RAIL PATHWAYS INITIATIVE

PHASE 1: LANDSCAPE DOCUMENT

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Executive Summary

Canada's rail sector currently provides a low-carbon means of transporting both goods and people throughout the country. In terms of freight transport, the carbon intensity of rail is roughly four times lower than that of on-road freight movement. Despite being responsible for almost half of all freight movement within the country, the sector only accounts for 4% of total transportation-related greenhouse gas (GHG) emissions. However, as Canada and other nations accelerate transportation decarbonization efforts towards the achievement of climate-related targets, further reductions in GHG emissions intensity from the sector will be necessary.

The purpose of Phase 1 of the Rail Pathways Initiative is to develop a landscape document which delivers on the following objectives:

- Develop a common understanding of the current state of rail sector decarbonization in Canada, which can be used as a tool for collaboration between industry and government;
- Create a repository of current federal, provincial and territorial GHG reduction legislative instruments and activities impacting the rail sector; and
- Contribute to next-phase work on a roadmap to achieving future GHG reductions in Canada's rail sector.

To help achieve these objectives an expert steering committee comprised of public and private rail sector stakeholders was convened. A major role of the Rail Pathways Steering Committee was to review and supplement an inventory of legislative instruments and activities that impact rail carbon intensity in Canada. Specifically, the inventory found in Sections 4 to 7 and in Appendices B to F, includes:

- Federal Instruments: Regulations, policies and programs being led at the federal level;
- Provincial Instruments: Regulations, policies and programs being led at the provincial level;
- Federal and Provincial Research, Development and Demonstration (RD&D) initiatives: specifically, in areas such as technologies, fuels and feasibility assessments;
- Canadian Rail Industry Activities: GHG reduction activities in the areas of efficiency, alternative fuels, alternative propulsion and infrastructure; and
- International rail GHG reduction landscape and best practices.

To help with the identification of gaps and to illustrate areas of strength, GHG reduction mechanisms are categorized into five areas: fuel efficiency, alternative fuels, alternative propulsion, infrastructure and modal shift. Currently available and emerging technologies within these categories are touched upon in this document, although an assessment of the GHG reduction potential and barriers to the implementation of various technologies and practices in a Canadian context will be conducted in Phase 2 of the Pathways Initiative.

In terms of legislative instruments related specifically to rail decarbonization, most provincial and territorial legislation that impacts rail carbon intensity is not rail specific, or even transportation specific, but rather broadly addresses GHG emissions through climate action plans and strategies. At the federal level, however, a series of overarching policies are working to reduce GHG emissions from the rail sector by driving a shift towards lower emitting fuels and technologies, as well as towards lower emitting types of transportation.

These include the Pan-Canadian Framework on Clean Growth and Climate Change (which includes supportive policies such as carbon pricing and the Clean Fuel Standard) and the Canadian Environmental Protection Act (CEPA).

In terms of non-regulatory instruments impacting rail carbon intensity, of greatest impact is the MOU between the Railway Association of Canada and Transport Canada, which lays out GHG intensity reduction targets of 6% from 2017 levels by 2022 for Class I freight and intercity passenger operations, and reductions of 3% in the same timeframe for short line operations.

Direct support for RD&D initiatives within the rail sector in Canada was found to take place predominantly at the federal level. Similar to regulatory approaches, much of this support is not aimed specifically at the rail sector, but at transportation decarbonization efforts broadly. Canada is home to several organizations and bodies that explore and address the environmental performance of the nation's rail sector. These include the Railway Association of Canada (RAC), Transport Canada's Innovation Centre, the Rail Research Advisory Board of Canada (RRAB), and, in a limited capacity, the Canadian Rail Research Laboratory (CaRRL). Research was found to be focused largely on decreasing carbon emissions by improving efficiency and fuel switching. It appears that relatively little attention is being paid to assessing the GHG reduction potential of modal shifts to rail for the movement of goods and people – a gap that can perhaps be addressed in future RD&D efforts.

Canada's rail industry is engaged in decarbonization activities across all five categories explored in this document. The category being most intensively addressed continues to be fuel efficiency. This is being largely driven by fleet renewal and the implementation of software and data analytics related to energy and route optimization. The utilization of alternative fuels continues to advance as well, as does infrastructure expansion to enhance network capacity and fluidity.

Canada's geography, climate, economy and population density make its rail sector unique in a global context, however global rail decarbonization trends can nonetheless provide useful input into future planning. Many global jurisdictions are pursuing modal shifts to rail to support decarbonization efforts, and are conducting RD&D across all decarbonization categories to further reduce the carbon intensity of rail using emerging technologies and best practices. These jurisdictions include the UK, Germany, France (and the EU more broadly), Russia, China, India, Japan and Australia. Specific initiatives taking place in these and other parts of the world are profiled in Section 7.1 and Appendix F. Section 7.2 provides some examples of rail decarbonization roadmapping exercises currently taking place internationally. Elements from these examples may prove useful in informing a comparable exercise in Canada, which is to be the focus of Phase 2 of the Rail Pathways Initiative.

Phase 2 will use this landscape document to inform the development of a roadmap towards deeper GHG reductions. It will continue to involve federal and industry stakeholders and will further engage provincial and territorial governments to collaborate on the development of a common vision and path forward, including setting priorities for the near, medium and longer term.

1. Introduction

With over 49,000 route kilometres of track running from coast-to-coast, three national railway companies and numerous regional and shortline railways that carry freight, passengers or a combination of both, Canada's extensive rail network supports both the Canadian economy and the quality of life enjoyed by Canadians. Class I and shortline freight rail moves more than $328 billion worth of goods, and passenger rail moves 88 million people per year – 82.8 million passengers by commuter rail and an additional 5 million by intercity passenger railways.[1]

Close to a quarter of Canada's greenhouse gas (GHG) emissions come from the transportation sector.[2] Once dominated by passenger transportation, emissions from this sector are increasingly as a result of the movement of freight. Emissions from freight are projected to exceed those from passenger transportation by 2030.[3] On a tonne-km basis, rail is the most prevalent method of transporting freight domestically (44%, versus 33% by truck). Yet the rail sector accounts for only 4% of Canada's total transportation-related greenhouse gas (GHG) emissions[4], and 98% of these are as a result of the transportation of freight[5]. This is a testament to the fuel efficiency of this mode.

By consistently investing in efficiency and sustainability, Canada's freight railways have reduced their GHG emissions intensity by over 40% since 1990, and intercity passenger railways have reduced their GHG emissions intensity by about 55%.[6] These efficiency gains have largely been realized through locomotive engine upgrades. As Canada and the world moves towards deep carbon reductions, however, all sectors will need to look beyond efficiency to decarbonize the sources of energy they consume.

Since 1995, Transport Canada and the Railway Association of Canada (RAC) have signed four Memoranda of Understanding (MOU) to establish voluntary reduction targets for emissions produced by locomotives in Canada. The most recent of these, the 2018 – 2022 MOU, includes a commitment to collaborate on a "comprehensive pathway document for aligning government and industry efforts to reduce emissions produced by the railway sector." The two-phase Rail Pathways Initiative is intended to build off the successes achieved to date by the MOU via collaborative public-private efforts to explicitly target GHG reductions from Canada's rail sector. Phase 1 will catalogue ongoing and potential activities related to rail sector decarbonization that are led by industry and government, or collaborations between the private and public sectors. Phase 2 will develop a roadmap to deep GHG reductions in the rail sector through development of a comprehensive pathway document for aligning government and industry efforts to reduce emissions produced by the railway sector.

This landscape document represents the culmination of Phase 1 of the Pathways Initiative. Developed collaboratively with government and industry, it explores the current emissions-

1 RAC
2 In 2017, 24% of Canada's GHG emissions came from the transportation sector, per the National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada (Annex 10, Table 3).
3 Government of Canada. Canada's Second Biennial Report on Climate Change. (2016). https://www.canada.ca/content/dam/eccc/migration/main/ges-ghg/02d095cb-bab0-40d6-b7f0-828145249af5/3001-20unfccc-202nd-20biennial-20report_e_v7_lowres.pdf
4 Transport Canada
5 National Inventory Report 1990-2017: Greenhouse Gas Sources and Sinks in Canada
6 Canada's Railways - Helping Canada Stay on Track to Fight Climate Change, RAC, 2020 https://www.railcan.ca/wp-content/uploads/2020/05/RailCan_EnvironmentalBrief_Final.pdf

reduction landscape through an inventory and analysis of current policies, regulations, programs, operations practices, research and technology related to GHG reductions that impact the rail sector. It fulfils the following objectives:

1. Develop a common understanding of the current state of the rail GHG reduction landscape between industry and government that can be used as a tool for collaboration.
2. Create a repository of current GHG reduction federal and provincial instruments, programs and activities impacting the rail sector; rail sector activities to reduce GHG emissions; and the current research and technology landscape for reference by officials, researchers and technologists.
3. Contribute to next-phase work on a roadmap to achieving future GHG reductions, both in the rail sector and enabled by the rail sector.
4. Phase 2 of the Pathways Initiative will continue to engage stakeholders in government and industry in order to develop a roadmap to deeper GHG reductions in the rail sector. This will entail establishing a common vision, developing a framework for assessing GHG reduction opportunities and planning for the deployment of these opportunities over time to meet established targets.

2. Methodology

The Rail Pathways Initiative is a collaboration between the federal government (Transport Canada; Natural Resources Canada; Innovation, Science and Economic Development Canada; and Environment and Climate Change Canada) and the rail sector. It was spearheaded by Transport Canada in conjunction with the Railway Association of Canada and is supported by a project Steering Committee. The latter is comprised of public and private sector stakeholders along with members of the MOU Management Committee. A list of Steering Committee members is included in Appendix A.

The Steering Committee was first convened in April 2020. This initial meeting focused on finalizing a methodology for creating a repository of federal and provincial regulatory instruments, programs and activities impacting the rail sector; rail sector activities to reduce GHG emissions; and the current research and technology landscape. The following information was flagged for collection:

- Federal Instruments: Regulations, policies and programs being led at the federal level;
- Provincial Instruments: Regulations, policies and programs being led at the provincial level;
- Federal and Provincial Research, Development and Demonstration (RD&D) initiatives: specifically, in areas such as technologies, fuels and feasibility assessments;
- Canadian Rail Industry Activities: GHG reduction activities in the areas of efficiency, alternative fuels, alternative propulsion and infrastructure; and
- International rail GHG reduction landscape and best practices.

This Landscape Document is based on information provided by Steering Committee members from federal departments and from the rail industry; and from rail safety and environmental personnel in provincial and territorial governments with rail sector activity. Information collected through these means was supplemented by a literature review to ensure that what is reflected here is comprehensive, and to characterize the international landscape.

3. GHG Reduction Mechanisms for the Rail Sector

GHG reductions for the rail sector typically fall into one of five categories: fuel efficiency, alternative fuels, alternative propulsion, infrastructure and modal shift.

Fuel efficiency is commonly measured in litres of fuel consumed per passenger km for passenger rail, or per revenue tonne-kilometre (RTK) for freight rail. Measures around fuel efficiency may address infrastructure and equipment including engines, railcars, components or tracks; and software, such as for route and speed optimization and automation.

Alternative fuels are low-carbon alternatives to petroleum diesel. These include liquefied natural gas (LNG), which must be used in purpose-built LNG locomotives or existing locomotives that have been retrofitted; and biofuels such as biodiesel and renewable diesel, which can be blended with petroleum diesel up to the limits imposed by OEMs[7] and used to power regular locomotives. In some cases, alternative fuels require the use of specialized refueling infrastructure such as compressors and pressurized storage tanks and dispensers.

Alternative propulsion systems avoid the use of combustion engines and are instead powered by electricity derived from hydrogen fuel cells, local electrical grids, or batteries. These may provide motive power to trains on their own or in tandem with combustion technologies in the case of hybrid systems. Some alternative propulsion technologies necessitate specialized infrastructure such as overhead catenary wires or electrified third rails, or hydrogen distribution pipelines, compressors and storage tanks.

Infrastructure relates to Class I and shortline tracks, bridges, tunnels, road crossings, signalling devices and signage, spurs and sidings, along with stations, depots, terminals and container yards. Infrastructure may impact the value proposition of rail relative to other, higher-carbon modes of transport. For example, double-tracking can enhance network fluidity and shortlines and rail spurs can enable the more direct delivery of goods and mitigate the need for multi-modal last mile options such as on-road freight trucks.

Modal shift refers to the shift of freight and passenger transportation away from higher emitting modes including trucks, cars and air, to the more efficient rail. In particular, shifting freight from truck to rail represents an opportunity for significant GHG emissions savings, as trucks represent the greatest source of transportation emissions in the movement of goods, and GHG emissions from the movement of freight trucks has more than doubled in the past three decades.[8] While such a shift will be expected to raise the overall GHG emissions from the rail sector as a result of increased usage, because the emissions intensity of rail is lower than on-road and air, overall transportation emissions will be reduced. In addition to GHGs, it is also necessary to account for impacts on CAC emissions in the context of modal shift.

This report applied the above categorizations when cataloguing activities that contribute to the reduction of GHG emissions from the rail sector, including RD&D, actions on the part of the Canadian rail industry, and international activities. Prior to addressing GHG reduction activities, however, it examines the regulatory and non-regulatory federal and provincial instruments that overlay them.

7 OEM warranties limit blending to 5% for biodiesel and 30% for renewable diesel.
8 Modal Optimization as a Contributor to Reducing GHG Emissions in Canada. The Delphi Group and Pollution Probe for Natural Resources Canada, March 2020.

With regard to specific technologies that can be utilized by rail stakeholders to further reduce the carbon intensity of this mode, the table below provides a high-level overview of available and emerging options for rail decarbonization.

