GROWING AND GREENING CANADIAN CONSTRUCTION

Five Ways for Canadian Construction Companies to Build More and Emit Less

Phase 1: OnSite Emissions

The Transition Accelerator
L'Accélérateur de transition

About this Report

This report represents a collaborative effort by Canada's leading general contractors:

Research partner:

Acknowledgement:

This analysis is based on real operational data from 617 construction projects across Canada, representing the most comprehensive sector-wide emissions analysis conducted to date. We thank all participating companies for their transparency and commitment to advancing sustainable construction practices.

Executive Summary

Canada's Construction Sector: A Strategic Roadmap for Decarbonization

Canada's construction sector faces unprecedented infrastructure demands while navigating the imperative to reduce greenhouse gas emissions. This report, developed through a voluntary collaboration among industry leaders Aecon, Bird, Chandos, EllisDon, Graham, Ledcor, Multiplex, PCL, and Pomerleau in partnership with the Transition Accelerator, presents a strategic roadmap for achieving substantial emissions reduction from construction jobsite activities (A5 in the lifecycle stages), while strengthening competitive positioning.

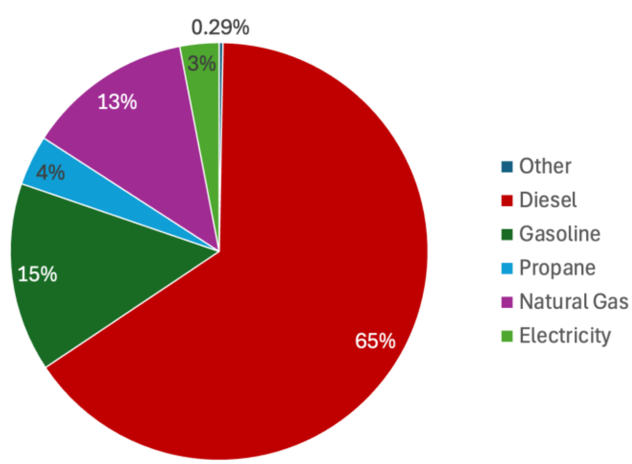
Based on the most comprehensive analysis of Canadian construction emissions conducted to date—drawing from 600+ real-world projects—this analysis provides practical cost-effective pathways that aim to simultaneously address decarbonization and enhance operational performance.

The Strategic Context: Building What Canada Needs

Canada's construction demands are extraordinary: 3.5 million new homes by 2030, $130 billion in transit infrastructure, $24 billion in healthcare facilities, and over $630 billion in industrial projects. The construction sector, responsible for an estimated 4% to 13% of national emissions depending on scope definition, will play a pivotal role in meeting Canada's commitment to reduce GHG emissions and achieve net-zero by 2050.

Construction-related emissions are significantly underestimated in national inventories, especially when considered in the broader context of building sector emissions. Notably, embodied carbon emissions from building products has a significant contribution to the sector's emissions profile. Yet, our analysis shows that construction processes alone represent a substantial and distinct source of emissions.

The sector's emissions profile for construction jobsite activities is dominated by diesel fuel consumption (65% of project emissions), followed by gasoline (15%) and natural gas (13%). The comprehensive project data analysis demonstrates that remote locations and diesel-dependent operations drive the highest emission intensities, while grid-connected projects demonstrate significantly lower environmental impacts. It is also important to underscore that general contractors often have limited direct control over all emission sources, as these stem not only from their own operations but also from decisions made by clients and subcontractors.

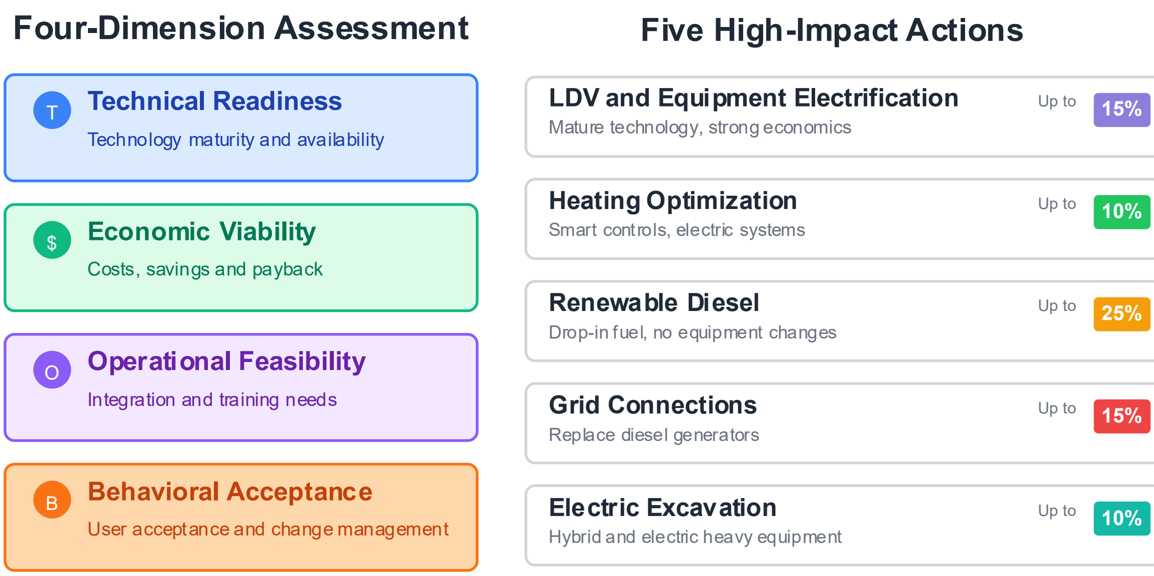


Proportion of emissions attributable to each fuel type

Rather than treating emissions reduction as a separate objective, this report examines how decarbonization can be integrated with and support the industry's core priorities of building more efficiently and affordably. This multidimensional approach serves as a critical stress test that filters out theoretical options and focuses on what is truly implementable.

Five High-Impact Actions: Practical and Integrated Solutions

To identify the most practical decarbonization pathways, each equipment category and fuel type was analyzed across the four key dimensions Listed below. This assessment, grounded in real-world project data and sector expertise, revealed five coordinated actions that can reduce emissions from jobsites by 75% while delivering immediate business benefits:



Action 1: Electrify Light-Duty Vehicles and Small Equipment Light-duty vehicles scored highest across all assessment dimensions, with mature electric technology, strong economics, and minimal operational changes required. This action contributes up to 15% of total emissions reduction by eliminating gasoline consumption and displacing some diesel usage.

Action 2: Optimize and Electrify Heating Systems Heating emerged as a major emission source, particularly in cold climates and remote locations. Diesel remains the dominant heating fuel on many sites due to its high energy density, ease of transportation, and wide availability. Optimizing heating presents an immediate opportunity for cost savings and emissions reductions. When combined with the electrification of the heat source, this approach can contribute up to 10% emissions reduction while improving worker comfort and reducing fuel costs by displacing natural gas and some diesel heating systems.

Action 3: Adopt Renewable Diesel as Bridge Fuel For heavy equipment where electrification faces technical or economic barriers, renewable diesel provides immediate 40-80% lifecycle emission reductions without equipment modifications. While renewable diesel can achieve 80% emission reductions per litre, this action contributes up to 25% of total project emissions reduction because it addresses the remaining diesel consumption after other actions have already displaced significant diesel usage through electrification and grid connections.

Action 4: Connect to Grid Power Instead of Diesel Generators Project data revealed generators as major emission sources at remote sites. Grid connections or hybrid systems contribute up to 15% emissions reduction while reducing noise and operating costs by eliminating diesel generator usage and enabling broader site electrification.

