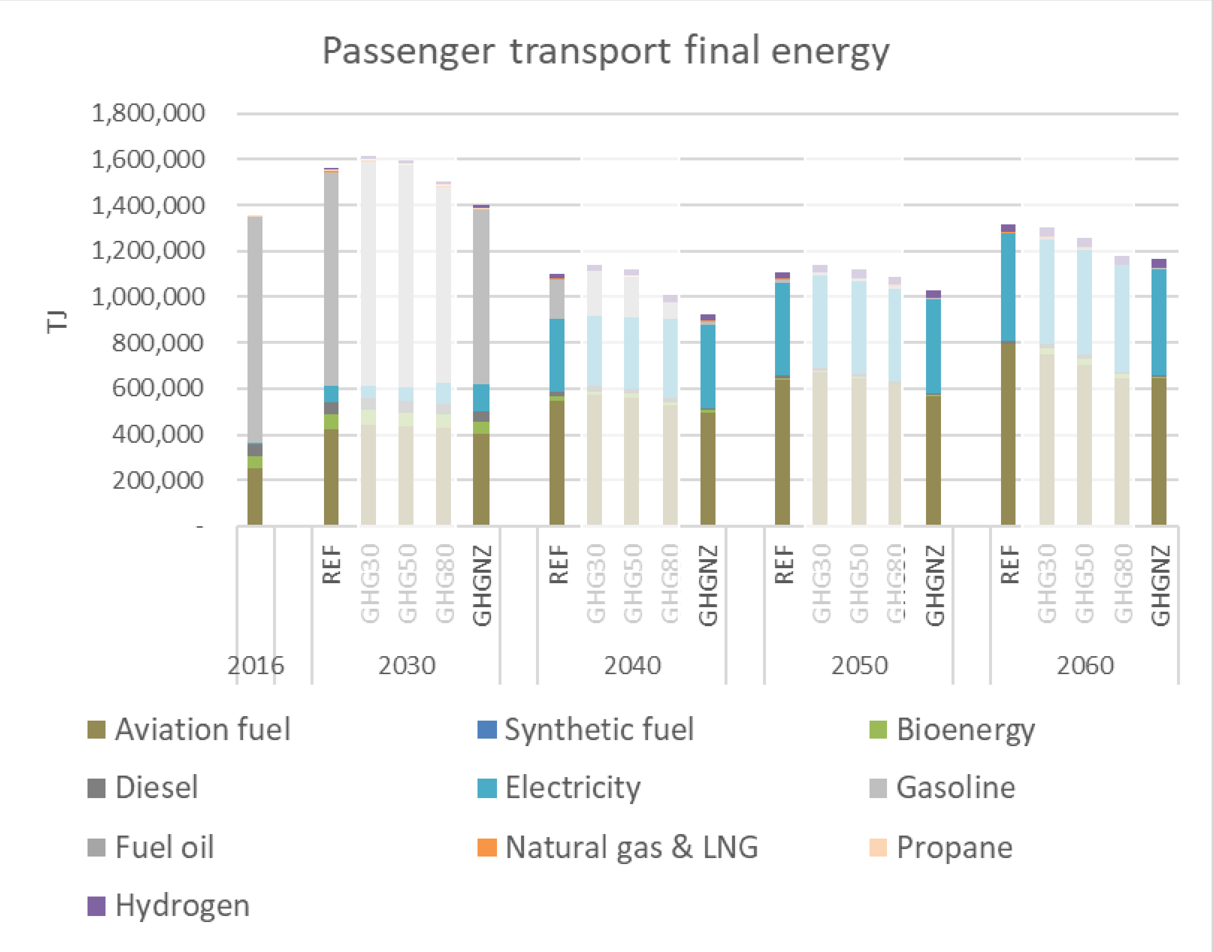
The deep mitigation scenario for the passenger transport sector in Canada

Transport sector in Brazil	Assumptions in the deep mitigation scenario	Key findings in the deep mitigation scenario compared to the reference
Overall	• No changes apart from higher carbon price	• Decrease of energy use compared to reference until 2030 + beyond (efficiency). • Limited contribution of hydrogen (more robust than for heavy freight).
Road transport	• No changes	• Stronger electrification of passenger cars and light trucks. • No changes with regard to natural gas and biofuels.
Other modes	• No changes	• Uses of biofuels and hydrogen to decarbonize. • International air transport GHG are not part of the targets.