Table 1: Technology-Related Measures to Reduce Rail Carbon Intensity

Technology	Category	Description	Readiness Level*
Engine and drivetrain upgrades	Fuel Efficiency	Fleet renewal and retrofitting using higher efficiency engines have been the primary means of realizing significant fuel efficiency gains and GHG emissions reductions in Canada's rail sector.	High
Energy Management Software	Fuel Efficiency	Software (e.g., Trip Optimizer) related to fuel and energy management systems, route and speed optimization, traffic management and scheduling, track monitoring, and cargo and container optimization can use data analytics to significantly enhance fuel efficiency within individual trainsets and across rail networks.	High
Hybridization	Fuel Efficiency	Diesel-electric hybrid locomotives containing energy storage systems such as batteries, flywheels, and/or supercapacitors properly sized to capture braking energy have been shown to significantly reduce fuel consumption through the use of regenerative braking.	Medium
Lightweighting	Fuel Efficiency	Lightweighting of railcars and components (e.g., through the use of composite materials, lightweight alloys or 3D printed components) can significantly decrease trainset weight, thereby enhancing fuel economy.	Medium
Aerodynamics	Fuel Efficiency	Efficiency enhancements through enhanced aerodynamics (e.g., streamlined noses, surface microstructures, railcar gap reductions, enhanced coupling systems, bogie and nose fairings) are most pronounced in high speed rail applications, however efficiency gains can also be realized within lower speed networks.	Medium
Passenger Hydrail	Alternative Propulsion	Passenger hydrail offers zero operational GHG or air pollutant emissions through the use of compressed hydrogen fuel coupled with a fuel cell stack and batteries. In essence it is a mode of electric traction in which electricity is generated onboard and used to charge batteries which in turn power electric motors. While light passenger hydrail has begun commercial operation in Germany, key barriers include equipment costs due to low production volumes, achieving power output levels required for heavy passenger rail applications, and fuel availability.	Medium

Technology	Category	Description	Readiness Level*
Wired Electrification	Alternative Propulsion	Electrification using overhead catenary lines negates the need for large batteries or other types of energy storage to power electric motors. While this technology has no operational emissions, the carbon intensity of regional electrical grids must be factored into its GHG reduction potential. There are significant cost and geospatial barriers to implementation in a Canadian context.	Medium
Battery Electrification	Alternative Propulsion	Battery electric locomotives, which can operate independent of a continual source of power, are in the early stages of RD&D globally, and are not ready for commercial applications. However the use of battery electric switcher locomotives in railyards is actively being explored globally.	Low
Freight Hydrail	Alternative Propulsion	Freight hydrail utilizes the same suite of technologies as passenger hydrail. Like battery electric trains, the power produced by hydrogen locomotives is currently inadequate to move freight trains the distances required for commercial viability. However switcher locomotive applications are being explored in many jurisdictions including Canada.	Low
Biodiesel	Alternative Fuels	Biodiesel can be produced from a wide variety of plant and animal biomass, but lacks sufficient chemical similarity with petroleum diesel to serve as a drop-in fuel. Due to its chemical properties, the typical blend limit for biodiesel use in diesel locomotives is 5%, and this is even lower in extreme cold weather operations. Higher blends have been tested successfully but are not approved for use by engine manufacturers.	High
Renewable drop-in biofuels	Alternative Fuels	Renewable drop-in biofuels are exchangeable with diesel as they have sufficient chemical similarity with it. They are typically produced through upgrading oils derived from a wide variety of organic feedstocks. They are capable of being used in existing diesel locomotives, either on their own or in blends (although most engine manufacturers limit the blend rate to 30%). The major barrier to their implementation is high fuel costs stemming from a lack of production capacity.	Medium
Compressed and Liquefied Natural Gas	Alternative Fuels	CNG and LNG have been explored as alternative fuels in the rail sector over the past two decades. They can be used in purpose-built spark-ignition natural gas engines or in retrofitted dual fuel diesel engines as blends.	Medium

**For the purposes of this document, technology readiness level refers to a given technology's current ability to contribute to the deep decarbonization of the rail sector from the perspective of both global technological development and the Canadian experience with the technologies. The GHG reduction potential and barriers to the implementation of various technologies will be assessed in Phase 2 of the Pathways Initiative.*

Regarding the five categories of rail decarbonization activity, it should be noted that there can be significant overlap between actions within a given category. For example, infrastructure enhancements can result in enhanced fuel efficiency through reducing the need for braking or idling.

Modal shift is closely related to the infrastructure category, as rail infrastructure significantly impacts the potential timeliness and geographic reach of rail transport. Neither of these categories encompass discrete technologies per se, but are influenced by extraneous factors such as physical geography, pre-existing transportation networks, and public policy. With regard to modal shift, one of the major advantages of on-road trucking relative to rail is the speed and precision with which goods can be delivered. If rail infrastructure is available which allows for shortened delivery timelines, the business case for shipment by rail improves. Further, if rail infrastructure is adequate to allow railway companies to deliver goods as close to their destinations as possible, this will also help to provide an environment in which increased modal shift to rail can occur.

4. Federal, Provincial and Territorial Instruments

Federal, provincial and territorial governments offer a variety of instruments that impact GHG emissions from rail. These include high-level policies; regulations targeting various aspects of railway operations; non-regulatory programs that incent emissions reductions from railway operations or a shift from more emitting modes to rail; and other instruments. These primarily consist of broad, overarching climate change policies and their associated regulations and initiatives that work through multiple avenues to reduce GHG emissions from rail via all five categories described in Section 3.

Key federal, provincial and territorial instruments are summarized here and described at greater length in Appendices B and C.

4.1 Federal Instruments Matrix

Of the federal legislative instruments that are most impactful on GHG emissions reductions from railway operations, only one is specific to the rail sector: the Railway Safety Act's Locomotive Emissions Regulations. While this acts primarily to target criteria air contaminant (CAC) emissions, it aims to reduce GHG emissions largely through idle-reduction measures. Most federal measures target transportation more broadly, or act at an even higher level to address fuels and emissions.

In terms of non-regulatory federal instruments that have an impact on the rail sector's GHG intensity, the 2018 MOU between the Railway Association of Canada and Transport Canada lays out GHG intensity reduction targets of 6% from 2017 levels by 2022 for Class I freight and intercity passenger operations, and reductions of 3% in the same timeframe for short line operations. Progress towards these targets is summarized and made public annually through the Locomotive Emissions Monitoring (LEM) Program.[9]

Transportation-specific policy impacts the rail sector via actions to enhance rail safety standards, support innovation to reduce emissions, and catalyze investment in efficiency within trade corridors through infrastructure funding and modal optimization. Innovation is also supported through non-transportation-specific instruments, such as Sustainable Development Technology Canada's (SDTC's) Sustainable Development Tech Fund.

Overarching policies such as the Pan-Canadian Framework on Clean Growth and Climate Change (PCF, which includes supportive policies such as carbon pricing and the forthcoming Clean Fuel Standard) and the Canadian Environmental Protection Act (CEPA) reduce GHG emissions from the rail sector by driving a shift towards lower emitting fuels and technologies, as well as towards lower emitting types of transportation.

CEPA

The 1999 Canadian Environmental Protection Act spawned the Renewable Fuels Regulations which mandated an average renewable fuel content of 2% in diesel fuel. This will be replaced by the Clean Fuel Standard (CFS) under the PCF by 2022. The CFS will govern GHG emissions from fuel production and combustion by requiring reductions in life-cycle carbon intensity and will further incent a transition away from petroleum-based fuels.

9 Railway Association of Canada. Locomotive Emissions Monitoring. (2018). https://www.railcan.ca/rac-initiatives/locomotive-emissions-monitoring-program/

PCF

The PCF has set out an approach for reducing emissions from the transportation sector, including a commitment for the federal government to "improve efficiency and support fuel switching in the rail sector." The Pathways Roadmap that will be developed in Phase 2 will contribute towards satisfying this commitment. The PCF also included among its four transportation pillars "support the shift from higher to lower-emitting types of transportation, including through investing in infrastructure,"[10] which would include investments in rail infrastructure as described in Section 3.

Carbon pricing is a central component of the PCF that will impact on all of the GHG reduction mechanisms addressed in Section 3 by dis-incentivizing the consumption of petroleum-based fuels. This includes both measures intended to reduce overall fuel use, such as fuel-efficiency, infrastructure and modal-shift related measures; and also measures that promote non-petroleum based fuels including alternative fuels and alternative propulsion. Under the 2018 Greenhouse Gas Pollution Pricing Act, provinces had an opportunity to design and implement their own carbon pricing plans. British Columbia, Québec, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador did so. For those provinces that did not – Alberta, Saskatchewan, Manitoba, Ontario and New Brunswick – the federal fuel charge is in effect.

Table 2: Federal Regulatory and Non-regulatory Instruments

Federal Department/ Organization	Policies	Regulations	Programs	Other
Environment and Climate Change Canada	❖ Pan-Canadian Framework on Clean Growth and Climate Change ❖ Canadian Environmental Protection Act	❖ Clean Fuel Standard ❖ Renewable Fuels Regulations		❖ Greenhouse Gas Pollution Pricing Act (Carbon Pricing) ❖ PCF Initiatives: ▶ Setting emissions standards and improving efficiency ▶ Shifting from higher- to lower-emitting modes and investing in infrastructure
Natural Resources Canada			❖ SmartWay Transport Partnership	
Transport Canada	❖ Transportation 2030: A Strategic Plan for the Future of Transportation in Canada	❖ Locomotive Emissions Regulations (Railway Safety Act)	❖ National Trade Corridors Fund	
Sustainable Development Technology Canada			❖ Sustainable Development Tech Fund	

10 https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework/complementary-actions-reduce-emissions.html#3_3

4.2 Provincial and Territorial Instruments Matrix

Similar to the federal landscape, most provincial and territorial instruments that impact GHG reductions from the rail sector are not rail specific, or even transportation-specific, but more broadly address climate change. These include climate change strategies, carbon pricing, and renewable and clean fuel standards. Together with the associated regulations and programs, these policies work to shift the transportation sector, including the rail industry, towards lower emitting fuels and technologies in much the same way that the CEPA and PCF do, as outlined in Section 4.1.

Québec and British Columbia have been the most active in addressing GHG reductions from transportation through targeted policies and programs. Québec in particular is directly supporting both the development and uptake of low-carbon technologies, fuels and infrastructure in the transportation sector, along with a modal shift to rail through a number of initiatives, outlined in Table 3, below, and further described in Appendix C. BC is taking a broader, non-sectoral view of GHG reductions through its CleanBC strategy and addressing rail efficiency specifically in the context of trade corridors (including ports).

Table 3: Provincial and Territorial Regulatory and Non-regulatory Instruments

Province	Policies	Regulations	Programs	Other
BC	❖ Carbon Target ❖ CleanBC ❖ B.C. on the Move: A 10-Year Transportation Plan (2015)	❖ Renewable & Low Carbon Fuel Requirements Regulation	❖ Trade Corridors Initiative	❖ Carbon Tax
AB	❖ Transportation Business Plan 2019–23	❖ Renewable Fuel Standard		
SK	❖ Climate Change Strategy			
MB	❖ Climate and Green Plan Implementation Act	❖ Clean Fuel Standard		
ON	❖ Environmental Protection Act	❖ O. Reg. 97/14: Greener Diesel Regulation		
QC		❖ Renewable Fuel Standard	❖ Electrification and Climate Change Fund ❖ Marine, Air and Rail Transportation Efficiency Assistance Program (PETMAF) ❖ Greenhouse Gas Emissions Reduction / Avoidance Program through Intermodal Transportation Development (PREGTI) ❖ Technoclimat	
NB				
NS				❖ Cap and Trade Program
PE				
NL				
YK				
NWT			❖ GHG Grant Program for Buildings and Industry	❖ Carbon Tax

5. Canadian Research, Development and Demonstration Activities

Research, Development and Demonstration, or RD&D, facilitates the determination of achievable GHG reduction levels for the rail sector and the identification of actions and policies that will help the sector contribute to broader decarbonization efforts and targets.

Canada's federal, provincial and territorial governments conduct rail RD&D initiatives to support continual improvement in terms of environmental performance while ensuring the sector's continued economic competitiveness. Within Canada there also exists a robust ecosystem of organizations and bodies that explore and address the environmental performance of the nation's rail sector. These include the Railway Association of Canada (RAC), Transport Canada's Innovation Centre, the Rail Research Advisory Board of Canada (RRAB), and, in a limited capacity, the Canadian Rail Research Laboratory (CaRRL).

Direct support for RD&D initiatives in Canada takes place predominantly at the federal level. Much of this support is not aimed specifically at the rail sector, but at transportation decarbonization efforts broadly. Provincial support for RD&D, where applicable, tends to happen through non-regulatory programs (Section 4.2) and partnerships rather than being led directly by government. Provincial engagement on efforts related to transportation decarbonization also tends not to be aimed specifically at the rail sector, but at either the movement of freight or people.

Although the federal government and several provinces have identified shifting to higher efficiency modes such as rail as an effective means to reduce GHG emissions, there is little RD&D occurring focused on assessing and quantifying the GHG reduction potential of modal shifts to rail for the movement of goods and people. Increased engagement in this area could help to situate rail transport more concretely into climate-related plans, targets and programming, and could help to provide guidance on funding priorities to reduce the carbon intensity of the transportation sector.

Table 4: Canadian RD&D Initiatives Related to Rail Decarbonization

Department, Jurisdiction	Fuel Efficiency	Alternative Fuels	Alternative Propulsion	Infrastructure	Modal Shift
Transport Canada (TC)	Transport Canada Innovation Centre (TCIC)				
	Rail Research Advisory Board of Canada (RRAB)				
	Clean Transportation System - Research and Development Program (CTS-RD)				
	MOU between TC and the RAC for Reducing Locomotive Emissions				
		Higher-Concentration-Blend Lignin-Derived Diesel Fuels for Rail Applications (partnership between TCIC and NRCan's CanmetENERGY)	Electrification of the Freight Rail Sector in Canada: Review of the Feasibility, Costs and Benefits	Canadian Rail Research Laboratory (consortium led by TC)	
			Hydrail Switcher Locomotive Project (partnership between TCIC and ECCC)		
Natural Resources Canada (NRCan)		Economic and Environmental Benefits of Natural Gas Fuel for the Rail Sector in Canada			Modal Optimization as a Contributor to Reducing GHG Emissions in Canada
		Evaluation of Liquefied Natural Gas Infrastructure Build-up for Supplying Fuel to the Rail Market in Canada			
Sustainable Development Technology Canada (SDTC)	Sustainable Development Tech Fund				
	Energy Efficient Transit Propulsion Pilot Program Project				
Ontario Ministry of Transportation			High Speed Rail in Ontario: Report by the Special Advisor for High Speed Rail		
Metrolinx (Ontario)	Tier 4 locomotives				
	Throttle Control Program				
	Excess Idle Reduction				
Canadian Urban Transit Research and Innovation Consortium (CUTRIC)	National Rail Innovation Initiative (partnership with TCIC)				
Government of British Columbia (with industry and academic partners)		The British Columbia Sustainable Marine, Aviation, Rail and Trucking (BC-SMART) Biofuels Consortium			
TransPod			TransPod Hyperloop		

6. Canadian Rail Industry Activities

Canada's freight rail industry is dominated by two Class 1 freight rail companies, Canadian National Railway (CN) and Canadian Pacific Railway (CP). CN and CP represent more than 95% of Canada's annual rail tonne-kilometres and more than 75% of the nation's tracks.[11] There are also numerous shortline and regional railways in operation throughout the country. Shortline railways feed traffic to and from the mainlines, and regional railways provide local service in areas that are not serviced by the mainline railways.

VIA Rail Canada is Canada's dominant intercity rail passenger service operator. Commuter rail service is provided by TransLink in Metro Vancouver, GO Transit in the Greater Toronto and Hamilton Area, and exo in the Greater Montreal Area.

Rail industry GHG reduction activities are summarized here and described at greater length in Appendix E.

Canada's Class 1 railways, both freight and passenger, have been active in the fuel efficiency space for well over two decades,[12] implementing strategies to enhance operating practices and employing fuel saving technologies such as telemetry, energy and route management software, and distributed power. Fleet renewal has included both refurbishment of existing locomotives and railcars, and the purchase of more fuel efficient trains, including Tier 4 locomotives[13] and new generation railcars.

In the past decade, technology has changed across the transportation sector at a rapid pace, with new innovations such as electric and hydrogen cars, buses, and medium-duty trucks gaining market share. This change is likely to accelerate if climate change mitigation continues to be a priority for industry and government.

In line with this broader shift, emission reduction measures in the rail sector have expanded beyond fuel efficiency. Alternative fuels have been and continue to be explored. Testing of renewable fuels has occurred, though the scope of these efforts has been limited by engine manufacturers, as some warrantees only cover use of blends of up to 5% for biodiesel and 30% for renewable diesel. One LNG demonstration project was also undertaken.

More recently, these activities have broadened to include alternative propulsion. Uptake of alternative propulsion technology has largely been limited to corporate fleet vehicles, though there is indication of interest in testing rail-based electric and hydrogen technologies. While most regional and shortline railways have been less active in pursuing GHG reduction initiatives, there are a few exceptions as noted in the table below.

11 Transport Canada https://www.tc.gc.ca/eng/policy/anre-menu-3020.htm

12 TC and RAC signed the first MOU to establish voluntary reduction targets for emissions produced by locomotives in Canada in 1995, and since then have signed three additional MOUs on this issue. Emissions from locomotives have been gradually falling since 1995.

