

REVIEW OF EXISTING TECHNOLOGIES (VEHICLE FUELS AND DEVICES): APPLICATIONS, BENEFITS AND LIMITATIONS

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Purpose of the Paper

- Provide an overview and update on GHG and air pollutant emissions in Canada and related developments, with focus on heavy-duty road freight/trucking.
- Review key existing emissions improving technologies (established or emerging) for trucks by identifying their application, benefits and limitations.
- Present some key observations and considerations for accelerating technology adoption by the freight trucking industry.

Road Freight **GHG** Emissions in Canada and Ontario

**Road freight is a significant contributor to
GHG emissions and air pollution**

Canada: Total emissions in 2014

Transportation sector: 24%

Road Freight: **33%** of transportation

Ontario: Total emissions in 2015

Transportation sector: 37%

Road Freight: **26%** of transportation

Road Freight Air Pollutant Emissions in Canada and Ontario

Light-duty gasoline vehicles achieved comparatively faster air pollutant emissions reduction than heavy-duty diesel vehicles

AQ emissions (tons per year)	Heavy-duty diesel vehicles				Gasoline cars and LD trucks			
	NOx+VOCs		PM 2.5		NOx+VOCs		PM 2.5	
	1998 -2010	1990 -2016	1998 -2010	1990 -2016	1998 -2010	1990 -2016	1998 -2010	1990 -2016
Canada	383,357	303,136	13,878	14,911	659,973	593,675	6,128	6,801
	350,416	253,066	12,833	8,546	305,300	222,216	3,023	2,422
Ontario	102,838	85,797	3,652	4,129	241,856	207,659	1,887	2,152
	90,166	59,368	3,402	1,995	106,608	67,835	1,001	770

AQ emissions <i>change</i>	Heavy-duty diesel vehicles				Gasoline cars and LD trucks			
	NOx+VOCs		PM 2.5		NOx+VOCs		PM 2.5	
	1998-2010	1990-2016	1998-2010	1990-2016	1998-2010	1990-2016	1998-2010	1990-2016
Canada	-9%	-17%	-8%	-43%	-54%	-63%	-51%	-64%
Ontario	-12%	31%	-7%	-52%	-56%	-67%	-47%	-64%

Regulatory Developments in US and Canada

**Emissions regulations and standards
developed and implemented in alignment**

2014 - 2018: Phase I and II

Regulations for heavy-duty vehicle/engine GHG emissions

- Set increasingly stringent mandatory standards for new on-road heavy-duty vehicles, trailers and engines

2004 - 2015: Tier 2 and 3 Standards

Regulations for on-road vehicle/engine emissions

- Set increasingly stringent mandatory standards against smog-forming emissions from passenger cars, light trucks and some heavy-duty vehicles

Road Freight Emissions Reduction

Demand- and Supply-sides

Demand: volume and level of activity

Supply: energy and carbon intensity of fuel

- **Demand-side** measures about managing *volume* of the demand and *level of activity* for on-road freight transport - number of freight trucks on the road, total tonne-kilometres per year, vehicle-kilometres travelled
- **Supply-side/fuel use** about the *energy intensity* (correlated to efficiency) as measured in mega-joules litres per tonne-kilometre and *fuel carbon intensity* (the carbon content of the fuels consumed) as measured by amount of carbon emitted per unit of energy demand, depending on the fuel used

Road Freight Emissions Reduction

Fuel Switch and Fuel Saving

- **Direct contribution to emissions reduction**
- **Practical pathway for road freight industry**

GHGs and air pollutants are derived from burning fuels (diesel) to power truck engines: tailpipe emissions. The most direct and practical contributions are from:

- Fuel switch which means lower carbon content of fuels burnt (alternative fuels) and thus of emissions
- Fuel saving which means less fuel consumed and thus fewer emission for a given number of kilometres travelled

Road Freight Emissions Reduction

Existing Technologies

Established and Disruptive technologies

- Most are established technologies: already exist or recently emerged but not fully developed or commercialized
- A few are considered “disruptive”: not currently broadly used but with the potential to achieve strong fuel and emissions reductions

Road Freight Emissions Reduction

List of Key **Existing** Technologies

Established e.g. Natural Gas, Hybrid, Side-skirt
Disruptive e.g. Battery Electric, Hydrogen Fuel Cell

Supply side of freight transport	Key Technologies (fuels or devices)	Emission (tailpipe)		Breakdown(including conversions)	Other technologies
		GHG emissions	Air Pollutants		
Fuel switch (from diesel/gasoline)	Natural Gas (NG)	Lower	Lower	CNG, LNG, RNG Dual Fuel (Diesel/NG)	-
	Electrification (battery & hydrogen)	100% Lower	100 Lower	Electric	DME Hybrid-electric Propane Biodiesel Bi-fuel
	Other fuels	Lower	Lower	-	
Fuel -saving (diesel or gasoline)	Anti-idling devices	Lower	Lower	APUs	Idle Management
				Cab coolers	
				Cab heaters	
Aerodynamic devices	Lower	Lower	Side skirt, Boat Tail Under-body fairing Roof Cab extenders, Gap reducer	LRRTs, WBS tires Auto Tire Inflation & Tire Pressure Monitoring systems	
			Refrigeration Units	Lower	Lower