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Conceptual background: Transformation bottlenecks + policy mix elements

	Transformation bottlenecks (generic examples!!)
Social feasibility	• lack of acceptance by important groups • deviation from societal trends + norms • required behavioral changes
Political feasibility	• established power structures • limitations of current political system. • deviation from political targets + strategies
Technological feasibility	• transformation of physical infrastructures • required technological maturity of certain technologies not yet available
Economic feasibility	• mobilizing needed investments • need of importing certain goods. • deviation from current market trends
Socio-economic impacts	• job losses • price increases deemed unacceptable
Socio-ecological impacts	• additional uses of land and other natural resources deemed unacceptable

Source: Wachsmuth, J.; Jackwerth-Rice, T.; Seus, S.; Warnke, P. (2021): Outlining a Methodology for Co-Creating Transformative Policy Mixes. Full paper at the IST 2021 conference.

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Conceptual background: Transformation bottlenecks + policy mix elements

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<table>
<tr><th></th><th>Transformation bottlenecks (generic examples!!)</th><th>Relevant policy mix elements (generic examples!!)</th></tr>
<tr><td>Social feasibility</td><td>lack of acceptance by important groups
deviation from societal trends + norms
required behavioral changes</td><td rowspan="2">Inclusive policy making: Processes that foster dialogue,, new ways of thinking or interaction modes, societal experimentation, user spaces or demonstration projects, e.g. roundtables, living labs, …
Flexible governance: adaptive mechanisms that reflect power structures btw. governments, market actors + civil society, public private partnerships, …
Systemic instruments: linking different elements (stakeholder and activities) of innovation systems, , e.g. institutionalized niche markets</td></tr>
<tr><td>Political feasibility</td><td>established power structures
limitations of current political system.
deviation from political targets + strategies</td></tr>
<tr><td>Technological feasibility</td><td>transformation of physical infrastructures
required technological maturity of certain technologies not yet available</td><td rowspan="2">Technology push: Instruments that pay attention to innovative technology options, e.g. grants for demonstration projects, investment loans
Demand pull: Mechanisms that stimulate the demand side (economic or regulatory): quotas, contracts for difference,
Systemic instruments: mechanisms that foster the provision of the required infrastructures, e.g. regulation of discriminatory-free access</td></tr>
<tr><td>Economic feasibility</td><td>mobilizing needed investments
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<tr><td>Socio-economic impacts</td><td>job losses
price increases deemed unacceptable</td><td rowspan="2">Systemic instruments: mechanisms that tackle structural change and social inequalities as well as socio-ecological impacts
Inclusive policy making: processes that foster participation of ‘dormant’ stakeholder</td></tr>
<tr><td>Socio-ecological impacts</td><td>additional uses of land and other natural resources deemed unacceptable</td></tr>
</table>

Source: Wachsmuth, J.; Jackwerth-Rice, T.; Seus, S.; Warnke, P. (2021): Outlining a Methodology for Co-Creating Transformative Policy Mixes. Full paper at the IST 2021 conference.

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Transformation bottlenecks for the transport sector in Canada

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	Bottlenecks for more ambition in the transport sector (literature-based, ELABORATED DURING THE WORKSHOP)	Bottlenecks for realization of the deep mitigation scenario (literature-based, ELABORATED DURING THE WORKSHOP)
Social feasibility	• Goal of a strong electrification not shared by all actors • Consumer uptake of e-mobility • Uptake of public transportation still limited	• Acceptance of CCS and BECCS • Acceptance of large-scale renewable expansion
Political feasibility	• Partial resistance by oil and automotive industries • Different energy resources in provinces and strong influence of provinces on transport systems	• Independent provinces may hinder stringent implementation • Integration with US economy
Technological feasibility	• Maturity of hydrogen-fueled and all-electric HDVs • Limited options for modes other than road transport	• Maturity of CCS technologies
Economic feasibility	• Growing transport activity • Much lower prices of fossil fuels compared to electricity • Infrastructure rollout (catenary) requires large investment	• Large-scale investments in BECCS needed with uncertain revenue
Socio-economic impacts	• Increasing costs for mobility • Denser urban living and transport areas	• Potential job losses in oil sector
Socio-ecological impacts	• Resource use for battery production	• Potential negative impacts of large-scale hydropower expansion • Nuclear waste treatment • Reliance on land use sinks

Source: own representation of Koasidis, K. et al. (2020a) and expert knowledge

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