13 While Tier 4 emissions standards are focused on reducing criteria air contaminant (CAC) emissions, Tier 4 locomotives also improve fuel efficiency. (https://www.aar.org/article/new-locomotive-technology-makes-freight-rail-more-efficient-environmentally-friendly/)

Table 5: Canadian Rail Industry Activities

Company	Fuel Efficiency	Alternative Fuels	Alternative Propulsion	Infrastructure	Modal Shift
MAINLINE FREIGHT					
CN	❖ Fuel saving technologies: ▶ Trip optimization ▶ Distributed power ❖ Fleet Renewal: ▶ Tier 4 locomotives ❖ Data collection to improve performance and fuel conservation: ▶ Horsepower Tonnage Analyzer (HPTA) ❖ Enhanced operating practices: ▶ Precision Scheduled Railroading	❖ Use of biodiesel blends ❖ LNG demonstration project: ▶ Retrofit of two 3,000-horsepower locomotives with engines that run on a fuel mix of 90-per-cent liquefied natural gas and 10-per-cent diesel.	❖ Investment in hybrid and electric vehicles	❖ Fleet Renewal: ▶ New-generation railcars	❖ Providing low carbon transportation and logistics solutions to customers
	❖ Investments in rail infrastructure, network fluidity and efficiency			❖ Double-tracking into the Port of Vancouver	
CP	❖ Fuel saving technologies: ▶ Trip optimization ▶ Automatic engine start stop systems ❖ Enhanced operating practices: ▶ Precision Scheduled Railroading	❖ Use of biofuel blends		❖ Fleet renewal: ▶ 8,500-foot High Efficiency Product Trains (HEP) ▶ Locomotive Modernization Program – upgrades to locomotive fleet	❖ Deployment of CP Fast Pass Technology
REGIONAL AND SHORTLINE					
Southern Railway of British Columbia (SRY)			❖ Supporting UBC research on hydrogen-fueled and battery hybrid switching locomotives		

Company	Fuel Efficiency	Alternative Fuels	Alternative Propulsion	Infrastructure	Modal Shift
Quebec North Shore & Labrador Railway (QNS&L)	❖ Anti-idling devices installed on four locomotives				
PASSENGER					
VIA Rail	❖ Enhanced operating practices: ▶ Locomotive Engineer Scorecard including mapping optimal operating parameters, use of telemetry and simulator training to improve fuel efficiency ▶ Optimization of cycling, including deployment of most fuel efficient engines on most demanding routes ▶ Idle reduction policy, including no idling in yards ❖ Fleet renewal: ▶ Tier 4 locomotives with electrified rail functionality ▶ Fleet refurbishment of older F-40 locomotives with separate HEP engine ▶ Replacement of electrical systems in cars with more efficient options	❖ Use of Biodiesel (B5) ❖ Test of B20 on one engine	❖ Green strategy for fleet vehicle replacement: zero-emissions vehicles ❖ Future initiatives that are being explored include electrification		❖ Promotion of rail over less efficient modes ❖ Intermodal partnerships

7. Literature Review: State of GHG Emissions Reduction Technology and International Best Practice

7.1 State of GHG Emissions Reduction Technology and Practices

When considering Canadian initiatives in the context of global rail sector GHG reduction initiatives, it is critical to be cognizant of geographic, climatic and demographic realities that make Canada unique on the global stage. Canada's massive size, rugged Rocky Mountain topography, harsh winters, low population density, and natural resource-based economy mean that low-carbon rail solutions being tested and implemented elsewhere may not be feasible here. While these factors may not preclude Canadian adoption of certain global practices and technologies, they may increase both the complexity and cost. A review of global trends nonetheless provides useful insights into potential areas for Canadian engagement. Likewise, Canadian initiatives may contribute to the evolution of global rail decarbonization efforts.

In recent years, the Government of Canada has led several national assessments focused on determining the technological readiness, environmental performance and costs of alternative fuels and propulsion technologies for both passenger and freight rail. These assessments, which are overviewed in Appendix D, have looked at both alternative fuels and alternative propulsion technologies: liquefied natural gas, biodiesel, renewable diesel, as well as electric and hydrogen-powered propulsion. This is largely consistent with fuels and technologies being examined outside of Canada as strong candidates to replace or reduce the use of diesel in the rail sector. Additional alternative fuels being assessed outside of Canada (primarily in the USA) include dimethyl ether (DME) and compressed natural gas (CNG). Canada's Renewable Fuels Regulations already require that all diesel fuel used south of 60°N latitude contain at least 2% renewable content. The Regulations will be replaced by the Clean Fuel Standard (CFS) in the near future, which will require increasingly higher blends of renewable content or shifts to other fuels.

Many global jurisdictions are pursuing the expansion of passenger and freight rail networks to reduce the carbon intensity of their transportation sectors and the number of cars and trucks on their roads.[14] The UK is targeting a diesel-free rail network by 2040, as part of its broader efforts to completely decarbonize its transportation sector by 2050. It is also aiming to significantly enhance rail's modal share for both passenger and freight movement through the construction of a high speed rail network connecting cities and regions where most freight and passenger movement is currently confined to trucks and cars. Germany is likewise pursuing an increase in freight modal share for its rail sector through its Freight Rail Masterplan and a series of related, targeted initiatives which delve into policy and economic measures as well as technological innovations. France and Russia have a long history of low-carbon national rail networks which leverage domestic energy sources, and both are currently in the process of major rail modernization efforts. China and India have prioritized the expansion of existing electric rail networks to facilitate the movement of their massive populations and reduce the carbon intensity of their transportation and industrial

14 See Appendix F for details on recent rail initiatives in global jurisdictions.

sectors. Trends like these allude to the fact that many national governments foresee an expanded role for rail in the decades ahead, having determined that it provides a low-carbon and cost-effective alternative to other modal options such as on-road transport and aviation. A key facilitator of increased modal shift to rail globally has been the expansion of high speed rail networks – a mechanism that may be worth exploring for certain regions of Canada with high rail traffic volumes.

A common challenge for rail networks throughout the world, especially in the face of increased modal shifts to the sector, is allocating an appropriate amount of rail infrastructure to accommodate high speed passenger rail while ensuring it does not conflict with the delivery of time-sensitive freight. Common measures being taken to address this globally include the construction of dedicated tracks and infrastructure for high speed rail lines, tunnels and bridges to minimize road crossings, and physical barriers to keep people, animals and other obstructions off of tracks. Double-tracking is a common measure globally to minimize delays and idling, providing right-of-way to high speed and/or time-sensitive trains and facilitating the bi-directional flow of rail traffic. This measure is becoming more common in Canada and is rolling out along busy stretches of its Class 1 railroads.[15] It can be complemented by the addition of sidings and loops, which also serve to mitigate downtime and create more efficient networks. While these measures help rail traffic flow more smoothly, spur construction can also be used to help rail access more destinations directly, thereby expanding its potential role in the movement of goods and passengers.

While foundational infrastructure like that referenced above is essential and should not be overlooked in terms of its direct and indirect GHG reduction potential, cloud-based and "smart" infrastructure is uniformly playing a bigger role in rail logistics around the world. Software related to fuel and energy management systems, route and speed optimization, and cargo and container optimization are leading to trains and rail networks that are increasingly autonomous and interconnected. As transport hubs continue to grow spatially and with regard to the volume of goods and passengers transported, software, big data and connectivity will allow the rail sector to play a bigger role in multi-modal transport systems around the world.

A comparable scope of measures are being taken in Canada and globally related to rail fuel efficiency. Engine and drivetrain upgrades, hybridization, lightweighting, energy management software, friction reduction and wheel-track lubrication, eco driving practices, higher capacity freight cars and even enhanced coupling systems and aerodynamics are being explored in multiple jurisdictions to yield incremental efficiency benefits. Numerous studies, consultations and demonstrations have recently been conducted within Canada (Appendices D and E) and globally (Appendix F) that focus on efficiency and operational measures to reduce the carbon footprint of rail transport. Global organizations such as the International Union of Railways (UIC), Union Of European Railway Industries (UNIFE), European Commission (EC), The European Rail Research Advisory Council (ERRAC), The Community of European Railway and Infrastructure Companies (CER), the Australasian Railway Association (ARA), Association of American Railroads (AAR), Federal Railroad Administration (FRA), and California Air Resources Board (CARB) have all conducted work and promoted measures related to efficiency enhancements to rail operations. Harmonized regulations and standards, enhancing rail interoperability across jurisdictional boundaries,

15 Trains Magazine. CN envisions slowly double-tracking main line from Edmonton to Winnipeg. (2018). (https://trn.trains.com/news/news-wire/2018/07/25-cn-envisions-slowly-double-tracking-main-line-from-edmonton-to-winnipeg)

and improving access to intermodal transport hubs can also indirectly serve to enhance efficiency and the environmental performance of rail operations.[16] In Canada, a key focus of recent industry-led decarbonization activities (Appendix E) has been fuel efficiency enhancements to further improve rail's carbon intensity advantage over on-road shipping. These efforts primarily revolve around fleet renewal and retrofitting using higher efficiency engines, and the implementation of software that optimizes energy, routes, and scheduling to reduce fuel consumption and time spent idling. These voluntary fuel efficiency efforts are in some cases expected to lead to fleet-wide GHG emissions reductions in excess of 20%.

The table below provides a high-level glimpse into recent global initiatives related to rail sector decarbonization. For further information on these and additional initiatives please refer to Appendix F.

Table 6: International Rail GHG Emissions Reduction Activities

Country	Fuel Efficiency	Alternative Fuels	Alternative Propulsion	Infrastructure	Modal Shift
USA	AAR - Transportation Technology Center		AAR - Transportation Technology Center		
	Wabtec - Sustainability improvements		BNSF - Battery electric high-horsepower freight locomotive prototype		
	CARB - Technology Assessment: Freight Locomotives				
			Norfolk Southern - 999 battery electric switcher locomotive		
			Port of Los Angeles - Zero-Emission Track-Miles Locomotive Project		
Germany			Alstom - Coradia iLint Hydrogen Powered Train		
	Rail Freight Masterplan				
UK		National Rail - High Speed 1 (HS1)			
		National Rail - High Speed 2 (HS2)			
	Decarbonising Transport: Setting the Challenge				
France			RATP - Battery-overhead electric maintenance locomotives		
Japan	The Association of Japanese Private Railways – Commitment to a Low Carbon Society				
Russia			Electrification program: Trans-Siberian Railway		

16 See Appendix E for information on specific initiatives led by these groups.

Country	Fuel Efficiency	Alternative Fuels	Alternative Propulsion	Infrastructure	Modal Shift
China			Rail and transport hub electrification		
India			Broad gauge rail network electrification		
EU	UNIFE - RAILENERGY				
	ERRAC - Rail 2050 Vision				
	UIC and EC - CAPACITY4RAIL				
	EC - SHIFT2RAIL EC - White Paper: Roadmap to a Single European Transport Area				
	ERRAC - Rail 2050 Vision				
	CER and UIC - Moving Towards Sustainable Mobility				
Global	UIC - Energy Efficiency Best Practice Workshops			UIC - Door to Door	

7.2 International Roadmapping Initiatives

While initiatives addressing the environmental performance of rail operations are many and varied, comprehensive rail decarbonization roadmapping exercises are not. A review of global literature revealed only three recent examples of such exercises: Germany's Rail Freight Masterplan, the UK's Decarbonising Transport: Setting the Challenge, and The European Rail Research Advisory Council's (ERRAC) *Rail 2050 Vision*.[17]

Germany's Rail Freight Masterplan aims to increase the competitiveness and market share of rail freight transport while improving environmental performance. These efforts will ensure that the German freight rail sector is future-proofed and sustainable. The Masterplan contains discrete milestones for different elements of the freight rail network categorized under the following themes: infrastructure, digitalization, automation, innovative technologies (e.g., electric locomotives with batteries for wire-free last mile travel capabilities), multimodality enhancement, electric haulage expansion, reductions in infrastructure charges (i.e., charges for track access and service facilities – key inhibitors of increased rail freight transport), reducing the levy and tax burden on freight carriers, ensuring that labour, social and safety standards are harmonized across all transport modes, and improved employee training and professional development. Germany's current coalition government has committed to electrifying 70% of the freight rail network by 2025. It has also committed to additional measures, some of which are put forward in the Masterplan, to enhance the rail's share of domestic freight movement. While the Masterplan does not include any sector-specific targets for emissions reductions, it does stress that a low-carbon freight transport sector will help to achieve national targets. It also suggests potential perks for rail companies that use low-emissions technologies, such as preferential access to certain multimodal hubs.

While it lacks an exclusive focus on the rail sector, the UK's Decarbonising Transport: Setting the Challenge roadmap addresses rail in detail. This pan-modal initiative is actually a precursor to a more fulsome transportation roadmap – The Transport Decarbonisaton Plan (TDP) – which is currently under development. Setting the Challenge states that the primary means to decarbonize rail is through government intervention to expand electrification. TDP measures will also be informed by an industry-led effort which will provide information on the possible scale and pace of decarbonization out to 2050, the government-mandated timeline for net zero carbon transportation. The UK government recently issued a challenge to its rail sector to develop a pathway to eliminate the use of diesel-only trains by 2040. Subsequent industry recommendations were focused on increased electrification using overhead wires for freight, complemented by hydrogen and battery electric trains for passenger transport. It was stated that current hydrogen and battery powered trains lacked sufficient power for freight haulage.

The European Rail Research Advisory Council (ERRAC) released its Rail 2050 Vision roadmap in 2017. The Vision highlights the critical roles that rail plays in Europe's current and future economy and sustainability efforts, as well as key challenges (e.g., climate change) and opportunities (e.g., the creation of a Single European Rail Area (SERA), smart and low-carbon transport technologies). It states that rail is to "become the backbone of an intermodal 'Mobility as a Service' for passengers and 'Delivery as a Service' for goods" throughout Europe. The vision touts rail as both the safest and greenest mode of transport and discusses the many potential synergies between rail and increasingly digitalized, data-

17 For further information and links to the original documents please refer to Appendix F.

driven economies as well as smart technologies and cities. The technology-driven Vision looks beyond low-carbon fuels and propulsion and foresees the decarbonization of entire supply chains – not only within the rail sector but for the goods shipped by the rail sector. It envisions a role for trains not only in the movement of goods and people, but for electricity distributed by means such as dynamic wireless power transfer. It foresees automated, connected train operations, robotics, lightweight materials, and smart infrastructure playing major roles in improving rail efficiency. Being based in Europe, ERRAC sees rail becoming the default mode of transport for people within cities and for trips up to 1,000 km. To achieve these goals ERRAC calls for a seamless European rail research and innovation system, increased cooperation within the rail sector and between rail and other transport modes, and increased contributions from experts outside of the transportation sector.

8. Conclusion and Next Steps

Phase 1 has developed a comprehensive landscape document that includes: regulatory and non-regulatory instruments that support GHG emissions reductions from the rail sector; and activities on the part of government and industry to both study and implement GHG emissions reductions in five areas: fuel efficiency, alternative fuels, alternative propulsion, infrastructure and modal shift.

Phase 2 will use this landscape document to inform the development of a roadmap towards deeper GHG reductions. It will continue to involve federal and industry stakeholders and will further engage provincial governments to collaborate on the development of a common vision and path forward, including setting priorities for the near, medium and longer term.