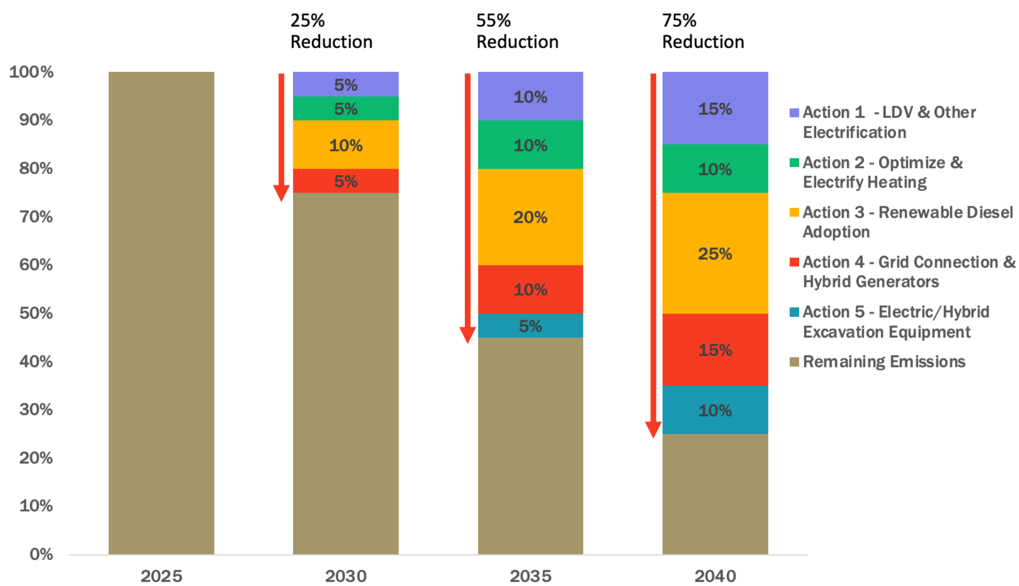
Action 5: Deploy Hybrid and Electric Excavation Equipment While heavy equipment electrification scored lower on current readiness, hybrid and electric systems contribute up to 10% emissions reduction while building operational experience with next-generation technologies and further reducing diesel dependency in heavy equipment operations.

Recommended Implementation Timeline: Balancing Ambition with Pragmatism

These projections provide directional understanding of emission reduction potential across the sector while recognizing that company-specific circumstances may differ significantly from these industry-level estimates. The pragmatic approach balances technical feasibility with economic viability, operational constraints, and organizational readiness for change, based on realistic fleet turnover cycles and typical infrastructure development timelines. The analysis establishes foundational groundwork for strategic planning, helping companies understand the order of magnitude of various strategies that will align the sector toward emission reductions.

- **By 2030: 25% Total Reduction** - Early adoption through vehicle electrification (5%), heating optimization (5%), renewable diesel adoption (10%), and grid connections (5%).
- **By 2035: 55% Total Reduction** - Scaled implementation with renewable diesel reaching 20% cumulative impact and electric excavation equipment beginning deployment.
- **By 2040: 75% Total Reduction** - Mature adoption with renewable diesel as the largest contributor (25%), followed by vehicle electrification and grid connections (15% each).

Companies with ambitious sustainability commitments can accelerate these timelines to achieve higher reductions by 2030.



Enabling Market Transformation

Success requires coordinated action across the entire value chain, with each stakeholder playing a critical role in scaling decarbonization technologies from pilot projects to industry-wide adoption:

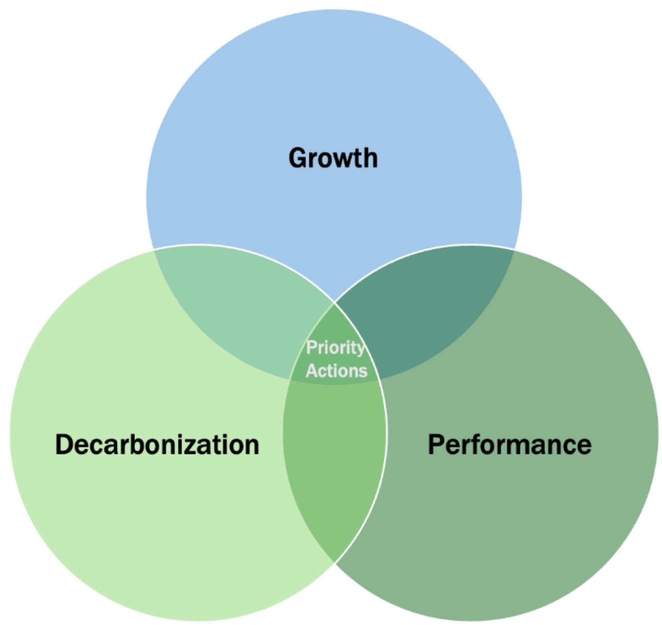
- **Construction Companies:** Drive adoption through collective procurement power, early implementation, and workforce training to build market demand and operational expertise.

- **Equipment Manufacturers:** Expand electric product lines, provide operator training, and offer flexible rental terms to reduce customer risk and accelerate technology deployment.
- **Utilities and Energy Providers:** Streamline grid connection processes, offer rapid hookup services, and develop charging infrastructure to enable widespread electrification.
- **Fuel Distributors:** Secure renewable diesel supply chains, expand distribution infrastructure, and educate customers to make alternative fuels readily available.
- **Governments:** Sustain incentives for clean technology adoption while leading through public procurement requirements that create market demand and demonstrate viability.

Strategic Value of Coordinated Action

The five high-impact actions represent more than individual initiatives—they form a coordinated strategy that amplifies the construction sector's competitive advantages while achieving substantial emissions reductions. When implemented together, these actions create an amplification effect across three critical business dimensions:

- **Construction Company Growth:** Actions create new market opportunities, establish leadership in emerging low-carbon markets, and drive industry transformation through collective implementation.
- **Decarbonization of Operations:** Up to 55% emissions reduction achievable by 2035, positioning the sector to meet evolving climate requirements while contributing to Canada's national targets.
- **Project Performance Excellence:** Cost control through lower operating costs and reduced maintenance, schedule reliability through optimized equipment, quality assurance via precise control systems, and safety leadership through cleaner work environments.



Strategic Implementation Approach

Successful implementation requires a coordinated approach that leverages current market conditions, builds on proven economic models, and engages stakeholders across the entire value chain to create the enabling conditions for widespread adoption.

- **Build on Current Momentum:** Leverage government emphasis on infrastructure building to align decarbonization with national priorities.
- **Focus on Economic Winners:** Prioritize actions with clear payback periods to demonstrate value and build momentum.
- **Coordinate Across Value Chain:** Use collective buying power to influence suppliers while demonstrating value to clients and policymakers.
- **Lead Through Procurement:** Government clients can accelerate adoption through contract requirements for electric equipment, renewable fuels, and grid connections.

The Path Forward

The construction industry has everything needed to begin this transformation: proven technologies, viable business cases, willing partners, and growing client demand. These five actions provide a practical roadmap treating decarbonization as core business improvement rather than environmental compliance.

By implementing these evidence-based actions, Canada's construction sector can achieve up to 75% emission reduction over the next 15 years while building the foundation for continued growth and competitiveness. The question is not whether to act, but how quickly the industry can move forward together.

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I. Introduction

Growing and Decarbonizing Construction Companies

Canada's construction sector is at a hinge moment as it grows to create high-paying jobs and build high-quality projects, while greening and decarbonizing how it builds. More can be done to support growth of Canadian construction companies to prosper and profit, while becoming even more environmentally efficient with lower greenhouse gas (GHG) emissions generated from building projects.

Canada has committed to reducing GHG emissions by 40%-45% below 2005 levels by 2030 and achieving net-zero emissions by 2050. To meet these targets, the construction sector—responsible for an estimated 1.5% to 13% of national emissions, depending on how its footprint is defined, will play a pivotal role. Its broad influence across materials, energy use, and infrastructure development positions it as a key lever in the country's overall decarbonization strategy.

Already, the largest leading general contractors are delivering new infrastructure and aspiring to reduce GHGs as part of their business performance. While infrastructure owners decide on what gets built, the largest contractors are modernizing how they build and already putting in place practical and operational solutions on construction sites.

Decarbonizing construction and making climate action a competitive advantage for the sector won't happen one project or company at a time. The construction sector, taking specific actions with greater scale and speed, can grow and become greener.

Identifying Sector Challenges to Climate Action

The need to build more infrastructure is clear – rapidly expanding housing supply, modernizing aging public infrastructure from health to defence, and developing new industrial infrastructure from energy to trade networks at a time of significant economic uncertainty.

Inflation caused by the pandemic impacted construction projects and companies. Now, companies face tariff-induced unpredictable material costs, skilled labour shortages, complex project risks, and evolving client expectations around project sustainability. The global trading system is undergoing significant shifts in response to high and broad-based tariffs, particularly affecting building materials like aluminum, lumber, steel, and other more specific components. While tariffs may increase cost volatility in the short term, they could also stimulate domestic production of construction materials and equipment, potentially strengthening Canadian supply chains.