Road Freight Emissions Reduction Technologies for Evaluation

Chosen for impacts on both emissions as well as business needs and priorities





Technologies chosen for evaluation:

- Impact on emissions or fuel savings, e.g. zero-emission or 10% fuel saved (energy or carbon intensity)
- Industry/user needs and priorities, e.g. efficiency, cost-competitiveness, market access or business opportunities

Alternative Fuel Platforms

Fuel	Vehicle types & operation	Tailpipe emissions	Fuel efficiency	Performance	Cost	Other limitations or benefits
		Compared to Diesel				
Natural Gas: CNG,LNG, RNG	Refuse, dump, delivery trucks; Tractor trailers Return to base; Long haul	12% lower	Lower	Similar / Comparable High horse -power engine unavailable	Lower fuel cost (volatile) Higher engine cost	Infrastructure limitations Fuel supply limited, particularly RNG
Dual fuel (CNG/ Diesel)	Heavy duty long haulers; LCVs	Lower	Lower	Comparable Overall range unlimited	Lower fuel cost (volatile) Conversion cost	Dual-fuel mode less range Complex storage system
Hybrid-electric HD •Hyliion •Effenco	Mostly light and medium duty / MD (delivery & short haul operations) Heavy-duty trucks mostly not yet commercialized	Lower emissions (less fuel used)	higher in MD urban operations	Comparable, depending on battery size	Lower fuel cost High incremental and battery costs	Need no special infrastructure or recharging Less benefit for heavy-duty highway operations
Electric: Battery or Hydrogen fuel cell (Nikola, Tesla, Peterbilt, Volvo)11	Currently only medium duty vehicles available Nikola & Tesla announced plan to produce HD trucks	100% lower/zero emissions	45% higher	Limited range and speed Vehicle/cargo weight and range trade-off	High battery costs or High cost for fuel cell, storage and hydrogen fuel	Limited hydrogen infrastructure or connectivity to electrical grid

Aerodynamic Devices & Energy Efficient Tires

Device	Vehicle types	Main Operation	SmartWay Verified (California)	Fuel savings (SmartWay)	Limitations
Aerodynamic Devices					
Trailer Side skirt	Class 8 Tractor-trailer	Line-haul Highway High speed		5%	<ul style="list-style-type: none"> • Trailer underside access • Tire storage & maintenance • Prone to damage/breakage
Trailer Boat tail	Class 8 Tractor-trailer	Line-haul Highway High speed		4%	<ul style="list-style-type: none"> • Manual deployment (Changing to some automatic)
Energy Efficient Tires					
Low rolling Resistance	Class 8 Tractor-trailer	Line-haul Highway High speed		3%+	<ul style="list-style-type: none"> • Winter traction concern • 10% premium • Frequent tire replacement
Wide Base Single	Class 8 Tractor-trailer	Line-haul Highway High speed		3%+	<ul style="list-style-type: none"> • Adverse pavement impact • Sensitive to tire over or under inflation issues • No limp-home capability

Reefer Technologies

Device	Fuel Engine	Vehicle types	Main Operation	Fuel & emissions benefits	Limitations
Reefer Technologies					
Truck / body Insulation	Diesel Hybrid	Van Truck Tractor-trailer	Long haul refrigeration transport	<ul style="list-style-type: none"> • Zero-emissions • Lower fuel use • Lower fuel cost 	<ul style="list-style-type: none"> • time-consuming • high cost to install • quality uncertain
Eutectic system	Diesel Hybrid	Van Truck Tractor-trailer	Long haul refrigeration transport	<ul style="list-style-type: none"> • Zero-emissions • Lower fuel use • Lower fuel cost • More range if used with refrigeration unit 	<u>Cold plate technology</u> <ul style="list-style-type: none"> • can affect payload • can affect loading • better for return to base
Cryogenic system	Diesel Hybrid	Van Truck Tractor-trailer	Long haul refrigeration transport	<ul style="list-style-type: none"> • Zero-emissions • Lower fuel use • Lower fuel cost • Less maintenance 	<ul style="list-style-type: none"> • fuel expensive • limited range • vehicle parts need special material • periodic certification

Road Freight Emissions Reduction

Key Considerations

- User needs/business priorities dictate industry decisions on technology adoption, such as cost-competitiveness, efficiency and market opportunities;
- Balance to be found between industry needs and government priorities;
- Time for developers and manufacturers to go beyond just investing in R&D and make technologies affordable for users to accelerate adoption for decarbonizing freight trucking.