Appendix A – Steering Committee Members

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Appendix B – Federal, Provincial and Territorial Legislation Related to GHG Reductions from Rail

Department	Legislation	Regulation	Year	Description	Relevance (High, Medium, Low)	Links
Alberta Ministry of Environment and Parks	Emissions Management and Climate Resilience Act	Renewable Fuels Standard Regulation	2010	The RFS requires a minimum annual average of 5% renewable alcohol in gasoline and 2% renewable diesel in diesel fuel sold in Alberta by fuel suppliers.	High - will encourage development and uptake of low carbon technologies in transportation sector	Link 1 Link 2
BC Ministry of Environment & Climate Change Strategy	Climate Change Accountability Act		2007	Targets a 40% economy-wide GHG reduction from 2007 levels by 2030, a 60% reduction by 2040, and an 80% by 2050.	Medium - will encourage development and uptake of low carbon technologies in the transportation sector.	Link 1
	Carbon Tax Act	Carbon Tax Regulation	2008	Tax is currently $40 per tonne on fossil fuels (gasoline, natural gas and diesel). To be increased to $45 in September 2020, and to $50 in April, 2021.	High - this directly impacts rail companies (though currently only large industrial emitters can access funding based on revenues).	Link 1 Link 2
	Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act	Renewable & Low Carbon Fuel Requirements Regulation	2008	The previous regulation required fuel suppliers to decrease the average carbon intensity of their fuels by 10% by 2020. The updated regulation requires a 20% decrease by 2030.	High - will encourage development and uptake of low carbon technologies in the transportation sector.	Link 1 Link 2
Environment and Climate Change Canada	Canadian Environmental Protection Act	Renewable Fuels Regulations	2013	These regulations require petroleum producers and importers to have an average of 5% renewable fuel content in gasoline and 2% renewable fuel content in diesel fuel and heating distillate oil based on volume. There is a system that can be utilized to trade renewable fuel compliance units. Will be replaced with Clean Fuel Standard in the near future.	High – renewable fuels are low-carbon relative to diesel, with the potential of being zero carbon.	Link 1 Link 2

Department	Legislation	Regulation	Year	Description	Relevance (High, Medium, Low)	Links
Environment and Climate Change Canada	Greenhouse Gas Pollution Pricing Act	Output-Based Pricing System Regulations	2019	An Act to mitigate climate change through the pan-Canadian application of pricing mechanisms to a broad set of greenhouse gas emission sources and to make consequential amendments to other Acts. The regulations cover reporting requirements for facilities that produce hydrogen, as well as carbon intensity standards for hydrogen produced via SMR and hydrogen used in various industrial applications. As part of the Pan-Canadian Framework on Clean Growth and Climate Change, carbon pricing is central to Canada's plan to meet our emissions reductions targets. The federal carbon pollution pricing system applies in provinces and territories that request it or that do not have a system that meets the federal stringency requirements. The federal carbon pollution pricing system consists of an output-based pricing system for large emitters and a regulatory charge on fossil fuels ("fuel charge"). The fuel charge applies to a broad range of fuels, including light fuel oil (e.g., diesel) used in locomotives in backstop jurisdictions. The federal fuel charge currently applies in Alberta, Saskatchewan, Manitoba, Ontario, Yukon and Nunavut.	High—incentivizes lower GHG emissions throughout supply chain, including fuel switching to lower carbon fuels.	Link 1 Link 2

Department	Legislation	Regulation	Year	Description	Relevance (High, Medium, Low)	Links
Environment and Climate Change Canada	Clean Fuel Standard (proposed)		TBD	The objective of the Clean Fuel Standard is to achieve up to 30 million tonnes of annual reductions in greenhouse gas emissions by 2030, making it an important contribution to the achievement of Canada's target of reducing national emissions by 30% below 2005 levels by 2030. The CFS will be a performance-based approach designed to incent the innovation and adoption of clean technologies in the oil and gas sector and the development and use of low-carbon fuels throughout the economy. The Clean Fuel Standard regulations will cover all fossil fuels used in Canada, but will set separate requirements for liquid, gaseous and solid fossil fuels. It is being developed in a phased approach, with liquid fuel class regulations being developed first followed by gaseous and solid fuel class regulations. Publication of the draft liquid class regulation is expected in Canada Gazette, Part I, in fall 2020, with a final publication in 2021. The first year of required reductions in carbon intensity of fuel would be 2022.	High — Rail operators who import diesel fuel into Canada would be subject to requirements to reduce the carbon intensity of those fuels. The CFS will result in the diesel pool for rail having a lower carbon intensity (e.g. reduced upstream emissions) and increasingly higher blends of renewable content. Rail operators could also electrify their transportation fleet and create CFS credits for compliance or sale into the credit market, or could purchasing CFS credits from others. It may also incent fuel switching for locomotives.	Link 1
Manitoba Department of Conservation and Climate	The Climate and Green Plan Act	Clean Fuel Standards	2020	Manitoba will increase the ethanol content requirement of gasoline to 10% from 8.5%, and the biodiesel content of diesel to 5% from 2% - pending consultations. These numbers represent the highest renewable fuel content requirements in Canada.	High - will encourage development and uptake of low carbon technologies in transportation sector	Link 1

Department	Legislation	Regulation	Year	Description	Relevance (High, Medium, Low)	Links
Northwest Territories Department of Finance	Petroleum Products and Carbon Tax Act		2019	Rates for diesel will be $0.082/L as of July 2020, rising to $0.137/L by 2022. Applicable on fuel sold in NWT.	Low - based on low levels of fuel consumption by the rail sector in this region.	Link 1 Link 2
Nova Scotia Environment	Environment Act	Cap-and-Trade Program Regulations	2018	2020 price is $20 per emission allowance, but that will increase by 5% plus inflation annually. Revenue from program will be reinvested into climate change initiatives	High - Incentivizes lower GHG emissions throughout supply chain, including fuel switching to lower carbon fuels. Program revenues may be available for transportation RD&D.	Link 1 Link 2
Ontario Ministry of Environment, Conservation and Parks	Environmental Protection Act	Greener Diesel Regulation (O. Reg. 97/14)	2015	Ontario has set minimums for the amount of bio-based diesel in the diesel fuel distributed, used, and/or sold in Ontario. As of 2017, 4% of the total volume of diesel fuel must be bio-based. The bio-based diesel component of this blend must have 70% lower greenhouse gas emissions than standard petroleum diesel.	High - will encourage development and uptake of low carbon technologies in transportation sector	Link 1 Link 2
Québec Ministry of the Environment and the Fight Against Climate Change	Bill 44 - An Act mainly to ensure effective governance of the fight against climate change and to promote electrification		2019	The fight against climate change includes all measures to reduce, limit or prevent GHG emissions, in particular by electrification, to remove GHGs from the atmosphere, to mitigate the economic and social consequences of such measures and to promote adaptation to the impacts of global warming and climate change, as well as Québec's participation in regional or international partnerships in these areas and the development of such partnerships. The Minister shall ensure the coherence and coordination of policies, action plans, programs, consultation processes and other measures of the Government that concern the fight against climate		

Department	Legislation	Regulation	Year	Description	Relevance (High, Medium, Low)	Links
				change and shall be involved in their preparation. Each minister or public body concerned continues to be responsible for choosing and implementing the means to achieve the results. The Minister must be consulted when measures that could have a significant impact in the fight against climate change are developed. The Minister shall give the other ministers and the public bodies any opinion they considers appropriate to promote the fight against climate change, in particular when a proposed measure does not, in their opinion, comply with the principles and objectives set out in the climate change framework policy provided for in section 46.3 of the Environment Quality Act (chapter Q-2) or with the GHG reduction or limitation targets set under section 46.4 of that Act, and may recommend to them the adjustments required to ensure such compliance.	Medium – Act includes nothing specific to rail sector yet applies to all modes of transport. The Minister must approve all monetary transfers to the Land Transportation Network Fund, which supports programs aimed at providing low-carbon shared mobility options (including passenger rail) in Québec.	Link 1 Link 2
Québec Ministry of the Environment and the Fight Against Climate Change	Petroleum Products Act	Minimum volume of renewable fuel in gasoline and diesel fuel (proposed)	2019	The Regulation sets standards for the integration of renewable fuels into gasoline and diesel fuel. As of July 2021, 2% minimum bio-based diesel fuel (annual average blend) is required, increasing to 4% in 2025.	High - will encourage development and uptake of low carbon technologies and fuels in transportation sector	Link 1
Transport Canada	Railway Safety Act	Locomotive Emissions Regulations	2017	To reduce CAC emissions, the Locomotive Emissions Regulations require federal railway companies to: meet emissions standards set out for new locomotives, carry out emissions testing, follow labelling and anti-idling requirements, keep records, file reports with Transport Canada.	Medium – the Locomotive Emissions Regulations do not explicitly apply to GHGs, yet actions to limit certain CAC emissions are likely to have positive impacts on GHG emissions	Link 1 Link 2

Appendix C – Federal, Provincial and Territorial Non-regulatory Programs Related to GHG Reductions from Rail

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
Alberta Ministry of Transportation	Transportation Business Plan 2019–23	2019 - 2023	Outcomes and objectives that could impact rail sector include: Outcome #1: Competitiveness, Market Access and Economic Growth: Alberta has a safe and efficient multi-modal transportation system that supports the economy. Key objectives: Implementing transportation initiatives that promote economic growth, and supporting opportunities in multiple sectors. None of the plan's initiatives supporting key objectives focus on rail. Outcome #6: Environmental Stewardship: Alberta has a transportation system that is managed in an environmentally responsible and sustainable manner. Key objectives: Advancing clean transportation technologies to support environmental stewardship and economic development; investigating opportunities and partnerships to develop public transportation systems through grant funding programs that support more sustainable, energy-efficient forms of transportation.	Low - no explicit focus on rail but outcomes/objectives are somewhat relevant	Link 1
BC Ministry of Energy, Mines and Petroleum Resources (in collaboration with industry and academic stakeholders)	The British Columbia Sustainable Marine, Aviation, Rail and Trucking (BC-SMART) Biofuels Consortium	2018 - ongoing	Encourages the production and use of low carbon intensity drop-in biofuels for long-distance transport to support CleanBC targets. Consortium states that: "While electrification and other technologies can decarbonise urban transport, they are not viable short-term (2030-horizon) options for long-distance transport sectors. Marine, aviation, rail and long-distance trucking require sector-compatible, low carbon intensity renewable fuels."	Medium – focus is on decarbonizing freight transport, however the exclusive area of focus is drop-in biofuels	Link 1

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
BC Ministry of Environment & Climate Change Strategy	CleanBC	2018 - 2030	The CleanBC plan outlines the province's overarching climate strategy. It provides a blueprint for reducing GHG emissions and fostering sustainable development and economic growth. Priority areas for the transportation sector are: cleaner fuels, cleaner vehicles and more support for measures that get people out of their cars.	Medium – a blueprint document to outline actions that will lead to achievement of provincial climate targets (no actions specific to rail sector)	Link 1
BC Ministry of Transportation and Infrastructure	Trade Corridors Initiative	2019 - ongoing	As containerized traffic increases, the Initiative is increasing safety and efficiency through partnerships and focused investments. Examples of rail-related programs supported are: enhancing container capacity at shipping ports and adding road underpasses to reduce the number of level road-rail crossings.	High - addresses rail efficiency specifically	Link 1
	B.C. on the Move: A 10-Year Transportation Plan (2015)	2015 - 2025	This plan sets out 12 priorities that will be key to BC's transportation investments and strategic policy actions from 2015 to 2025. One of the priorities has relevance for efforts to reduce emissions from freight: Enabling Efficient Ports and Rail: Invest in infrastructure that enhances efficiency of goods movement by rail. The Province will work with private sector partners to explore road/rail grade separations on key trade corridors to support the efficient movement of goods by rail. Multi-modal corridor analysis of infrastructure will be carried out, so growing trade from resource sectors can move efficiently through the Pacific Gateway. The plan states that safeguarding the environment and taking measures to reduce environmental impacts is a key priority in all of the projects and programs that are delivered to improve transportation. However, there is no discussion regarding the GHG emissions of increased freight activity by rail or GHG reduction measures specific to the rail sector.	Low – no focus on reducing GHG emissions from rail, however activities within scope may serve to enhance rail fuel efficiency	Link 1

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
Environment and Climate Change Canada	Pan-Canadian Framework on Clean Growth and Climate Change (PCF)	2016 - 2030	The Framework is Canada's plan to meet its emissions reduction targets, grow the economy, and build resilience to a changing climate. The plan includes a pan-Canadian approach to pricing carbon pollution, and measures to achieve reductions across all sectors of the economy. It aims to drive innovation and growth by increasing technology development and adoption to ensure Canadian businesses are competitive in the global low-carbon economy. It also includes actions to advance climate change adaptation and build resilience to climate impacts across the country. There are four areas for action related to rail emissions identified in the PCF [relevant areas included as separate rows below].	High – will encourage development and uptake of low carbon technologies in transportation sector	Link 1
	Setting emissions standards and improving efficiency (PCF)	2016 - 2030	Includes standards for: increasingly stringent emissions requirements for LDVs and HDVs, fuel-efficient tires, HDV fuel-saving devices (e.g., aero), fuel switching in the rail, aviation, marine and off-road sectors.	High – will encourage development and uptake of low carbon technologies and fuels in transportation sector	Link 1
	Shifting from higher- to lower-emitting modes and investing in infrastructure (PCF)	2016 - 2030	Work with other levels of government to enhance investments in public transit upgrades and expansions. Build more efficient trade and transportation corridors including investments in transportation hubs and ports. Consider opportunities with the private sector to support refueling stations for alternative fuels for LDVs and HDVs, including natural gas, electricity and hydrogen.	High – will encourage development and uptake of low carbon technologies, fuels and infrastructure in transportation sector	Link 1
	Using cleaner fuels (PCF)	2016 - 2030	Develop a Clean Fuel Standard to reduce emissions from fuels used in transportation, buildings and industry.	High – see "Clean Fuel Standard" in Appendix B	Link 1
	Low Carbon Economy Fund (PCF)	2016 - 2030	The $2 billion Fund supports the PCF by leveraging funding in projects that will: generate clean growth, reduce GHG emissions, and help to meet or exceed Canada's Paris Agreement commitments. The Fund has two components: the Low Carbon Economy Leadership Fund ($1.5B in funding for provinces and territories that have adopted the PCF) and the Low Carbon Economy Challenge ($500M in funding for innovative private sector projects that reduce emissions and generate clean growth).	High – will encourage development and uptake of low carbon technologies, fuels and infrastructure in transportation sector	Link 1

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
Government of Saskatchewan (GOS)	Implementation of the GOS climate change strategy	2017 - ongoing	In 2017, the GOS released its overarching Prairie Resilience climate change strategy. This strategy recognizes the importance of the transportation sector to our province and also identifies the need to work towards greater efficiency and lower emissions. Specifically, the strategy commits to continue to support industry in expanding the size and usage of the short haul (short line) rail systems.	Low – The GOS is currently developing a baseline utilization of the short line railway industry in SK. The GOS is also working to identify ways to either directly or indirectly encourage modal shift from truck to rail in situations where the shift will result in reduction in overall GHG emissions.	Link 1
Natural Resources Canada / US EPA, freight carriers, logistics companies, truck carriers, multimodal carriers	SmartWay Transport Partnership	Canada / 2012-ongoing	A voluntary, North America-wide program to enhance the environmental performance and reduce GHG emissions and fuel use of freight supply chains. Offshoot programs in Canada include SmartDriver and the Green Freight Assessment Program, which are also led by NRCan. SmartWay has proven to be an effective voluntary program for monitoring performance, sharing best practices, and assessing low-carbon technology and fuels.	High – SmartWay provides a wide variety of resources and opportunities for engagement within all four rail decarbonization areas	Link 1
Ontario Ministry of Transportation	Metrolinx: GO Rail Expansion and Network Electrification Project	2017 - ongoing	Through the GO Rail Expansion program, the Province is transforming the GO Transit rail network into a comprehensive, all-day rapid transit network with two-way, all-day service every 15 minutes over core segments of the GO Transit rail network. The Province will look to the private sector to propose innovative approaches to meet future GO Transit rail service levels, including opportunities for technology that could be used to electrify core segments of the GO Transit rail network.	Medium – focus is on expanding GO passenger rail network and exploring options for electrification, and GHG reductions can be realized both through modal shift from cars to passenger diesel rail and through rail propulsion switching from diesel/combustion to electric	Link 1 Link 2