In this challenging context, any private sector action to reduce emissions in construction operations must intersect with strategies that avoid driving up costs and slowing down delivery.

Proposing Practical, Operational, and Integrated Solutions

This report focuses on practical approaches that can simultaneously address decarbonization of construction operations without limiting private sector growth by general contractors.

Rather than treating emissions reduction as a separate objective, we examine how it can be integrated with and support the industry's core priorities of building more efficiently and affordably. In doing so, we assess decarbonization solutions through the lens of technical feasibility, economic viability, operational alignment, and behavioural fit within the industry. This multidimensional approach serves as a critical stress test—filtering out theoretical options and focusing on what is truly implementable—thereby enhancing the credibility and relevance of the proposed pathways.

Indeed, for construction companies, this approach offers multiple benefits. More efficient equipment typically means lower fuel costs and reduced maintenance downtime. Strategic electrification can shield operations from volatile fuel markets. Prefabrication and modular approaches that could reduce material waste also accelerate project schedules. And companies that adopt these practices early are better positioned to access preferential financing, attract talent in a tight labor market, and win contracts from clients increasingly focused on lifecycle performance.

Working to Improve the Construction Industry

This report is the result of work by and for a group of the largest Canadian general contractors. It was prepared in partnership with the Transition Accelerator to identify high-impact, practical strategies that deliver emissions reduction alongside cost and schedule improvements. The work was made possible because of extensive collaboration amongst industry leaders Aecon, Bird, Chandos, EllisDon, Graham, Ledcor, Multiplex, PCL, and Pomerleau. All companies involved contributed operational information and real-world data from hundreds of Canadian construction projects.

The analysis focuses primarily on energy use and associated emissions from construction activities themselves. This includes direct emissions from fuel combustion on construction sites, emissions associated with purchased electricity, and in some analyses, broader lifecycle considerations for certain fuels. Future work will examine emissions embedded in construction materials and from building operations.

By outlining key directional actions and providing relevant data, this report aims to support construction companies in developing strategies that enhance both decarbonization and economic performance, tailored to their specific operations yet grounded in a shared understanding of available technologies, costs, and opportunities. It also seeks to identify the critical roles and actions that external market actors—such as suppliers, regulators, and policymakers—must undertake to enable and accelerate the construction industry's decarbonization.

This report explores:

- **Why Construction Decarbonization Matters** The role of general contractors is critical to Canada's economy and this section outlines the key challenges facing construction companies, especially with regard to decarbonization.
- **What Project Data Shows** Real-world emissions from hundreds of Canadian construction projects are analyzed to show what's actually happening on job sites across the country, identifying where the biggest opportunities for improvement exist.
- **Pathways to Decarbonization** This section evaluates specific technologies and approaches based on their technical feasibility, economic viability, operational considerations, and behavioral factors. We provide a clear-eyed assessment of what's ready now versus what needs more time to mature.
- **Making It Happen** The heart of the report—five concrete, high-impact actions the industry can take now, with specific steps for construction companies and other stakeholders. These "no regrets" moves make business sense today while positioning the sector for future opportunities.

Whether you read cover-to-cover or jump straight to the recommendations, we've designed this report to provide practical insights for construction leaders navigating today's complex building landscape. In particular, it focuses on the decarbonization of construction job sites, offering targeted strategies and data-driven pathways to help the sector reduce emissions while maintaining operational efficiency.

II. Why Construction Decarbonization Matters?

Building What Canada Needs

Canada's construction sector is essential to Canada's national priorities: housing supply, infrastructure modernization, business-led economic growth, labour force capacity, and decarbonization.

Here's a snapshot of what needs to get built in Canada by the private sector general contractors and their partners like subcontractors, skilled trades, and other design, engineering, and finance partners:

- **Housing**: Canada faces a critical housing shortage, with estimates suggesting we need up to 3.5 million new homes by 2030 to address affordability and meet population growth.[1] Construction will need to increase from the current rate of ~250,000 homes per year to meet demand.[2] Additionally, stormwater, water and wastewater systems all need to be built out as enabling infrastructure for housing.
- **Public transit infrastructure:** The planned expansion of Canadian public transit systems requires investment exceeding $130 billion over the coming decade to reduce congestion and improve mobility.[3]
- **Health care facilities:** Over $24 billion in healthcare and hospital construction projects are currently in procurement across Canada, with another $18 billion of projects under construction to address capacity shortfalls exposed during the pandemic.[4]
- **Trade and Transport infrastructure:** Canada's roads, bridges, ports, and telecommunication infrastructure are aging, and many need upgrading or replacement. Conservative estimates suggest an infrastructure deficit of approximately $270 billion.[5] In light of recent tariffs $5 billion is being put towards a trade diversification corridor fund.[6]
- **Industrial projects:** As of September 2024, more than 500 major projects are planned or under construction in Canada's energy, forest, and mining sectors, with a combined capital value exceeding $630 billion. These investments are critical for maintaining Canadian competitiveness and resource development.[7]
- **Energy Transition:** Meeting Canada's net-zero goals by 2050 involves major investments in grid modernization, renewable energy, and electrified transportation and heating. The Canadian Infrastructure Bank has committed $20 billion for clean electricity and clean growth infrastructure projects.[8] Additional infrastructure will be needed for alternative fuels and hydrogen.

For the construction industry, this represents both an opportunity and a challenge. Industry forecasts anticipate substantial growth, with annual expansion potentially exceeding 8% and market size reaching

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[1] https://www.cmhc-schl.gc.ca/professionals/housing-markets-data-and-research/housing-research/research-reports/accelerate-supply/housing-shortages-canada-updating-how-much-we-need-by-2030

[2] https://www.cmhc-schl.gc.ca/professionals/housing-markets-data-and-research/market-reports/housing-market/housing-market-outlook

[3] https://it.steergroup.com/it/insights/notizia/future-transit-infrastructure-investment-canada

[4] https://outpostrecruitment.com/blog/job-search/healthcare-construction-canada/

[5] Boston Consulting Group (BCG), 2019. 15 things to know about Canadian Infrastructure.

[6] https://liberal.ca/mark-carneys-liberals-announce-plan-to-diversify-canadian-trade-by-improving-canadas-trade-enabling-infrastructure/

[7] https://natural-resources.canada.ca/science-data/data-analysis/natural-resources-major-projects-planned-under-construction-2024-2034

[8] https://www.canada.ca/en/department-finance/news/2023/03/a-made-in-canada-plan-affordable-energy-good-jobs-and-a-growing-clean-economy.html

between $261 and $575 billion by 2030. However, delivering this volume of construction while managing costs and timelines will require significant innovation and efficiency improvements across the sector.[9,10]

Construction Sector Context

Recognizing the need to build is only the first step. Delivering on that ambition is another challenge entirely. Even with growing demand, there are a number of barriers or considerations that face Canada's construction sector and can impede progress.

Meeting sector and government climate objectives

To date, efforts to decarbonize the construction sector have been largely pursued at the level of individual companies. While these initiatives reflect the growing leadership within the sector, a coordinated, industry-wide strategy is now essential to accelerate momentum and ensure continued contribution to Canada's emissions reduction targets. Under the Paris Agreement, Canada has pledged to cut GHG emissions by at least 40% below 2005 levels by 2030 and reach net-zero emissions by 2050. The construction sector, which accounts for between 1.5%[11] and 13%[12] of the country's emissions (depending on how the footprint is counted), will necessarily need to be a large contributor. Many provincial governments have put forward similar commitments.

Changing Standards for Building Performance and Embodied Carbon

A growing number of project commissions from both government and the private sector require the project to deliver lower emissions and increased resilience to extreme weather. Some of these expectations are for operating performance—buildings that deliver improved operating efficiency. But there is also a push for more sustainable, lower-carbon construction processes and materials. For example, beginning in 2025, new federal buildings will be required to have at least 30% lower embodied carbon in their major materials.[13] Vancouver has set targets to cut embodied emissions from construction by 40% by 2030.[14] Similarly, many private developers and construction firms are setting their own embodied carbon reduction targets and adopting leading standards and tools. This includes pursuing LEED or IFLI green building certifications and using the EC3 calculator to guide low-carbon designs.