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
Québec Department of Energy and Natural Resources	Marine, Air and Rail Transportation Efficiency Assistance Program (PETMAF)	ongoing	Aims to reduce or avoid GHG emissions by improving the energy efficiency of organizations and companies that operate marine, air and rail transportation services, including the use of more efficient transportation equipment and equipment and the use of at energies emitting less GHGs. Businesses must have an establishment in Québec. It offers funding in two areas: infrastructure and equipment, and studies and pilot projects.	High - will encourage development and uptake of low carbon technologies, fuels and infrastructure in transportation sector	Link 1
	Greenhouse Gas Emissions Reduction / Avoidance Program through Intermodal Transportation Development (PREGTI)	ongoing	Reduce or avoid GHG emissions from the transportation of goods and people through the establishment of intermodal projects and the promotion of maritime and rail services. Businesses must have an establishment in Québec.	High - will encourage development and uptake of low carbon technologies, fuels and infrastructure in transportation sector	Link 1
	Technoclimat	ongoing	Financial support to encourage the development, in Québec, of technological innovations in energy efficiency, renewable energies, bioenergy and reduction of GHG emissions (up to 50% of eligible expenses to a maximum of $3 million). It is financed through the Electrification and Climate Change Fund.	Medium - not rail specific, although rail GHG reduction initiatives are within scope	Link 1
Québec Ministry of the Environment and the Fight Against Climate Change	Electrification and Climate Change Fund (previously the Green Fund)	2006 - ongoing	A roughly $1.3 billion fund that is financed through Québec's participation in the North American carbon market, and the province's 4% gas tax. It will support public and private programs that contribute to the electrification of the transportation and industrial sectors, as well as infrastructure.	High – will encourage development and uptake of low carbon technologies, fuels and infrastructure in transportation sector	Link 1 Link 2
Sustainable Development Technology Canada (SDTC)	Sustainable Development Tech Fund	Canada / ongoing	The SD Tech Fund supports projects that are pre-commercial and have the potential to demonstrate significant and quantifiable environmental and economic benefits in one or more of the following areas: climate change, clean air, clean water and clean soil. Covers (on average) 33% of eligible project costs, with an average contribution of $3M. Funding must be applied for by the technology provider (e.g. OEM). SDTC generally focuses on SMEs. The Fund is not specific to rail, but broad enough to encompass it.	High – the Fund supports pre-commercial RD&D that has clear linkages to clean air and climate change	Link 1

Department	Program	Years In Effect	Description	Relevance (High, Medium, Low)	Links
Transport Canada	National Trade Corridors Fund	Canada / 2017 - 2028	Provides funding support to trade-related infrastructure projects in Canada. The $2-billion National Trade Corridors Fund (NTCF) helps fund infrastructure projects in Canada. Infrastructure projects could include work to airports, ports, rail yards, transportation facilities and access roads. Funding for infrastructure projects that increase the flow of people and goods, or help adapt transportation systems to climate change and new technology.	High – NTCF provides funding for a various types of low-carbon rail infrastructure	Link 1

Appendix D – Federal, Provincial and Territorial RD&D Activities

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
CUTRIC and Transport Canada / TC Innovation Centre	National Rail Innovation Initiative	Canada / 2018 - 2020	A technology scan to support the department's efforts to facilitate a more integrated and sustainable transportation system through the deployment of new technologies in close collaboration with private industry, academia, rail operators, and other government agencies. • Scan rail technologies that reduce GHG emissions & improve mobility services • Identify the "Top 10" feasible technology theme areas that will build Canada's future passenger and freight mobility systems	Focus Areas: Alternative Propulsion (catenary-free rail electrification; hydrail switching yards as step towards hydrail freight; hydrail for passenger and light-rail); Energy Efficiency (data collection, information management and AI; simulation tool for propulsion systems; CNG and H2; commuter rail electrification); Operational Optimization (enhancing Union Station's flow an capacity); Alternative Materials (build a rail car demonstrator to assess different materials (includes designing, manufacturing, validation, operability, and joining techniques); 3D printing of rail parts; hybrid lightweight structures; sandwiched sheet polymers) Catenary-free electrified rail facilities was most popular idea at 5 cross-Canada workshops, followed by passenger hydrail. Efforts to coordinate and streamline academic research are needed.	Link 1
Metrolinx	Hydrail Feasibility Study	Ontario / 2017 - 2018	The study investigated the technical and economic feasibility of the Hydrail System using hydrogen fuel cells to electrify the GO rail service (by 2025). It's an exploration of how hydrogen fuel cell technology, as an alternative to traditional overhead wires, can support the operation of a large scale commuter rail network.	Findings: 1. It should be technically feasible to build and operate the GO Transit network using hydrogen fuel cell powered rail vehicles 2. The overall lifetime costs of building and operating the Hydrail System are equivalent to that of a conventional overhead electrification system 3. The implementation of the Hydrail System of this scale and complexity is innovative and presents a different set of risks as well as benefits, as compared to conventional electrification. Key challenges include designing and building a fleet of H2 trains, and securing enough electricity to produce H2 via electrolysis (would require 1% of Ontario's daily generated supply).	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Metrolinx	Throttle Control Program	Ontario / 2018 - ongoing	Reduce fuel consumption by managing throttle while running locomotives on the line.	Minimize the need to speed up between stations which reduces fuel consumption.	Link 1
	Excess Idle Reduction	Ontario / 2014 - ongoing	Reduce fuel consumed by reducing the time the locomotive is on idle.	GO introduced the IntelliTrain reporting technology to minimize excess idling. It resulted in a 66% reduction in excess idling.	Link 1
	Tier 4AC locomotives	Ontario / 2018 - ongoing	Reducing fuel consumption by introducing a more fuel efficient technology.	Invest to introduce a more fuel efficient locomotive into the active fleet.	Link 1 Link 2
Natural Resources Canada	Evaluation of Liquefied Natural Gas Infrastructure Build-up for Supplying Fuel to the Rail Market in Canada	Canada / 2017 - 2018	This study is intended to look for opportunities where an initial deployment of LNG-fuelled locomotives in Canada could make economic and operational sense. The results from this study will be used to inform research and development activities aimed at encouraging the use of natural gas as a locomotive fuel in Canada.	This study mapped 80% of diesel used by Class 1 freight rail in Canada to mainlines between major hubs. NG pipelines were found to service all major hubs where locomotives are refuelled. The report identified an immediate opportunity to leverage existing LNG capacity in Vancouver and Montreal by converting approximately 120 CP locomotives deployed in coal hauling service from the Elk Valley to Vancouver and 60 CN locomotives deployed in the Montreal - Toronto corridor. A focused expansion program providing LNG at just four new key locations in the rail network would enable the conversion of a further 800 locomotives. All freight moving in the Vancouver-Montreal corridor would therefore be converted to LNG displacing a cumulative total of up to 1 million litres of diesel annually and producing savings of up to $500 million annually. The investment in liquefaction facilities and refuelling infrastructure is calculated to be $680 million. The investment in locomotive conversion kits and LNG tenders, estimated at just over $1 billion, has a healthy return on investment so long as diesel prices remain above 80c/L and locomotive conversion technologies maintain substitution above 75%.	Report shared by Transport Canada

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Natural Resources Canada	Economic and Environmental Benefits of Natural Gas Fuel for the Rail Sector in Canada	Canada / 2016 - 2017	The objective is to estimate the economic benefits of using natural gas as a fuel for locomotives in Canada, to evaluate where gaps exist in current research on environmental benefits and make recommendations for addressing the gaps that are found.	If the cost of rail diesel remains over 80c/L, then 40-50% savings in fuel cost can be achieved by converting existing locomotives to run on a blend of natural gas fuel and diesel using OEM supplied conversion kits, leading to a favourable business case. To achieve these savings, large fleets of locomotives need to be converted and refuelled at centralized refuelling depots with new co-located liquefaction plants. Carbon pricing is unlikely to affect the business case decision, even at $50/tonne. A major investment is required in liquefaction and locomotive equipment, estimated at $2.8 billion for the highest potential mainline freight locomotive population of 1,420 locomotives identified in the report. 30% average reduction in NOx and 88% reduction in PM are predicted if all locomotives were converted from their current tier status as of 2014 to the best available OEM-provided natural gas conversion kit. Initial dual fuel technologies being deployed do not reduce GHGs, however advances in engine technology currently under development by both major OEMs do have the potential to reduce GHG emissions. Further R&D is required.	Link 1
Northwest Territories Department of Infrastructure	GHG Grant Program for Buildings and Industry	Northwest Territories / 2019 - 2022	Funding program to support GHG reduction projects and initiatives (up to 25% funding)	The Government of the Northwest Territories' (GNWT) GHG Grant Program for Buildings and Industry is an application based non-repayable grant program designed to support greenhouse gas (GHG) emissions reduction projects and initiatives for NWT businesses, industry and non-profit organizations.Funding and resources for this program have been provided jointly by the GNWT in support of the GNWT's 2030 Energy Strategy, and by Environment and Climate Change Canada (ECCC) under the Low Carbon Economy Leadership Fund (LCELF) in support of the Pan-Canadian Framework on Clean Growth and Climate Change.Examples of potential projects include: fuel switching to lower GHG emissions, and energy retrofits to mobile equipment.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Ontario Ministry of Transportation (MTO)	High Speed Rail in Ontario: Report by the Special Advisor for High Speed Rail	Ontario / 2015 - 2016	Identify economic development opportunities, assess international experience in HSR, explore potential financing and delivery models, and provide advice on a preliminary business case for HSR in the Windsor, London, Kitchener-Waterloo, Toronto corridor.	The study assessed two scenarios: A) HSR on a dedicated right-of-way with top speeds up to 300 km/h, and B) HSR operating on a combination of conventional and dedicated tracks with top speeds up to 250 km/h. Scenario A was found to be cost prohibitive due to extensive tunnelling requirements, and scenario B was found only to be cost-effective in the London-Toronto portion of the corridor (due to higher anticipated ridership levels). The London-to-Toronto scenario B option was estimated to cost $7.5B, while the full Windsor-Toronto route would cost $21B.	Link 1
Sustainable Development Technology Canada (SDTC) / Unit Electrical Engineering Ltd.	Energy Efficient Transit Propulsion Pilot Program Project	British Columbia / 2012 - ongoing	Pilot electric propulsion systems for mass transit rail vehicles	Unit Electrical Engineering and its consortium are building more powerful, lighter and more efficient propulsion systems. One function of the propulsion system in particular, the Linear Induction Motor or LIM, is being redesigned and optimized to reduce the weight and improve efficiency of the current air-cooled unit by 10%. The optimization of the LIM translates into lowered capital costs, reduced lifecycle costs, and contributes to a reduction in electricity costs to the end user. The optimized LIM will also address the differing needs for transit systems in emerging markets by introducing a more effective cooling approach that protects from sand and temperature extremes, making this product ideal for export opportunities, specifically in the Middle East where rail is an emerging sector.	Link 1
TransPod	TransPod Hyperloop	2018 - ongoing	Create a high speed rail corridor between Calgary and Edmonton to reduce rail-based travel time from 3 hours to 30 minutes.	TransPod, a private consortium, has said the $6B project will be funded by the private sector. However it has requested support from the Government of Alberta before securing $100M in private funds to build a 10 km test track. The bullet-type high speed train could reach speeds of up to 1,000 km/h, and would be fully electrified. It would operate within a low-pressure vacuum tube to minimize friction. Pending government approval, construction of the 10 km test track would take place between 2021 and 2023.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Transport Canada / Alberta Innovates - Technology Futures (AITF), AAR, CP, CN, University of Alberta, NSERC	Canadian Rail Research Laboratory (CaRRL)	Alberta / 2019-2024	To conduct research related to ground hazards and winter service reliability (including winter-resilient fuels and materials)	Focus is not on fuel efficiency or emissions, but the lab can help to verify that emerging fuels, technologies and components are robust enough to perform well in Canadian winters. Themes of CaRRL's current phase of research are: assessing infrastructure performance, ballast quality and degradation, cold weather performance of rail and rolling stock, quantitative risk management of railways and optimizing rail operations and control systems.	Link 1
Transport Canada	Electrification of the Freight Rail Sector in Canada: Review of the Feasibility, Costs and Benefits	Canada / 2017 - 2018	To foster a better understanding among government and industry rail stakeholders on the costs, challenges, technology and environmental benefits of the electrification of the freight rail sector in Canada as a means to further reduce emissions from their operations. To assess the feasibility of an electrified freight rail network in Canada.	Heavy-haul rail freight electrification technology is mature and rapidly gaining a dominant share of traffic in countries around the world. Up to 2.3 Mt of CO2e emissions could be eliminated (43% of freight rail emissions) and annual cost savings of $520 million generated through electrification of all transcontinental Canadian Class I freight traffic between Vancouver and Montreal. To do this, an investment of over $10 billion would be required over a multi-year period. This would enable the conversion of ~60% of all freight traffic to electric traction and wold electrify 25% of Canada's entire freight network. A more economically attractive scenario of partial electrification from Vancouver as far as Regina or Winnipeg would cost between $2.3 and $5.2 billion with returns on this investment of between 6% and 25%, depending on the price of diesel and the cost per kilometer of electrification. GHG reductions in this scenario are only 1.3 million tonnes CO2e because a large portion of the electrification takes place in provinces that currently have a high electricity carbon intensity.	Report shared by Transport Canada

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Transport Canada	Transport Canada Innovation Centre	Canada / 2018 - ongoing	The Innovation Centre is a transportation innovation research, development and deployment (RD&D) organization that supports emerging transportation technologies to help ensure Canadians can benefit from a safe, secure, clean, and integrated transportation system.	A key focus of the Centre is to help prepare Canada for disruptive transportation technologies. It does this by partnering with industry, academia and government to help advance emerging transportation technologies through RD&D. The Centre's rail-related RD&D initiatives focus on six themes which mirror the priorities of RRAB: grade crossings and trespassing, service efficiency and capacity, energy, environment and climate change, infrastructure and rolling stock, human factors, and ground hazards research and cold weather operations.	Link 1
	Rail Research Advisory Board of Canada (RRAB)	Canada / 1989 - ongoing	1. Optimize collaboration and create synergy in the railway R&D programs of the three performing sectors of industry, government and academia; 2. Help mobilize resources and programs to address problem areas and issues of particular relevance in Canada; and 3. Facilitate participation by industry and academia in the formulation and implementation of railway-oriented R&D programs by the federal government.	RRAB is Transport Canada's primary mechanism for enhancing rail-related research collaboration between research bodies, industry and federal departments. A major focus is on advancing the safety of Canada's rail industry. RRAB has six themes for rail R&D which are the same as those of TC Innovation Centre for rail RD&D. Between 2009-2015, RRAB has undertaken 74 R&D projects, of which 8 were completed under Energy and Environment theme.	Link 1 Link 2
	Clean Rail Academic Grant Program	Canada / 2011 - 2018	To provide federal funds to academic researchers developing technologies and practices to reduce rail emissions	The Program awarded $250,000 in grants per year ($25k for 10 academic projects). Projects in scope included those on: locomotive systems, data management, infrastructure, railcars (lightweighting and friction reduction), fuels, optimizing rail operations.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Transport Canada	Clean Transportation System - Research and Development Program (CTS-RD)	Canada / 2019 - 2022	CTS-RD supports needed research in the aviation, marine, and rail sectors. It gathers the technical information needed to develop evidence-based regulations and measures to reduce emissions, and achieve Canada's goal of reducing GHG emissions.	CTS-RD has a budget of $1.5M over three years. Maximum grant per project is $100,000. Eligible projects in rail space must focus on reducing or measuring air pollutants, and be focused on one of the following topics: locomotive systems, network management, infrastructure, rail cars, fuels, optimizing rail operations.	Link 1
Transport Canada / CRB Innovations, ECCC, NRCan	Higher-Concentration-Blend Lignin-Derived Diesel Fuels for Rail Applications	Canada / 2014 - ongoing	This project, in partnership with NRCan's CanmetENERGY Ottawa, aims at developing the highest-concentration-blend possible of lignin-derived diesel fuel. It is also meant to assess the feasibility of using lignin-derived diesel fuels as drop-in biofuels in order to reduce emissions from the rail sector.	Current renewable diesels are produced from edible sources, including canola oil, soya oil and other lipids, which can have a negative impact on food prices. However, lignin is a highly abundant source that has no effect on food prices, and is readily available to be mixed with fuels to reduce transportation emissions of non-biogenic greenhouse gases and criteria air contaminants. The lignin-derived feedstock can be processed to create a diesel fuel fraction which meets all but one CGSB 3.18 locomotive fuel specification, but will have research and testing conducted to improve the quality of the fuel in order to meet that specification. CRB Innovations built a satellite plant that produced 5.5M L of fuel per year. Cost of fuel (with no profits) was $0.61/L. Payback period for plant was 11 years. Cost of raw biomass had large impact on costs and payback period. Emissions tests were conducted with drop-in fuel by ECCC in a Tier 4 engine. CO and HC measurements exceeded limits, but ECCC stated that with proper aftertreatment systems installed (DPF or DOC) emissions would easily meet standards. Further tests are needed, but it's expected that drop-in fuel will show reductions vs diesel.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Transport Canada and Environment and Climate Change Canada (ECCC)	Hydrail Switcher Locomotive Project	Canada / ongoing		TC and ECCC are working together to explore the design and deployment requirements for a hydrogen fuel cell switcher locomotive operating within a trainyard with supporting fuel infrastructure. The Phase I feasibility study examined the facets of deploying a hydrogen switcher locomotive in a long-term demonstration project. • Assessment of hydrogen fuel cell technology for rail primer movers • Identification of a representative and typically used switcher locomotive • High level design and deployment characteristics as well as estimated cost of conversion • Overview of refueling infrastructure options • Estimated air quality, GHG and economic impacts • Overview of codes, standards and regulations • Impact on railway operations • Recommendations to advance project The study concluded that hydrogen fuel cell technology is ready for deployment in a demonstration program. The recommendations direct parties to consider a demonstration project that gradually integrates hydrail use into railway operations over time.	
Transport Canada and Natural Resources Canada	Two-in-One Catalytic Converter for Simultaneous Removal of NOx and PM from Locomotives	Canada / ongoing		TC's Innovation Centre has partnered with NRCan CanmetENERGY Ottawa to design a two-in-one catalytic converter for locomotives that would control emissions of NOx and PM without a penalty to engine power. The improved catalytic converter would improve emissions reduction performance.	

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Transport Canada and Environment and Climate Change Canada (ECCC)	Locomotive Emission Testing During Revenue Operation	Canada / ongoing		TC and ECCC have partnered to evaluate locomotive exhaust emissions during revenue operations in summer and winter conditions. This project will expand knowledge of locomotive emissions which are currently tested in static conditions only. Revenue-service operation emission data will provide a baseline against which future experiments using emission-reducing technologies can be compared. The data collected in this project could be used to evaluate the effectiveness of GHG reducing technologies.	

Appendix E – Canadian Rail Industry Activities

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian National Railway (CN)	Fleet Renewal	ongoing	Overarching objective: this initiative will contribute to is to reduce GHG emissions intensity of fleet by 29% by 2030 (from 2015 levels)	CN is investing in and upgrading its fleet, making significant investments in Tier 4 locomotives, new-generation railcars, hybrid and electric vehicles. The new Tier 4 locomotives are designed to meet regulatory standards producing less criteria air contaminants. Cleaner, more fuel-efficient rail and non-rail equipment will be important to continue to decouple growth from GHG emissions.	Link 1
Canadian National Railway (CN)	Innovative Technology	ongoing	Overarching objective this initiative will contribute to is to reduce GHG emissions intensity of fleet by 29% by 2030 (from 2015 levels)	CN explore and invest in innovative technologies, from telemetry systems, to distributed power, to energy managements systems. Trip Optimizer – Regulates the speed of a train by controlling the locomotive throttle and dynamic brake, and computes the most efficient manner to handle the train. Distributed Power (DP) – Allows for remote control of the locomotives and improves braking performance, train handling and fuel efficiency. It improves safety from reduced sticking brakes and damaged wheels.	Link 1
	Use of Big Data	ongoing	Overarching objective this initiative will contribute to is to reduce GHG emissions intensity of fleet by 29% by 2030 (from 2015 levels)	Optimizing horsepower to gain fuel efficiency, through locomotive telemetry systems. CN is collecting data to improve performance and fuel conservation, using the Horsepower Tonnage Analyzer (HPTA). The HPTA tool was built in house and gives crews instructions and real-time monitoring to ensure they only use the power needed during a trip, by optimizing a locomotive's horsepower-to-tonnage ratio.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian National Railway (CN)	Enhancing Operating Practices	ongoing	Overarching objective this initiative will contribute to is to reduce GHG emissions intensity of fleet by 29% by 2030 (from 2015 levels)	CN operating model, Precision Scheduled Railroading, allow us to use fewer railcars and locomotives to ship more freight in a tight, reliable and efficient operation. Routing protocols and collaborations with ports and terminal operators are helping to minimize dwell times and further drive fuel efficiency. Through on-the-job training, CN is working closely with train crews and rail traffic controllers on best practices for fuel conservation – from locomotive shutdowns in yards to streamlined railcar handling, train pacing, coasting and braking strategies. CN's locomotive engineers receive real-time information on train characteristics, performance and terrain, through an Energy Management System (EMS), which helps to compute the most efficient train settings and regulate speed. Providing information to track performance in real time to enable fuel conservation through notch limiting, idling reduction and horsepower optimization.	Link 1
	Expanding use of Cleaner Fuel	ongoing	Overarching objective this initiative will contribute to is to reduce GHG emissions intensity of fleet by 29% by 2030 (from 2015 levels)	Driven by regulatory requirements, the growth of the renewable fuel market presents an opportunity for CN to further reduce emissions by using biodiesel blends in its locomotive fleet. In the coming years, CN look forward to working with suppliers to explore the greater use of renewable fuels.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian National Railway (CN)	LNG Demonstration	2013	Explore feasibility of LNG locomotives in terms of environmental performance and costs	In 2013, CN retrofitted two 3,000-horsepower locomotives with engines that run on a fuel mix of 90% liquefied natural gas and 10% diesel. They operated in AB. The project was abandoned for a few key reasons: • the fuel tank technology was not there yet for CN use (there were also regulatory hurdles as the high fuel volume required a rail tender) • the reductions in GHG emissions were fairly low considering high CAPEX costs (20 – 30% GHG reductions by using LNG instead of diesel) • the business case was not good (the initial driver was the cost of natural gas vs diesel but markets fluctuated)	Link 1 Link 2 Link 3
	Providing low carbon transportation and logistics solutions to customers	ongoing	Provide customers with suite of intermodal solutions to optimize environmental, social and economic benefits of different modes	In addition to providing a fuel-efficient transportation service, CN believes that rail can be an integral part of the climate change solution offering both environmental and economic advantages. Compared to other transportation modes, rail is the most fuel efficient method of moving freight over land – on average, trains are approximately four times more fuel efficient than trucks. To leverage these benefits, CN offers its customers intermodal freight shipping, which combines the resources of different transportation modes, such as trucking and rail – allowing each mode to be used for the portion of the trip to which it is best suited. As a result, intermodal shipping helps lower transportation costs, reduce emissions, traffic congestion, accidents, and the burden of an overstressed public road transportation infrastructure.	

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian National Railway (CN)	Investments in rail infrastructure, network fluidity and efficiency	ongoing	Deploy targeted investments to various elements of Canada's rail network to enhance efficiency, sustainability and capacity	In 2018, CN implemented its largest-ever capital expansion program to add new infrastructure needed to boost the railway's capacity, fluidity and resiliency. This included investment in double track and yard capacity to allow CN to better manage through and recover from unplanned network disruptions, as well as the addition of new, more efficient locomotives. Specifically, in 2018, CN invested a record C$3.5 billion in its capital program, with C$1.6 billion invested to maintain the safety, integrity and fluidity of the network, C$1.0 billion on strategic initiatives to increase capacity, enable growth and improve network resiliency, including line capacity upgrades and information technology initiatives, and C$500 million on equipment capital expenditures including 65 new high-horsepower locomotives.	
Canadian Pacific Railway (CP)	Trip Optimizer – Technology added to line haul locomotive fleet	2009 - ongoing	To date CP has installed TO technology on its active line haul locomotives with a goal to apply this technology to 85% of this part of our road fleet (approximately 600 locomotives) by 2025.	Since 2009, CP has actively installed Trip Optimizer (TO) technology on high-horsepower road haul locomotives. Effectively a sophisticated locomotive cruise control optimized for fuel economy, FTO equipped locomotives enable trip planning to significantly reduce fuel and energy consumption. TO takes into account factors such as train length, weight, and track grade to determine the optimal speed profile for a given portion of track. TO systems have been demonstrated to effectively reduce locomotive fuel consumption and corresponding GHG emissions by an average 5%. As of 2019 through the use of TO technology CP estimates an annual GHG emissions savings of 72,333 Tonnes CO2e.	

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian Pacific Railway (CP)	Locomotive Modernization Program – upgrades to locomotive fleet	2017 - 2024	Starting in 2017, and continuing through 2024, CP plans to significantly upgrade and retrofit up to 321 six-axle, high-horsepower locomotives. A conservative estimate of emissions reductions associated with this project have been calculated based on a fuel efficiency guarantee of 2.7% as provided by our equipment vendor. It is anticipated that the combined effect of locomotive upgrades coupled with installed fuel saving technology will result in a realized fuel savings beyond 2.7%.	The Locomotive Modernization program is a multi-year fleet renewal program at CP. Starting in 2017 through 2019 CP upgraded and retrofitted 171 locomotives to meet our operational needs. Locomotive modernization includes technology upgrades, advanced EPA Tier 1+ diesel engines, enhanced cooling and improved traction systems. All units will be equipped with GE Trip Optimizer and Distributed Power which are both EPA certified fuel/emissions reduction technologies. By the end of 2019, these improvements will be reflected in 25% of our active line haul fleet, having a direct and positive impact on CP's fuel efficiency and corresponding GHG and air pollutant emissions Modernized locomotives currently in service through 2019 were estimated to have reduced GHG emissions by 11,475 Tonnes CO2e.	Link 1 Link 2 Link 3
Canadian Pacific Railway (CP)	Precision Scheduled Railroading – efficiency focused railway operating model	2012 - ongoing	There are no specific GHG goals associated with PSR.	Since 2012, CP has successfully operated its precision scheduled railroading (PSR) approach. One of the first Class 1 freight railways to successfully implement this approach, PSR involves constant monitoring and optimization of all railway assets and processes to maximize operational efficiency, improve outcomes for CP's stakeholders and increase safety for employees and communities. To support PSR objectives, CP has made significant upgrades to its rail network, locomotive and car fleet, improved operational practices and invested in technological improvements. Notable factors contributing to improved fuel economy include enhanced productivity from running longer trains and proficient operating plan efficiency. Implementation of process improvements and changes to operating practices associated with CP's precision scheduled railroading operations model has driven a 3% improvement in fuel efficiency between 2017 and 2018 – saving an estimated 74,663 Tonnes CO2e annually.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian Pacific Railway (CP)	CP Fast Pass Technology – deployment of technology to improve operations and support CP value chain and low carbon transportation solutions.	2018 - ongoing	To better align with customer objectives for low-carbon transportation solutions, CP continues to optimize intermodal operations to provide opportunities for the proficient transfer of goods and materials from truck to train transport.	A significant portion of CP's business involves the long haul transport of consumer goods and materials that have typically shipped using heavy highway truck transport. By shifting an increasing portion of these materials from highway transport to freight rail services, CP is able to have a material impact on GHG emissions for customers and the North American transportation sector. In 2018, CP implemented Fast Pass technology at all 10 intermodal locations, expediting truck traffic through facilities improving efficiency and dramatically reducing truck wait times and associated idling. Collectively CP's improvements in intermodal operations have resulted in heightened demand for freight traffic through these facilities. In 2018 intermodal traffic increased by nearly 10% with an additional 2.4 billion revenue-ton miles transported for customers. CP estimates this project to have resulted in approximately 139,945 Tonnes CO2e less GHG emissions our customers avoided shipping these materials by train versus highway truck transport.	Link 1 Link 2 Link 3