Rising Costs and Supply Chain Issues

In the past five years, prices have been both high and volatile for critical building materials such as lumber, steel, and concrete. Global supply chain disruptions, trade policies, high demand, and a reliance on imported construction materials have all contributed to cost pressures.[15] Fuel and power costs have also risen impacting project budgets across the country.

Labour Shortages

There is a shortage of skilled labour in Canada. Around 700,000 construction workers are expected to retire by 2028[16] and more throughout the 2030s[17], with the retirement rate outpacing the current rate of recruitment. Contractors have reported that trade vacancies are already leading to labour cost increases and project delays. Additionally, new skill sets, and training or retraining are required for green buildings and energy transition projects.

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[9] https://www.researchandmarkets.com/reports/5918182/canada-construction-industry-databook-market. Canada Construction Industry Databook - Market Size & Forecast by Value & Volume

[10] https://www.nextmsc.com/report/canada-construction-market

[11] https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=aaa&juris=ca&year=2021&rn=3&page=0

[12] https://onlinelibrary.wiley.com/doi/10.1111/jiec.13548

[13] https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html

[14] https://vancouver.ca/green-vancouver/buildings.aspx

[15] https://suncorpvaluations.com/insight/impact-of-tariffs-and-labor-shortages

[16] https://suncorpvaluations.com/insight/impact-of-tariffs-and-labor-shortages

[17] https://www150.statcan.gc.ca/n1/pub/75-006-x/2024001/article/00005-eng.htm

Regulatory and Permitting Inefficiencies

Regulatory and permitting inefficiencies at federal, provincial and municipal levels can slow down project approval and construction. While this problem has been recognized in many jurisdictions and some steps are being taken, it has not yet been addressed comprehensively.

Access to financing and insurance

The ability to access financing and insurance has been changing over the past few years, for everything from major projects to individual homes. Increasingly, financing and insurance is predicated on the project's resilience to extreme conditions, climate performance, as well as the project's emissions.[18]

[18] https://www.mccarthy.ca/en/insights/articles/risky-business-how-carbon-emissions-are-impacting-lending-behaviour-and-access-capital

III. What Project Data Shows

This section provides an analysis of emissions based on real-world data about Canadian construction projects provided by members of the Construction Leaders Sustainability Working Group. As such, it represents real information specific to the Canadian context—not just theoretical estimates or analysis from other countries.

The analysis is based on information **from 617 projects across the country**, provided by Aecon, Bird, Chandos, EllisDon, Graham, Ledcor, Multiplex, PCL, and Pomerleau.[19] This represents the most comprehensive analysis of Canadian construction emissions performed to date, providing a reliable foundation for identifying sectoral patterns and opportunities.

This report focuses on emissions resulting from **energy use during on-site construction activities**. To provide a comprehensive assessment, we analyze full lifecycle emissions for all fuel types, including:

- Direct emissions from fuel combustion on-site
- Electricity used on-site (including generation emissions)
- Upstream emissions from fuel production, processing, and transportation

Energy used by all on-site activities was accounted for, including those performed by the contractor and subcontractors, as well as energy paid for by the client.[20]

This approach was chosen because it provides the most complete picture of climate impact and allows for fair comparison between different energy sources. In our analysis, lifecycle emissions associated with energy use are split between on-site emissions and upstream emissions from on-site energy use (A5 in Figure 1).[21]

This on-site activity focus spans across traditional Scope classifications—including Scope 1 (direct fuel combustion), Scope 2 (purchased electricity), and relevant Scope 3 (upstream fuel production)—to provide construction managers with the complete emissions picture needed for practical decarbonization decisions. This approach complements rather than replaces standard GHG accounting frameworks by offering a construction-specific analytical lens.

The analysis does not include other supply chain emissions such as employee commuting to work, those embodied in building materials or equipment, and other elements of the supply chain.

This framework is designed to support practical decarbonization strategies rather than formal emissions accounting or reporting. It allows construction companies to identify and prioritize the most impactful emissions reduction opportunities regardless of which entity has direct control over specific activities.

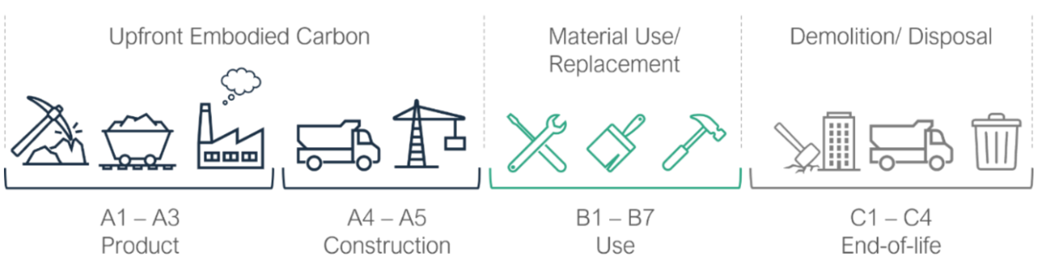

Figure 1 Lifecycle stages of construction materials and associated emissions

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[19] More projects were received but these were eliminated due to missing emissions, fuel type, cost, or timeline information.

[20] Approximation methods for missing or underestimated energy values are explained in the section 3.3 of the Methods Appendix.

[21] Calculation of upstream emissions is explained in section 5.2 of the Methods Appendix.

This dataset represents the most comprehensive analysis of Canadian construction emissions performed to date, providing a reliable foundation for identifying sectoral patterns and opportunities.

The data shared by companies about project-level emissions is commercially sensitive. This analysis has been careful to present aggregated data in ways that preserve the confidentiality and anonymity of specific companies and projects.

The dataset included substantial missing and inconsistent information across projects, requiring a number of assumptions to make the data usable (see Appendix 2 – Methods). While the analysis offers valuable insights, the results are best used to help the industry understand the broader emissions landscape and inform strategies for reducing those emissions.

To unpack the real-world data received from companies, this chapter analyzes emissions from the sample size of 617 projects across four criteria:

1. Project type;
2. Activities and equipment;
3. Fuel type; and
4. Project location.

Emissions by Project Type

The dataset included a diverse range of construction project types—bridges, hospitals, residential housing developments, transit infrastructure, and much more. While construction projects often share some common features, they can also differ substantially in terms of scale, material needs, and construction methods. This part of the analysis explores how emissions varied across different types of projects.

The projects were grouped into five project types as shown in **Table 1.**

Table 1: Project type groupings

Group	Buildings	Industrial Facilities and Energy Infrastructure	Linear Transportation Infrastructure	Nodes and Hubs	Water Management Infrastructure
What it includes	Buildings where people live, work and gather: • Residential • Commercial • Schools and universities • Community centres • Hospital or clinics • Public and government buildings • Correctional centres • Emergency services • Places of worship	• Light, medium and heavy industrial facilities • Energy and power generation facilities	• Bridges • Pipelines • Rail • Roads • Transit • Tunnels • Other civil transport infrastructure	• Airports • Ports and marine infrastructure • Marine infrastructure • Parks and other public recreation sites • Parkades	• Dams • Flood mitigation or retaining structures • Stormwater • Wastewater or water treatment facilities
Number of projects	399	68	74	30	46

Figure 2 compares emissions across the five project types using a whisker plot that shows median values and ranges. We excluded a few projects with extremely high emissions per dollar to make the chart easier to read.[22]

The median emissions (shown by the narrow belt in each bar) vary by project type. Industrial and energy facilities had the lowest median emissions at 9.2 tonnes CO_2e per million dollars, while node and hub projects had the highest at 17.5 tonnes CO_2e/$M.

However, looking beyond the medians reveals important context. The colored boxes show where the middle 50% of projects fall, and the lines (whiskers) show the broader range. There's significant overlap in these ranges across all project types, meaning that even though medians differ, the variation within each type is substantial.

This overlap suggests that project type alone isn't a reliable predictor of emissions for future projects.

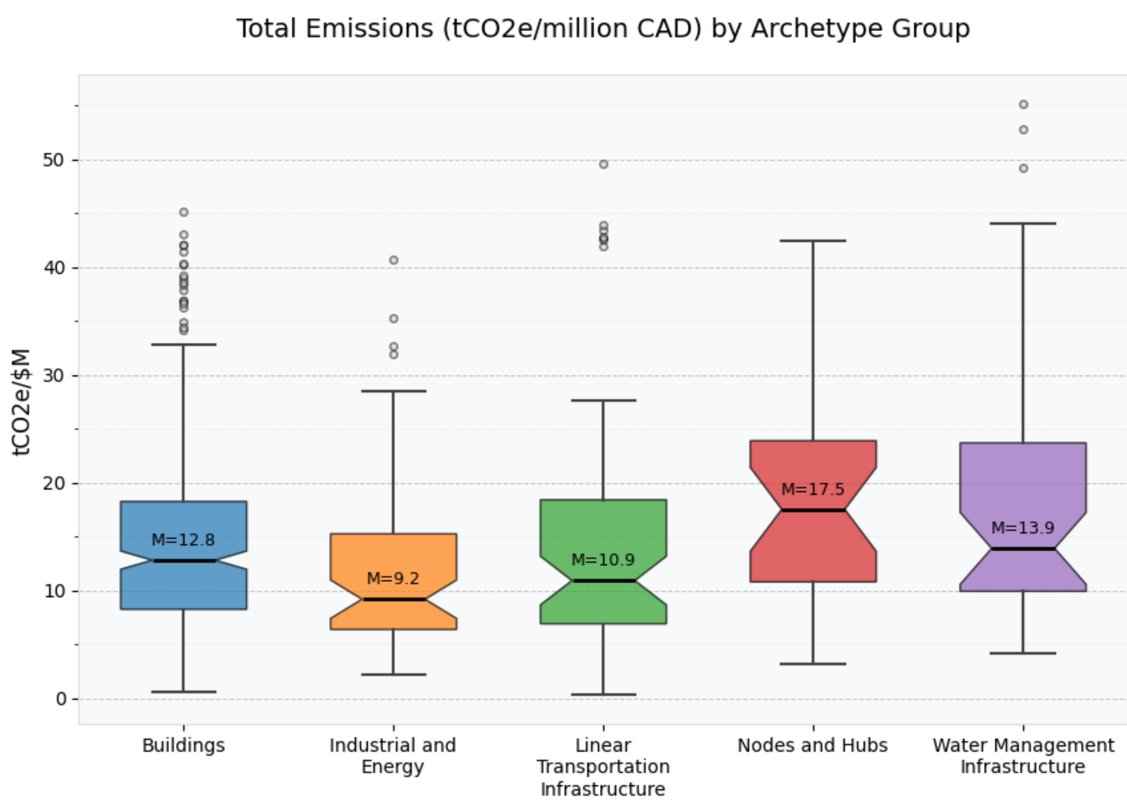


Figure 2: Median per-project emissions by project type

Emissions varied widely across projects but showed the strongest correlation with project cost, 68% overall and up to 100% when subdivided into specific archetypes. Using cost includes limitations, due to inconsistent scope definitions across companies (e.g., inclusion of land, design, or overhead costs) and inability to adjust for inflation or other price increases. However, despite these limitations, cost remained the most practical basis for comparison.

Crucially, it is important to consider projects within their contexts. Higher emissions are primarily linked to remote locations and associated greater diesel usage and concrete-intensive infrastructure like airports,

[22] Variance in project emissions is further explained in section 5.1 of the Methods Appendix.

ports, and water management facilities. When comparing a future project to reported medians, it is essential to account for the project's specific activities and location, particularly the availability of grid energy. These factors have the greatest influence on emissions outcomes.

Moreover, as is discussed later in this report, improving industry-wide data collection would enable an increasingly precise depiction of emission sources and drivers. With a longer time horizon and standardized reporting practices, more nuanced trends, such as regional differences and detailed activity-level emissions, may become visible.

Baseline accuracy could be improved in two ways. First, by standardizing cost reporting across projects and adjusting for inflation and scope differences to ensure more consistent comparisons. Second, by collecting more complete data on physical project attributes such as area or length. These physical metrics offer the potential for a more stable and permanent normalization factor, as they are less affected by external cost fluctuations like inflation, supply chain disruptions, or market volatility.

Emissions by Activities and Equipment

Construction is an energy- intensive industry. The work for any construction project includes hauling, digging, heating, welding, moving, mixing, assembling, and other activities that require reliable, heavy-duty power sources.

Currently, fossil fuels provide almost all of that power. As shown in **Table 2**, most of the **heavy machinery and equipment** used on job sites, including excavators, dozers, cranes, dump trucks, heaters, and generators—as well as a lot of vehicles—use diesel. Gasoline, natural gas, propane and electricity also contribute.

Table 2: Major emissions sources in construction

Category	Examples	Purpose	Fuel Type
A. On-Road Equipment and Vehicles			
A.1 Light duty vehicles	Small trucks and SUVs	Used on-site to transport small equipment and personnel, as well as for commuting to and from worksites.	Mostly gasoline, some diesel
A.2 Medium and heavy-duty vehicles	Large pickup truck and on-site hauling vehicles (class 3-8), and buses	Regional hauls, long-distance transportation, specialized applications such as construction and logistics.	Mostly diesel, can be gasoline for smaller vehicles
B. On-Site Mobile Machinery			
B.1 Excavation and Earthworks	Excavators, dozers, skid-steers, graders, tampers, wheel loaders, drilling rigs, and drum rollers	Digging, earthmoving, and site preparation.	Diesel
B.2 Concrete and Asphalt	Pavers and mixer trucks	Laying concrete, mixing cement, asphalt paving, and finishing.	Diesel
B.3 Misc. Equipment - Land	Articulated hauling trucks, UTVs, and forklifts	Movement of materials, waste, and equipment around site.	Diesel (small sized machinery can be gasoline)
B.4 Misc. Equipment - Marine	Marine vessels (boats)	Transportation of people and materials	Diesel (small sized machinery can be gasoline)

C. Stationary Equipment and Machinery			
C.1 Lighting	Light Towers	Lighting nighttime roadwork, emergency response and site security.	Diesel or gasoline
C.2 Heating	Direct and indirect heaters, gas boilers, and ground thaw systems	Maintain site conditions during cold months, prevent freezing of construction materials, and support temp sensitive processes.	Natural gas, propane, diesel, gasoline
C.3 Cranes and Lifts	Cranes, and boom cranes, aerial platforms, boom lifts, telehandlers, and scissor lifts	Material lifting, handling, structural assembly, and site preparation in a semi-fixed location.	Diesel (small sizes can be gasoline) or electric
C.4 Misc. Equipment	Air filters, compressors, pumps, cement blowers, fans	Drying spaces or concrete, power source for tools, and removing water from dig sites.	Electric, gasoline, diesel, or natural gas
C.5 Small Tools	Concrete hammers and saws, leaf blowers, welders, and fusion machines	Various activities such as welding, concrete removal, and waste removal.	Electric, gasoline
D. On-Site Power			
D.1 Generators	Diesel, gasoline, natural gas or propane generators.	Reliable and portable access to electricity for various construction activities.	Diesel, gasoline, natural gas, propane
D.2 Electrical Connection to the Grid	N/A		Depends on the provincial grid mix

Emissions by Project Location

Our analysis looked at two location factors: whether sites were remote and which province/territory they were in. Location matters because it determines what energy sources are available, which directly impacts emissions.