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Canadian Pacific Railway (CP)	8,500-foot High Efficiency Product Trains (HEP) – improving supply chain capacity and efficiency		Once fully implemented, HEP Trains will allow for more grain to be hauled within a shorter train, thus increasing shipping capacity and improving fuel consumption by reducing the number of trains required to haul the same volume of grain. Significant GHG savings are expected due to improved fuel efficiency.	CP is driving towards a supply chain model capable of loading, transporting and unloading 8,500-foot long, power-on, unit trains with a minimum of 134 hopper cars of export grain in Canada.To support the HEP train model, CP is purchasing 5,900 new grain hopper cars as a part of a $500 million dollar multiyear investment to upgrade its grain car fleet. New grain cars will replace an aging fleet, allowing CP to provide better and more efficient service to farmers and the North American economy. By 2022, CP has committed to purchase a total of 5,900 new hopper cars enabling a complete removal of all low-capacity hoppers from the fleet. The 8,500-foot train model will carry a minimum of 134 grain hopper cars based on industry-average car lengths, which is 20% more grain than traditional 112 car grain trains. As CP and the industry move towards shorter, higher-capacity cars, CP will be able to fit more cars and more grain on each 8,500-foot train. The end result is more grain transported to market more efficiently than ever before. CP is also investing in longer sidings and upgrades to its track network enable these longer trains to move seamlessly between elevators and ports. Elevators capable of receiving an intact 8,500-foot train to have the empty hoppers placed clear of our main track operations, loaded and made ready for pick up once again all clear for CP's main track, providing the best use of capacity to move more grain. CP's investment in longer sidings and upgrades to its track network enable these longer trains to move seamlessly between elevators and port. Through infrastructure investment and collaboration with grain companies and port operators, this enhanced train model allows railways, elevators, and ports to increase throughput and better utilize resources. Grain elevator and port terminal infrastructure is being built and expanded to load and unload 8,500-foot trains clear of the mainline track.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Southern Railway of British Columbia (SRY)	Alternative fuel research	ongoing	Initiative is designed to gain insight into the feasibility of alternative fuel locomotives in the context of switching activities.	SRY is supporting research being conducted at the University of British Columbia Okanagan into alternative fuels for switching locomotives: 1) hydrogen-fueled and 2) battery hybrid.	
VIA Rail	Fleet Renewal	2022 - ongoing	Increase the adoption of fuel efficient, low-carbon locomotive engines and fleet vehicles	Starting in 2022, the delivery of VIA's brand new fleet of trains will include more fuel efficient Tier 4 Diesel engines with the option to operate on electrified rail infrastructure as it becomes available. VIA established a green strategy for the replacement of its fleet of vehicles: 100% of administrative vehicles purchased in 2018 were zero emission vehicles.	Link 1 (see pages 9, 42, 43)
	Intermodal Partnership	ongoing	Reduce GHG from use of cars through addressing the first and last mile	Door-to-door type travel through partnering with a diverse range of intermodal carriers including commuter trains, motor coaches, car-sharing companies, airport shuttle bus services, and airlines.	Link 1 (see page 14)
	Fleet Refurbishment (renovation of older fleet)	2009 - 2013	Achieve GHG reductions of 15-20% through engine upgrades	Complete renovation of older F-40 locomotives (from 2009-2013) with separate HEP engines.	Link 1 (see page 39)
	Renovation of Cars	2018 - 2020	Achieve GHG reductions of 3-5% through electrical system upgrades	Multiple initiatives to replace older electrical systems with more energy efficient systems.	Link 1 (see page 39)
	Locomotive Engineer Scorecard	2019 - ongoing	Achieve GHG reductions of 3-5% through operating practices that reduce fuel consumption	Mapping optimal operating parameters for the train on specific segments (Safety & Environment (fuel consumption)) and coach others. Performance Measurement: VIA's innovative telemetry Wi-Tronix system is enabling it to compile data and monitor progress through the LE Energy Management Scorecards. Through on-the-job instruction, VIA coaches its LEs on ways to reduce train idling and improve fuel efficiency. Simulator Training: In support of VIA's fuel efficiency improvement objectives, last year it enhanced its apprentice LE simulator training program. By adding a new feature to the simulator, VIA can now train its apprentice LEs on how to better operate locomotives for lower fuel consumption.	Link 1 (see page 40)

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
VIA Rail	Optimization of Cycling	ongoing	Achieve GHG reductions of 3-5% through increasing capacity and efficiency of trains on high demand routes	Deployment of most fuel efficient engines on most demanding routes. Train Cycling: VIA significantly increased capacity on its trains where it experienced the highest demand on its network. By better cycling our trains, we increased the number of available seat miles by 5.3% when compared to 2016.	
	Idling Policy	ongoing	Achieve GHG reductions of 3-5% through the minimization of idling in railyards	Minimize idling in the yards. Use of telemetry Wi-tronix system to reduce train idling. The need for idling will be minimized in part through the use of Hotstart engine heating systems, and reduced layover times.	Link 1 (see page 41)
	Promote use of trains vs cars or other modes	ongoing	Promote the use of passenger travel by rail as a low-carbon option to cars	To promote the environmental benefits of passenger rail, VIA is taking important steps to educate and create awareness amongst Canadians. Provide an accessible and affordable alternative to cars and support the necessary shift we need to make to reduce the transportation sector's contribution to climate change and smog.	
	Use of Biodiesel (B5)	ongoing	Reduce net GHG emissions through the use of low-carbon biodiesel	Biodiesel blends up to 5% are used on a voluntary basis (not a requirement). Suppliers are not able to confirm precise amounts of biodiesel in batches purchased.	
	Test of B20 on one engine		Explore the impacts of higher biodiesel blends on existing engines	Test report completed. Technical issues are frequent on current engine with use of B5+, including less power generation. Requires higher consumption to develop the same power as regular diesel.	
	Adjustments to software	ongoing	Reduce GHG emissions by using software to limit available power at low speeds	To limit the available power at very low speeds as this can't be converted to traction power (thereby reducing fuel consumption).	
	Future initiatives: Dedicated tracks Electrification of Rail		Expand VIA's dedicated track network and explore options for electrification	More dedicated tracks will reduce idling due to delays caused by host railways. VIA network electrification has the potential to reduce GHG emissions by 13.9 million t CO2e.	
	Fuel Efficiency	ongoing	Enhance fuel efficiency to reduce GHG and CAC emissions	VIA has improved its fuel conservation and train idling practices, achieving a 21% reduction in GHG emissions since 2009. Related measures have also led to a reduction in CAC emissions by 20% based on 2009 levels.	

Appendix F – International Activities

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Association of American Railroads (AAR)	Transportation Technology Center (TTCI)	USA	Primary focus is rail safety.	Past TTCI research has indirectly contributed to GHG reductions through research into double-stack container cars, higher capacity freight cars, AC electric locomotives, wheel-rail lubrication, etc. No ongoing projects explicitly related to GHG emissions reductions. It hosts an Annual Research Review, and partners with external groups on strategic research initiatives.	Link 1
BNSF Railway Company / Wabtec	Battery electric high-horsepower freight locomotive prototype	USA / 2019 – ongoing	Reduce GHG and air pollutant emissions from yard and road operations.	EV locomotive prototype designed to work when coupled to diesel locomotive(s), which would result in a hybrid train. When completed, the locomotive will be tested on 350 mile stretch between Stockton and Barstow in California. The hybrid consist will use the electric locomotive in rail yards and will use it to supplement power while in transit. Uses Li-ion batteries on a large scale (~20,000 cells). Future versions might use up to 50,000 cells. Before testing begins, a charger will be installed at BNSF's Mormon Yard in Stockton. Locomotive will also charge via regenerative braking. Will use energy management software to analyze route ahead and optimize use of electric power to minimize fuel use. Testing should begin in late 2020. Pilot funded in part by $23M (USD) grant from CARB (through cap-and-trade revenues).	Link 1 Link 2 Link 3

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Federal Railroad Administration (FRA)		USA	FRA's focus is on improving transportation safety and fostering the development of high-speed rail (HSR) and other intercity passenger service (no explicit focus or programming on GHGs)	FRA's National Rail Plan Progress Report (2010) states that high-performance freight rail and high-speed rail can contribute to DOT's goal of reducing emissions from freight transportation by improving the fuel efficiency of freight vehicles, and by reducing transportation's petroleum consumption. In 2009, FRA funded a study that provided a comparative evaluation of rail and truck fuel efficiency on corridors and services in which both modes compete. The study examined 23 freight movements and took multiple distances and commodities into consideration. This evaluation concluded that rail was more fuel efficient than truck on all 23 movements and that fuel savings from using rail can be significant. Under The National Environmental Policy Act (NEPA), FRA must examine potential impacts to the social and natural environment when considering approval of proposed transportation projects.	Link 1 Link 2 Link 3 Link 4 Link 5 Link 6

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Norfolk Southern Corporation (NS) / Federal Railroad Administration, Penn State University	NS 999 battery electric switcher locomotive	USA / 2008 - 2017	Assess feasibility of battery electric switcher locomotives for energy savings and reduced emissions	The project to develop the NS 999 battery electric switcher locomotive started in 2008. The test locomotive was produced by converting an older locomotive. A problem with battery power management with the original lead-acid batteries led to the project being abandoned in 2011. A second round of testing using more capable lithium-ion batteries in both simulated and operating conditions was more successful. This testing showed that the lithium-ion pack provided significant energy storage and would be suitable for more rigorous switching duties, local service, and road use. Penn State University created a hybrid locomotive model that shared the load between a diesel engine and the lithium-ion pack. The model allowed for dynamic braking energy to recharge the battery pack. NS then used this model to conduct an experiment that showed a hybrid locomotive could reduce emissions of pollutants. However the experiment showed the resulting fuel savings did not offset the capital cost of the battery pack, so each hybrid locomotive would need a large annual subsidy. Battery charging and charging infrastructure was another challenge identified by the experiment.	Link 1
Port of Los Angeles	Zero-Emission Track-Miles Locomotive Project	USA / 2018 - 2020	Demonstrate a battery electric switcher locomotive in commercial service	The Port of Los Angeles has partnered with VeRail Technologies, Inc. to build and demonstrate a zero-emission switcher locomotive in the San Pedro Bay Ports. This project began as a concept for a near zero-emission natural gas system, and has now evolved into a fully zero-emission, battery electric platform. The 2,100 horsepower six-axle switcher locomotive will operate throughout the network of in-harbor rail lines that service the Ports of Los Angeles and Long Beach, and is anticipated to be capable of working a full 12-hour shift before needing to charge.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Argonne National Laboratory and Federal Railroad Administration (FRA)	Railroad Energy Intensity and Criteria Air Pollutant Emissions	USA / 2014 - 2018	1. FRA tasked Argonne with updating GREET model to include rail module 2. Updated model to include life-cycle costs and impacts of CNG, LNG, and dimethyl ether (DME) usage in the rail sector	The project report assumes that natural gas locomotives meet Tier 4 standards for all pollutant emissions. This assumption was made due to inability of Argonne to gather data from rail operators and manufacturers. It found that if the cost differential between diesel and natural gas increases, there "may still be a pathway for natural gas". On DME, the report states it's a good alternative to diesel due to high cetane number (helps auto-ignition at low temperatures) and high oxygen content (leads to less soot/PM formation than diesel). DME can be derived from natural gas or methanol cost-effectively, though it can also be produced from a wide range of biomass and organic waste. It is not a GHG and is believed to have lower NOx emissions than diesel. It only has 67% the energy density of diesel. GREET model data for DME were based on on-road trucking test results, as no DME locomotive data was available. DME is believed to result in significant reductions of NOx (27%), PM (94%), HC (74%) and CO (95%) relative to diesel. A challenge is that DME has only half the energy density of diesel, requiring its fuel tanks to be twice as large.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
California Air Resources Board (CARB)	Technology Assessment: Freight Locomotives	USA / 2016 (with demonstration and commercialization timelines out to 2029)	• To help inform and support CARB planning, regulatory and voluntary incentive efforts in support of CARB's objective to transition on-road and off-road mobile sources to zero tailpipe emissions everywhere possible, and near-zero emissions with clean, low-carbon renewable fuels everywhere else, to meet air quality and climate goals • Scope: considers potential advanced locomotive technologies that could operate on the existing rail network with emissions well below the current national Tier 4 emission levels	The CARB report recommends dual paths for locomotive technology development: 1) Seek criteria and toxic pollutant reductions beyond Tier 4 in the near to mid-term with aftertreatment augmented by on-board batteries. 2) Develop the zero-emission track-mile or zero-emission locomotive technologies needed in the mid to long-term (2025-2050). It identifies potential actions such as: a) Ask U.S. EPA to define the next generation of national emissions targets for locomotive engine manufacturers ("Tier 5" standards) b) Support development and demonstrations of on-board battery technologies that could also provide zero-emission track-mile capabilities in and around railyards c) For the longer term, advocate for the development of the solid oxide fuel cell gas turbine (SOFC-GT) concept, a potential technology to power an interstate line haul locomotive across the North American freight rail system. d) Support RD&D program to commercialize zero-emission track-mile and zero-emission locomotive technologies. e) Highest priorities for R&D: improvements in battery and fuel cell energy density and costs to support introduction of: – Battery and/or fuel cell powered switch locomotives. – Battery and/or fuel cell tenders for regional operation of medium horsepower and freight interstate line haul locomotives. – Fuel cell (SOFC/GT) freight interstate line haul locomotives.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Alstom / LNVG, Linde Group, Hydrogenics	Coradia iLint Hydrogen Powered Train	Germany / 2016 – ongoing	Replace diesel passenger trains with non-emitting alternatives on non-electrified stretches of rail	Alstom's hydrogen powered Coradia iLint passenger train entered into active service (two units) in 2018. Design elements include clean energy conversion, flexible energy storage in batteries, and smart management of traction power and available energy. Designed for operation on non-electrified lines. Alstom and LNVG signed contract for delivery of 14 H2 trains in 2017. This contract includes 30 years of maintenance and fuel supply. iLint range on full tank is 1,000 km. Top speed is 140 km/h. Trains were manufactured in Lower Saxony, the same region they will be used in. The Linde Group built H2 fueling station, with plans to eventually use wind-powered electrolysis to produce the fuel. Trains are GHG emissions free and quiet (60% noise reduction), and are direct substitutes for existing diesel trains. In Oct 2019, Dutch rail infrastructure provider ProRail, local rail operator Arriva and energy company Engie announced pilot to test the iLint in Province of Groningen, Netherlands. Two week trial scheduled to begin in Q1 2020.	Link 1 Link 2 Link 3 Link 4