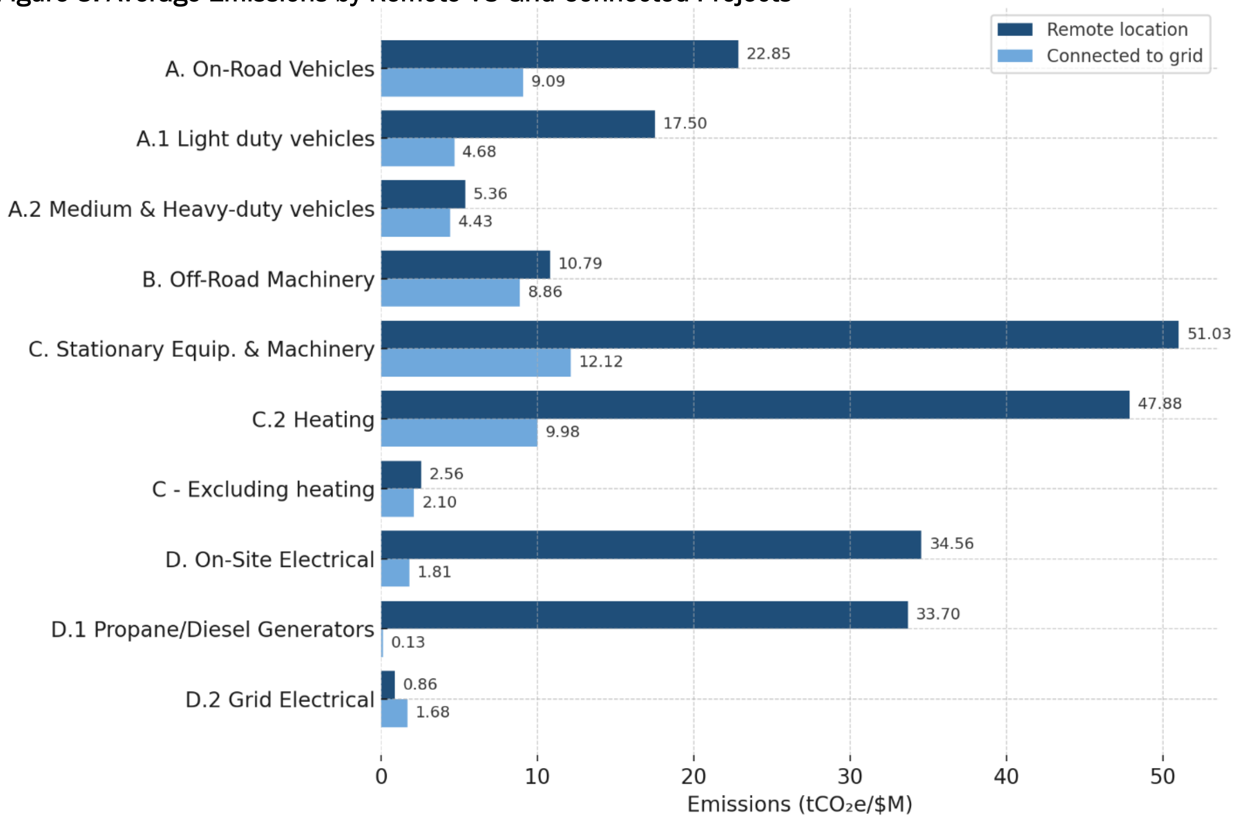
Remote locations (those without access to grid electricity, natural gas networks, or both) typically had to rely on higher-emitting and more expensive fuel sources like diesel.

Figure 3 compares emissions between remote and grid-connected projects. While many equipment categories showed similar emissions regardless of location, three key differences emerged:

1. Heating emissions were much higher in remote locations, likely due to limited availability of natural gas or electricity and increased reliance on diesel
2. Generator emissions were significantly higher in remote areas because of limited grid access
3. Light-duty vehicle emissions were substantially higher in remote locations, possibly due to longer travel distances

When examining provincial differences, we observed variations in emissions profiles, but these differences cannot be attributed solely to provincial location. Multiple confounding variables—including project type distribution, company-specific practices, proportion of remote projects, and other regional factors—make it impossible to isolate province-specific effects. Therefore, we've focused our analysis on the more definitive remote versus grid-connected comparison, which provides clearer insights for emissions reduction strategies. Emissions are greater for remote projects for all but grid electrical as the quantity of electricity used on connected projects is much greater.

Figure 3: Average Emissions by Remote VS Grid-Connected Projects



Emissions by Fuel Type

As noted above, one of the most significant ways that projects differed from one another is in what type of fuels they used, and how they used them. This subsection looks more deeply into the influence of fuel use patterns on project emissions.

The overall share that each fuel type contributed to emissions is shown in **Figure 4**. All fuels are labelled and the portion called "other" refers to fuels of low representation in the data set (small volumes and emissions), these include renewable diesel, biodiesel, acetylene, heavy oil, and light oil.

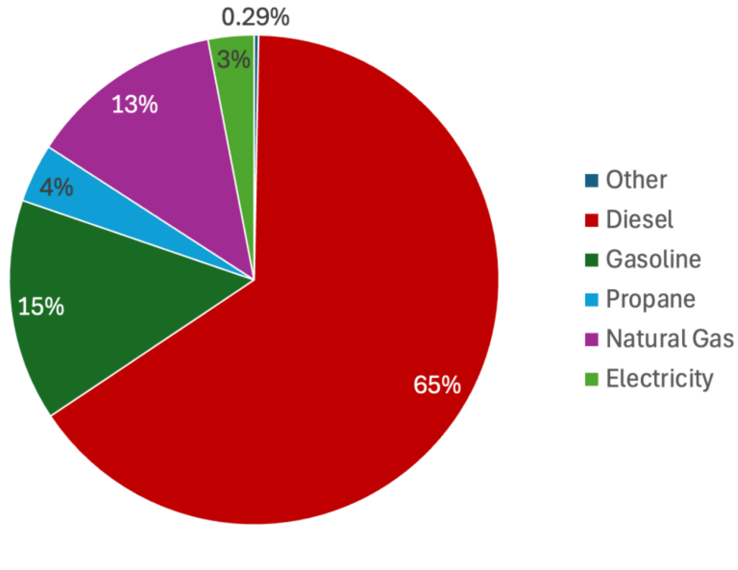


Figure 4: Proportion of emissions attributable to each fuel type

Electricity produces no on-site emissions, making it environmentally optimal. About 90% of projects used grid electricity, though availability depends on location and project characteristics. Remote sites, short-timeline projects, and linear projects often face grid access challenges.

Gasoline contributed 15% of total emissions. Companies reported its primary use was in light-duty vehicles.

Diesel was the largest emissions source, responsible for 65% of all emissions. Many companies lack precise tracking of diesel use, particularly from subcontractors. Better tracking would improve emissions management. Only 5% of projects used renewable or biodiesel alternatives, typically for less than 5% of their diesel needs.

Natural gas contributed 13% of total emissions. It's inexpensive and cleaner than diesel or gasoline, making it popular for heating. However, availability varies by region, with some provinces having limited access. Building projects typically showed higher natural gas use.

Access to electricity is often a key factor that influences project emissions. Remote sites, which often lack reliable grid connections or access to lower-carbon fuels, are typically forced to rely on diesel generators and other high-emitting sources. In contrast, projects in urban or infrastructure-rich areas can more readily tap into the electrical grid or alternative fuels like renewable diesel or propane, leading to significantly lower emissions profiles. This disparity is further exacerbated in smaller projects or those with low completion percentages, where the temporary nature of operations makes the setup of efficient fuel systems economically or logistically impractical.

These factors help explain the wide variance in fuel-type emissions observed across the dataset, particularly where a few remote, fuel-intensive projects disproportionately skew the average.

IV. Pathways to Decarbonization

The construction sector has more energy choices than ever before, each with different implications for emissions, cost, and operations. This section outlines practical decarbonization options and helps companies identify which solutions offer the best opportunities for their specific contexts.

Available Energy Options

Electrification: Electric equipment eliminates direct emissions, reduces maintenance needs, and often has lower operating costs. Many types of construction equipment already have electric versions available, from light vehicles to excavators and tools. While upfront costs are higher, they're offset by lower operating expenses.

- **Challenges**: Limited charging infrastructure, runtime constraints, higher upfront costs, cold weather performance concerns, required behavioural changes, and equipment availability in Canadian markets.

Hybrid Systems: These combine an electric motor with a conventional engine, allowing zero-emissions operation, when possible, with fossil fuel backup when needed. Hybrids offer moderate emission reductions (20-40%) with lower implementation barriers than full electrification.

- **Challenges**: Increased maintenance complexity, reduced performance from higher weights, limited model availability, and technician training requirements.

Renewable Fuels: Renewable diesel and biodiesel can be used in existing equipment with minimal modifications. While they produce similar emissions at the point of use, their lifecycle emissions are 40-80% lower than conventional diesel.

- **Challenges**: Limited supply chain, cost premiums in many regions, cold weather performance issues with higher blends, and warranty concerns from some equipment manufacturers.

Operational Efficiency: Simple changes to site layout, equipment use, and project scheduling can reduce fuel consumption by 15-25%. Anti-idling strategies, optimized traffic flow, and smart heating controls often have quick payback periods.

- **Challenges**: Requires behavioral change, potential scheduling complexity, coordination with multiple subcontractors, and overcoming established practices.

Foundations for Adoption: Technological, Economic, Operational, and Behavioural Considerations

Companies looking to make changes that improve efficiency and reduce emissions face a range of choices. Business managers know that for an alternative to be successfully adopted, it needs to perform well across a number of dimensions – including technological, economic, operational and behavioural considerations.

In assessing the potential opportunities for the construction sector, these four dimensions are crucial to ensure solutions can be appropriately implemented:

Technological Considerations

Technology considerations examine whether a solution is mature, reliable, and readily available for implementation. This dimension evaluates:

- **Maturity level:** Is the technology proven and commercially available, or still in prototype or development stages?
- **Performance reliability**: Does the technology consistently perform the required tasks in various conditions (including challenging environments like extreme weather or remote locations)?
- **Local availability**: Can the equipment or technology be readily sourced in Canada?
- **Technical limitations**: What are the practical constraints (range, power output, run time) that might affect functionality?

Economic Considerations

Economic considerations evaluate the financial viability of adopting new technologies, including:

- **Upfront capital requirements**: What is the purchase premium compared to conventional alternatives?
- **Operational cost savings**: What are the ongoing savings in fuel, maintenance, and other operational expenses?
- **Available incentives**: What government rebates, tax incentives, or other financial support programs can reduce costs?**Total Cost of Ownership and Payback period**: How long will it take for operational savings to recover the initial investment? For instance, while electric excavators may carry a 40-100% upfront cost premium, their significantly lower operating costs can lead to positive returns in 2-3 years depending on usage patterns and local electricity rates.[23]

Operational Considerations

Operational factors examine how easily a solution integrates into existing business processes:

- **Integration complexity**: How disruptive is the change to existing workflows, processes, and site logistics?
- **Infrastructure requirements**: What supporting systems (charging stations, specialized maintenance facilities) are needed?
- **Training needs**: What new skills, certifications, or safety trainings are required for operators and maintenance staff?
- **Downtime implications**: How does the technology affect equipment availability and scheduling?
- **Compatibility with existing systems**: Can the solution work alongside current equipment and processes?

For example, adopting electric heating requires consideration of site electrical capacity, potential grid connection costs, and planning for peak load management.

Behavioural Considerations

Behavioural factors address the human elements that influence technology adoption:

- **Safety perceptions**: How do workers perceive any safety implications of the new technology?
- **User acceptance**: How willing are operators and staff to embrace new technologies?
- **Perception of reliability**: Do staff trust the solution to perform as needed?
- **Cultural resistance**: What established practices or preferences might create resistance?**Change management requirements**: What communication and support strategies are needed for successful adoption?

[23] Additional details on the total cost of ownership are available in Appendix 1.

For instance, while renewable diesel has high behavioural acceptance because it requires no operational changes, fully electric equipment may face initial skepticism about reliability or range that needs to be addressed through demonstration projects and operator training.

By assessing potential decarbonization pathways across these four dimensions, construction companies can make more informed decisions about which solutions are truly ready for implementation, and which may require more development or supporting infrastructure before becoming viable options. This multi-dimensional approach helps identify not just what's possible, but what's practical in the near and medium term.

Connecting the Dots: Evaluating Possible Pathways

What does all this mean for construction companies? Ultimately, it comes down to making choices about the right tools and the right fuels at the right time.

To help with identifying the feasibility and viability of different alternatives, the Transition Accelerator conducted a detailed analysis of how each class of equipment (Categories A.1 through D.2 in Section 2) performed across the four dimensions (technical, economic, operational and behavioural) for the different emissions reduction approaches (electrifying, renewable fuels, hydrogen, operational efficiency).

Each combination of equipment, emissions reduction approach, and dimension was analyzed and scored from 1 to 5. These scores are grounded in the Transition Accelerator’s sector-specific expertise, supported by current data, market intelligence, and real-world project insights. The intention is to allow comparison across different emissions reduction approaches and equipment types.

A score of 1 indicates very low readiness or significant challenges and 5 a high level of readiness or ease in that aspect. For example, a score of 5 in Technology means the solution is proven and commercially available for immediate use, whereas a 1 would mean it is in early development or faces major technical hurdles. A detailed analysis is available in **Appendix 1.**

Example Analysis: Light-Duty Vehicles

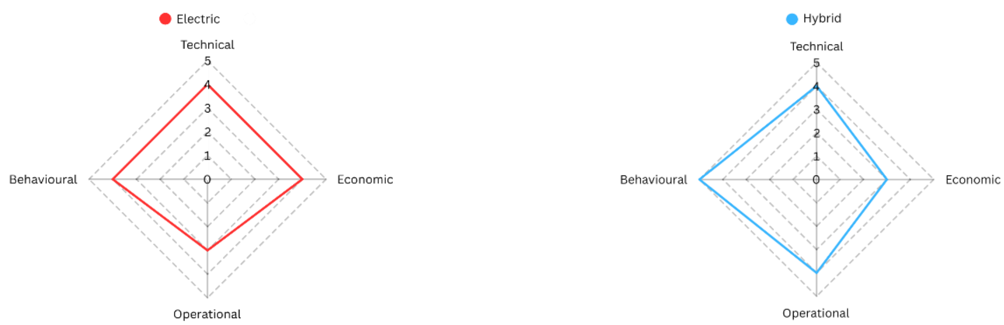
Battery electric vehicles (BEVs) show strong readiness across all dimensions. They eliminate direct emissions entirely, while plug-in hybrids reduce emissions by 50-75% depending on usage. Though BEVs have higher initial costs, operating expenses are substantially lower, resulting in payback periods of 1-2 years in most provinces, enhanced by incentives.

Operationally, they require minimal additional training, though planning for charging infrastructure is essential. Behaviorally, hybrids face fewer adoption barriers due to their operational similarity to conventional vehicles, while full BEVs require addressing range anxiety concerns.

Table 3: Feasibility of lower-emissions alternatives by equipment type

		Emissions	Technology	Economic	Operational	Behavioural
A1 Light Duty Vehicles	**Battery Electric Vehicles**	100% of direct emissions	4	4	3	4
			300-400km range	Higher upfront cost, lower operational	Overnight charging compatible	Range anxiety, unfamiliarity
	Plug-in Hybrid		4	3	4	5

		50-75% depending on usage	Mature technology	10-30% premium	Flexible operation	Proven technology



A.1 Light Duty Vehicles

These pathways analyses provide the foundation for identifying and comparing available decarbonization options based on their technical readiness, feasibility, and potential impact. By evaluating each solution through consistent criteria, we gain a clearer understanding of which approaches are most viable in the near term, and which may require further development or support. This structured assessment enables us to prioritize solutions into high-impact actions, which are explored in detail in the next section.

Key Patterns Across Equipment Types

Our analysis revealed several patterns across equipment categories:

1. **Immediate opportunities exist in light equipment**: Electric light-duty vehicles, small tools, and lighting systems show high readiness across all dimensions.

2. **Medium-term transitions for mid-sized equipment**: Equipment like small excavators and forklifts have viable electric options with moderate economic and operational considerations.

3. **Hybrid solutions as stepping stones**: For larger equipment where full electrification faces challenges, hybrid systems offer a practical transition that reduces emissions while overcoming range and power limitations.

4. **Renewable diesel as a universal bridge**: For equipment without viable electric alternatives, renewable diesel provides immediate emissions reductions without requiring operational changes.

5. **Grid connections over generators:** Where feasible, connecting to the electrical grid offers the most substantial emissions reductions compared to diesel generators.

The complete assessment for all equipment types and approaches is provided in **Appendix 1**, which construction companies can use to guide their equipment-specific decarbonization planning. They also provided the basis for recommending high-impact actions in the following section.