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Germany Federal Ministry of Transport and Digital Infrastructure (BMVI)	Rail Freight Masterplan	Germany / 2017	The masterplan commits to significantly increase rail's market share of all freight traffic in Germany by 2030. A related goal (not included in Masterplan) is to electrify 70% of Germany's freight rail network by 2025.	The Masterplan is a comprehensive package of measures to permanently boost the rail freight sector and offer shippers higher-quality rail freight services at more competitive prices. The focus is on: ensuring high-capacity infrastructure; making extensive use of the potential for innovation; and improving the transport policy framework. It identifies rail freight as a key element of a sustainable mobility and transport strategy, and contains specific milestones, actions, and timeframes. Relevant milestones and actions: • Increase the level of automation in railway operations: technical systems in mainline operations, such as driver assistance systems, will support the train driver in adopting an energy-efficient driving style, thereby reducing CO2 emissions and energy consumption. • Expedite technological innovations for rolling stock: deploy more hybrid locomotives (with electric propulsion for the "last mile" without overhead lines); streamline sets of regulations governing rolling stock with regard to the hampering of innovations by national and/or European provisions; create funding options for the deployment of low-emission and hybrid locomotives and innovative freight cars • Boost multimodality (e.g., granting regulatory privileges to electrically powered and low-emission road vehicles operating initial and terminal hauls in intermodal transport) • Expand electric haulage on and with the railways (e.g., launch a special programme for further electrification of the rail network; develop standardized solutions for the electrification of lines and service facilities with simple requirements; develop and fund electrically powered solutions for initial and terminal hauls to and from the railways; implement a double track approach) • Limit the burden imposed by levies and taxes	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
UK Department for Transport	Decarbonising Transport: Setting the Challenge	UK / 2020	Identify the current challenges and steps to be taken when developing the transport decarbonization plan (which should result in net zero carbon by 2050). Report states that the main way to achieve rail freight decarbonisation is through direct government intervention to roll out further electrification. Network Rail is currently developing the Traction Decarbonisation Network Strategy (TDNS), which will inform decisions about the scale and pace of decarbonization between now and 2050.	Notes on current government aims and targets: UK recognises the environmental benefits of rail freight, and invested £235M in the Strategic Freight Network between 2014 and 2019 to improve the capacity and capability for freight. In 2018, challenged the rail industry to produce a vision for removal of all diesel-only trains from the network by 2040. An industry taskforce assessed the decarbonization options available, and made recommendations for the rail sector. Current policies to deliver on the net zero by 2050 targets include: Investment in new technology (e.g., recently funded competitions that provided over £4M for projects to drive decarbonization across passenger and freight); and Providing freight grant schemes to support the carriage of freight by rail and water on routes where road haulage has a financial advantage. These policies helped remove around 900,000 freight truck journeys a year from Britain's roads. Planned future work: working with industry on the Traction Decarbonisation Network Strategy, which will consider both passenger travel and rail freight and will inform the deployment of electrification and novel technologies across the railway. Aims to build on Network Rail's internal Decarbonisation Programme to reduce carbon emissions from railway operations, including depots. Plans to publish a new multi-modal freight strategy which will build on the work of the National Infrastructure Commission and will include the Government's final response to the recommendations in the Commission's report Better Delivery: The challenge for freight.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
National Rail / Eurostar, South Eastern Railway, East Midlands Railway, Thameslink, DB Cargo UK	High Seed 1 (HS1)	UK / 2003 - ongoing	Provide rapid, low-emissions (90% less than flying) travel between London, Kent, and several destinations in mainland Europe. Also allows for rapid, sustainable freight transport.	All-electric trains connect London to the Channel Tunnel (109 km stretch). Trains travel up to 230 km/h in the UK, and up to 300 km/h in mainland Europe. Existing connections to Paris (2 hours), Amsterdam (4 hours), Brussels (2 hours), and Ashford, UK (37 mins)). This route has been in operation since 2007. The route is supplied by electricity using overhead catenary lines with 25 kV AC railway electrification. Some stations on the route include third-rail 750 V DC power to avoid the need to switch power supplies. Locomotive rolling stock on HS1 includes: Eurostar e300 (Class 373), Javelin (Class 395), and Eurostar e320 (Class 374) for passenger rail, and Class 92 for passenger and freight. HS1 launched freight services in 2011 to deliver time-sensitive freight from the UK to mainland Europe in a sustainable manner. It includes a connection to the DB Schenker freight depot at Dollands Moor (near the Chunnel).	Link 1 Link 2
National Rail / UK Department for Transport, municipal governments, airports	High Speed 2	UK / 2029 - 2040	1. Create better linkages between cities and regions to enhance economic development in struggling areas. 2. Add capacity by taking inter-city trains off of existing network to free up space for commuter and freight rail. This will address over-crowding and reduce the number of on-road freight trucks. 3. Reduce transport carbon footprint by providing low-carbon option for long-distance travel. HS2 will be 17 times less carbon intensive than flying and 7 times less than driving. 3 objectives summarized as: connectivity, capacity, carbon.	New high speed rail network under development, offering service to 8 of UK's 10 biggest cities. HS2 Phase One (215 km stretch between London and Birmingham) will open between 2029 and 2033. Phase Two will add over 330 km of track and connect to Manchester and Leeds. HS2 will serve more than 25 stations and help to connect over 30 million people. It is projected to create over 500,000 jobs and lead to the construction of 90,000 homes close to HS2 stations. Operating speeds will be 330-360 km/h. It will be a double track network using standard gauge rail, powered by 25 kV AC overhead catenary lines. Over 60 years, the network is expected to provide over 92B pounds in net benefits and 44B in revenue, for a total benefit-cost ratio of roughly 1.4.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Autonomous Parisian Transportation Administration (RATP)	Battery-overhead electric locomotives	France / 2017 - 2019		In 2017 RATP ordered 12 battery-overhead electric locomotives to be used to tow trains that provide maintenance for France's regional railway network infrastructure. These units will be able to charge their nickel-cadmium batteries via overhead catenary wires when wires are available, and will also be able to operate on non-electrified portions of track. The locomotives, produced by Spanish rail firm CAF, will have a maximum power output of 1MW.	Link 1 Link 2
French National Railway Company (SNCF)	Railway electrification and SNCF LGV (high-speed rail)	France / 1920 - 2020	Provide travellers with high speed ground-based transport powered by domestically-sourced energy	Railway electrification in France began in the 1920s, with mainlines originating in Paris and the Pyrenees electrified using overhead catenaries at 1,500 V DC. Today France is home to more than 15,000 km of electrified rail lines (55% of total rail network). Following WWII, 25 kV AC overhead lines became the norm. Today, all electrical equipment ordered by France's national railway company SNCF can use both 25 kV AC and 1,500 V DC. Exploratory work on high speed rail began in 1966, originally with the intent of being powered by gas turbines. The 1973 oil crisis caused the focus of efforts to shift to electric propulsion. The first line came into service in 1981, connecting Paris and Lyon, powered by 25 kV AC overhead catenary lines. As of 2017, the system has over 2,600 km of high speed rail, with top speeds ranging from 250 to 320 km/h. High speed trains run on conventional tracks and can utilize conventional rail and station infrastructure, unlike high speed lines in Spain and Japan. The high speed lines are typically reserved for use by high speed trains to avoid congestion. All lines are fenced to prevent people and wildlife from crossing tracks, and level crossings are not permitted.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Union Of European Railway Industries (UNIFE)	RAILENERGY	EU / 2006 - 2010	Reduce energy consumption in railway systems thus reducing life cycle costs of operation and CO2 emissions. The project target is to achieve a 6% reduction in the specific energy consumption of the rail system by 2020.	The special feature of RailEnergy is the holistic approach to energy efficiency. A global model was developed to simulate energy losses in railway systems. The model was based on a 'plug & play' principle for each component or operational pattern. RailEnergy serves as a platform for an integrated development of new methodologies, techniques and technologies. The final outcome of the RailEnergy project confirms that an average relative energy saving of more than 7% can be reached. Recommendations included predicting the energy performance of new rolling stock using the new technical standard TecRec 100_001, greater use of eco driving (saving potential between 5% and 15%), energy efficient traffic management (saving potential between 10% and 20%), and parked train management (saving potential of 4% to 8%).	Link 1 Link 2
International Union of Railways (UIC) and European Commission (EC)	CAPACITY4RAIL	EU / 2013 - 2017	Develop guidance, standards and technology demonstrations to help rail stakeholders optimize infrastructure, operations and vehicle performance, leading to a global freight rail sector that is adaptable, resilient and competitive.	CAPACITY4RAIL aims to pave the way for future railway systems, delivering coherent, demonstrated, innovative and sustainable solutions for track design, freight systems, operation and advanced monitoring. With a comprehensive system vision, it will contribute to the development of guidance documents identifying further actions to be undertaken and future technologies and systems to be developed. It will contribute to the development and definition of European Standards (e.g., EC white paper), future regulations, and European research policy and will facilitate a high degree of interoperability. Adaptable systems that offer high operational capacity and high reliability and resilience to hazards are needed. Such changes will only be achieved through global efforts that combine optimization of infrastructure, operations and vehicle performance.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
European Commission (EC)	Shift2Rail	EU / 2009 - ongoing	1. Enhance rail service quality by improving reliability and punctuality by up to 50% 2. Reduce congestion and CO2 emissions by doubling European rail capacity 3. Reduce costs of infrastructure and rolling stock by 50% 4. Retain Europe's leadership in global rail market	Shift2Rail seeks focused research and innovation (R&I) and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. Shift2Rail promotes the competitiveness of the European rail industry and meets changing EU transport needs. R&I carried out under this Horizon 2020 initiative develops the necessary technology to complete the Single European Railway Area (SERA). The program's scope applies to both passenger and freight transport. In 2019, Shift2Rail released "Study on the use of fuel cells and hydrogen in the railway environment". Study shows potential for use of H2 and fuel cells in multiple units, shunter locomotives and freight locomotives.	Link 1 Link 2 Link 3 Link 4 Link 5
The European Rail Research Advisory Council (ERRAC)	Rail 2050 Vision	EU / 2017 - ongoing	Roadmap sets out the future capabilities needed from railways to meet the future needs of Europe and provides a route to utilizing new technologies to achieve these capabilities.	A high-level freight and passenger rail roadmap for Europe out to 2050. Highlights critical roles that rail plays in Europe's economy and sustainability efforts, as well as challenges (e.g., climate change) and opportunities (e.g., the creation of a Single European Rail Area (SERA), smart transport technologies, low-carbon transport). The 2017 Vision document was preceded by a more detailed 2012 document called Rail Route 2050: The sustainable backbone of the Single European Transport Area (Link 2). It also draws from a high-level 2011 EC paper titled: White Paper: Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system (white paper is profiled as a separate item). The Vision is heavily technology-driven and foresees digitalization, automation and smart infrastructure significantly enhancing the efficiency of rail operations while eliminating carbon emissions.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
European Commission (EC)	White Paper: Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system	EU / 2011 - 2012	To ensure continued economic and environmental viability of the rail sector in Europe.	Reducing emissions and oil use is a core objective, to be addressed by new technology and infrastructure. Reducing congestion is a theme too, as are safety, security and noise reduction. Emissions reduction goal for entire transport sector in Europe was 60% of 1990 levels by 2050. Rail was seen as a major contributor towards achieving that goal.	Link 1
The Community of European Railway and Infrastructure Companies (CER) and International Union of Railways (UIC)	Moving Towards Sustainable Mobility: A Strategy for 2030 and Beyond for the European Railway Sector	EU / 2010	To provide a medium and long term plan for the European rail sector that aligns with broader environmental and public policy objectives.	A voluntary rail industry strategy to highlight rail's low-carbon performance and ensure it plays a central role in global transportation decarbonization strategies. Targeted CO2 reductions from 1990 levels are: 30% by 2020, 50% by 2030, and 100% by 2050. It calls for NOx and PM10 reductions of 40% by 2030 and 100% by 2050 (from 2005 levels). It also calls for a 50% improvement in energy efficiency by 2050. It lays out three broad ways to reduce CO2: improved energy efficiency, the electrification of lines, and the decarbonization of electricity generation. Several CER and UIC programs continue to aim for these targets.	Link 1
Australasian Railway Association (ARA)	Code of Practice for Management of Locomotive Exhaust Emissions	Australia and New Zealand	The Code of Practice describes recommended practices for the management and improvement of exhaust emissions of diesel freight locomotives in the Australian railway industry	The Code 1) sets a maximum particulate emission standard for new locomotives and 2) requires that locomotives receiving a major overhaul will, where current emissions of particulate matter are greater than 0.3g/kWh, be fitted with an upgrade kit to bring emissions to or below that level. ARA publishes data provided to it by freight rail operators to meet the operators' obligations under the Code of Practice. The Code focuses on two key priorities: GHGs and diesel particulates. Companies are required to report annually on their implementation of the Code.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Japan Ministry of Infrastructure Transport and Tourism (MLIT)	Eco Rail Line Project	Japan / 2016 - ongoing	Promote reductions in energy usage by rail lines and the adoption of carbon emission reduction technologies	The MLIT implements the Eco Rail Line Project, supporting rail operators who are implementing systematic efforts to reduce power consumption and carbon emissions for entire rail lines by using renewable energy in train stations and train control centers and installing energy saving facilities for efficient energy usage.	Link 1
Japan Ministry of Infrastructure Transport and Tourism (MLIT) / Railway Freight Association (RFA)	Eco Rail Mark	Japan / 2005 - ongoing	The "Eco Rail Mark" program was established in 2005 to certify companies and products which are proactively working to achieve low environmental impact rail freight transport. It is intended to support and promote a modal shift to freight rail transport.	Supporting companies and products certified with the "Eco Rail Mark" raises awareness of environmental impact reduction efforts among freight companies, manufacturers, and consumers. The MLIT and Railway Freight Association (RFA) are striving to further promote and expand the "Eco Rail Mark". As of September 2017 there are 188 "Eco Rail Mark" product certifications for 213 products, 85 certified companies, and 31 certified supporting companies.	Link 1
The Association of Japanese Private Railways	Commitment to a Low Carbon Society	Japan / 2020 and 2030 targets	Commitment targets: • Reduce power usage by 5.7% by 2020 in comparison to 2010; • Reduce power usage by over 5.7% by 2030 in comparison to 2010	The Commitment includes the following primary measures as means to reduce energy usage from the rail sector: • Introduction of energy saving cars: Energy saving trains such as VVVF controlled trains, which consume less power, and regenerative brake-equipped trains, which efficiently use power, are being introduced. • Usage of energy saving systems (regenerative brakes, regenerated power storage devices). Trains with regenerative brakes, which generate power when braking and return the power to the overhead power lines for reuse, are being actively introduced. • Noise and vibration reduction: Efforts to reduce noise and vibration include the introduction of reduced noise trains, the use of long rails to reduce the number of rail joints, the use of synthetic crossties, and the installation of elastic material such as rubber between concrete railbeds and crossties. • Use of natural energy: Solar panels and wind power generators are being installed on the roofs of stations, using sunlight and wind to generate the power used by the stations.	Link 1

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
Russian Railways	Electrification program: Trans-Siberian Railway (TSR)	Russia / 2002 (TSR electrification completed) – 2030 (upgrades and modernization)	Electrify the entire Trans-Siberian Railway network (~9,300 km) and additional rail corridors	Russia has accelerated electrification programs since 2000 with the stated goal of electrifying all major corridors in its rail network. Trans-Siberian railway electrification, which technically began 1929, was completed in 2002. This important freight corridor has seen increasing traffic – particularly international container freight – despite the challenging winter weather conditions. Traction voltage used is 3 kV DC, with 25 kV AC in some sections. The entire railway is a double track network. As part of a 3.2 trillion Rouble ($64B CAD) modernization and upgrading program, state-owned Russian Railways will electrify more than 7,400 km of track over the period 2008 to 2030, financed in part through public-private partnerships.	Link 1 Link 2
Indian Railways	Broad gauge rail network electrification	India / 2014 - 2023	Completely electrify India's broad gauge rail network by 2023	The Government of India has prioritized rail electrification to reduce costs, improve capacity and reduce dependence on foreign oil. 5,186 route kilometers were electrified between 2014 and 2017 alone. 58%, or 37,500 km, of the national broad gauge network is electrified as of early 2020. The remaining 27,000 km will be electrified between 2020 and 2023. Approximately two thirds of freight is currently moved by electric traction in India.	Link 1 Link 2 Link 3
Central Government of the People's Republic of China	Rail and transport hub electrification	China		China has seen rapid growth in railway electrification due to an extensive railway infrastructure investment program under the last three successive Five-Year Plans. Investment in railway fixed assets has exceeded 800 billion Yuan ($190B CAD) in each of the past five years. Nearly half (47%) of the Chinese railroad track was electrified by 2010. Close to 70% of China's 127,000 km rail transport network was electrified by the end of 2017. This includes over 22,000 km of high speed rail – the longest such national network in the world. In 2016, 75% of all rail activity (passenger and freight combined) was on electric trains, up from 21% in 1995. China is also pursuing the electrification of all major shipping ports and harbours on the Yangtze River and at other intermodal shipping hubs.	Link 1 Link 2

Owner/ Stakeholders	Title	Location / Timeline	Objectives	Description	Links
International Union of Railways (UIC)	Energy Efficiency Best Practice Workshops	Global / 2015 - 2017	To facilitate the exchange of experiences to provide practical advice to practitioners attempting to achieve energy efficiency improvements, and thereby reduce costs and emissions.	In recent years many projects have delivered promising results for energy efficiency (Railenergy, CleanER-D, Energy consumption, Parked Trains, etc.) and other important ones are ongoing (MERLIN, Shift2Rail). What is in many cases lacking is knowledge related to practical implementation and optimization in the field. This project develops and communicates best practices for rail energy efficiency through a series of workshops. These workshops will bring together experts to share experiences, find solutions and overcome obstacles. This series was followed-up by a European-specific workshop series from 2018-2020.	Link 1 Link 2
International Union of Railways (UIC)	Door to Door	Global / 2018 - ongoing	To support sustainable mobility strategies in countries and regions globally, by providing expertise on last mile mobility best practice in the passenger rail sector.	Passenger rail use could be increased through the provision of enhanced last mile mobility options for travellers. A modal shift to rail will lead to a wide range of environment, social and economic benefits, such as reduced congestion, improved air quality, reduced CO2 emissions, and equitable access to transportation services. This project assesses various options from multiple perspectives to provide guidance on last mile mobility solutions.	Link 1