V. Making it Happen – The High Impact Actions

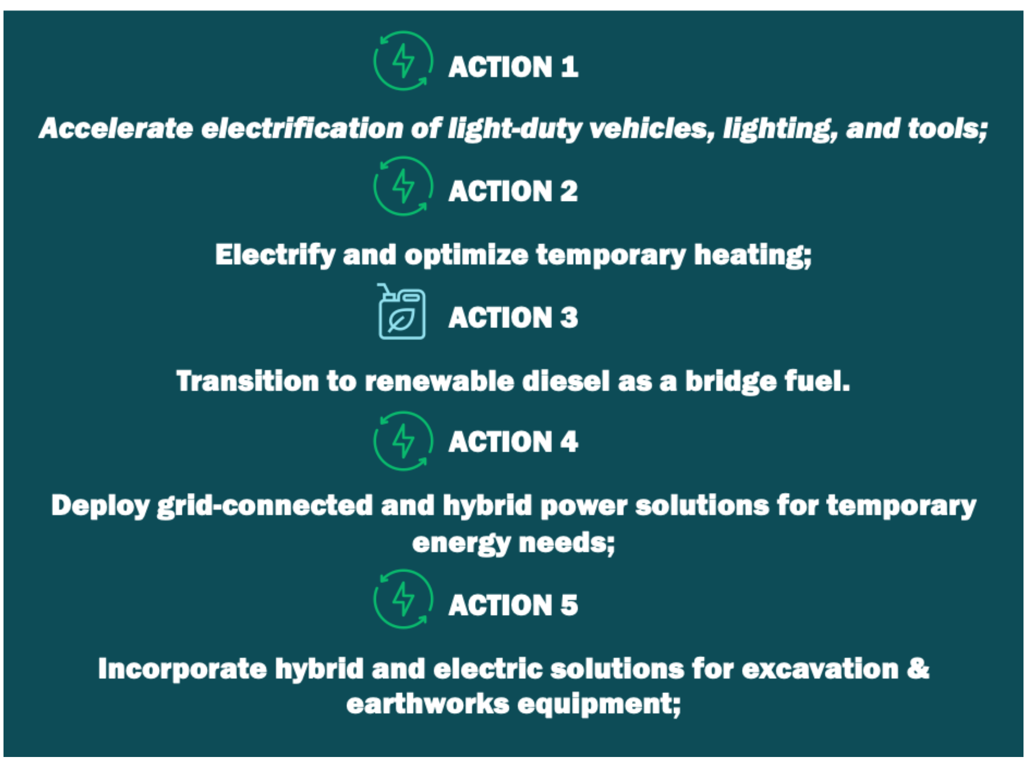
The previous chapter laid out a broad range of options, costs, and opportunities available to the sector. However, effective and successful decarbonization can't and won't happen all at once. It requires thoughtful sequencing and prioritizing actions that will yield the largest returns in efficiency, competitiveness and emissions reduction.

There are five high-impact actions that the construction industry can and should make now. This approach assumes that the market will continue to evolve to meet emerging demand with improved technologies, lower costs, and more accessible solutions. In other words, the challenge is not industry reluctance but rather ensuring that early action creates the right conditions to scale adoption as viable options become more widely available.

The five actions are technically feasible today, economically sensible in many cases, and foundational to deeper decarbonization in the years ahead. Implementing them now helps companies gain experience, reduce near-term emissions, and prepare their operations for the technologies and policies of tomorrow.

Diesel use is the dominant source of on-site construction emissions, accounting for most fuel-related climate impacts. This is why many of the recommended actions—such as equipment electrification, biofuel substitution, and improvements in site power management—are directly aimed at reducing diesel consumption. While not always called out by name, the focus throughout is on the systems and decisions that most significantly influence fossil fuel use, notably diesel, across project types.

The actions should be viewed as a coordinated approach rather than isolated initiatives. As a central industry operating across the entire Canadian economy, the construction sector holds a unique position to influence both upstream suppliers and downstream clients. By sending strong demand signals upstream to equipment manufacturers, energy providers, and technology vendors, while demonstrating value downstream to developers, project owners, and government procurers, the industry can accelerate the market transformation needed to achieve both business and climate objectives.



Action 1. Accelerate Electrification of Light-Duty Vehicles, Lighting, and Tools

This action delivers substantial emissions reductions with proven technologies and many cases strong economic rationale. Electrified vehicles, lighting, and tools are often superior, operating costs are lower, some subsidies are offered, and the equipment is widely available. Energy-efficient LED lighting and solar-powered lighting solutions further reduce emissions and energy costs on site.

Key Benefits

- Mature, cost-competitive solutions
- Rapid deployment potential
- Some incentives available
- Eliminates on-site emissions

Issues to Address

- Charging infrastructure and power access
- Range and performance concerns
- Fleet turnover time

The Impact

If this action achieved 100% implementation, nearly all gasoline would be eliminated, and the average project could expect a net lifecycle emissions decrease of 2.3 tonnes of CO_2e per million dollars of project spend—approximately 15% of total project emissions.

This table shows potential actions to help realize this opportunity, starting with the construction sector and moving to other entities that also influence viability and uptake.

Construction Companies	• **Electrify fleet vehicles and small equipment**, focusing on light-duty trucks, vans, and common tools like compressors, pumps, and welders. Plan purchases of electric vehicles or equipment based on the lifecycle of existing equipment. Transition to LED and solar-powered lighting for both temporary and permanent site illumination. • **Install depot or on-site charging infrastructure** to ensure operational readiness and minimize downtime. • **Monitor usage and emissions reductions** to support internal reporting and demonstrate ROI. • **Monitor peak loads** to avoid grid stress and manage electricity costs. • Implement guidelines which help to **choose the right size vehicle for the application**. • **Support companywide cultural changes** with incentives or competitions which promote electric equipment and vehicle use.
Utilities / Site Managers	• **Coordinate with developers** to install permanent or temporary power connections at project onset. • **Provide scalable site electrification kits** (e.g. pop-up charging stations, smart load balancing tools). • **Assess vehicle size requirement** (e.g. pick-up VS SUV) to maximize return on investment.
Equipment Manufacturers	• **Expand product lines** for battery-electric versions of common site tools and specialty equipment. • **Improve battery and charging interoperability,** reducing downtime and increasing fleet flexibility. • **Offer battery leasing or power-as-a-service models** to reduce upfront costs.
Incentive Providers (Public & Private)	• **Sustain and expand rebates** for light-duty vehicles (e.g. pick-ups), off-road equipment, and charging infrastructure. • **Include incentives** specifically targeting the adoption of energy-efficient LED and solar-powered lighting solutions • **Develop special financing vehicles** to de-risk early adoption for SMEs. • **Support bulk purchasing programs** for smaller contractors or industry associations.

Action 2. Optimize and Electrify Temporary Heating

Temporary heating is a major fuel user, especially in cold climates. Electric heating paired with smart controls and improved enclosures can slash fuel use while improving worker comfort and safety and ensuring quality finishes.

The Equipment

Indoor and outdoor heating equipment

Key Benefits

- Savings on fuel costs with increased energy efficiency and avoided on-site maintenance via smart controls
- Can help significantly reduce emissions, often at a comparatively low cost
- Improved health and safety through reduced noise, ventilation and fire risk

Issues to Address

- Electrical capacity constraints and costs in certain provinces
- Delays in obtaining permanent power
- Higher cost when switching for low-cost fuels

The Impact

If this action achieved 100% implementation, the average project could expect a net lifecycle emissions decrease of 2.0 tonnes of CO_2e per million dollars of project spend—approximately 12% of total project emissions. This assumes that all the natural gas for heating would be replaced with electricity. However, propane use is assumed not to change as this is associated with projects that are waiting for grid or pipe connections or cannot obtain them. The emissions reduction potential will be particularly important for projects in colder regions that rely comparatively more on heating.

Construction Companies	• **Adopt electric heaters with smart thermostats** to reduce energy waste and improve control. • **Integrate heating units and concrete probes** to enable high quality remote monitoring of curing. • **Use thermal enclosures** (e.g. tarping, insulated hoarding) to reduce heat loss and load. • **Schedule heating loads** to avoid peak grid use or generator overuse. • **Model heat loads** for each job phase and zone. • **Incorporate energy-efficient heating** into site setup planning and logistics. • **Optimize heater placement** for even coverage and safe operations.
Client	• **Obtain permanent electrical and heating** in the procurement or planning phases so that connections are available when work starts.
Vendors & Manufacturers	• **Bundle smart heating kits** with sensors, controls, and performance analytics. • **Offer mobile electric heating trailers** for quick deployment at large job sites. • **Develop modular systems** for various job types and seasonal requirements.
Utilities & Incentive Providers	• **Offer rebates for high-efficiency heaters** and energy management systems. • **Fund thermal enclosure retrofits** as part of emissions-reduction pilots. • **Support bulk purchases or group installations** for consortiums or associations. • **Ensure grid connection process is efficient** to align with project financing expectations.

Action 3. Transition to Renewable Diesel as a Bridge Fuel

Renewable diesel can play a significant role in reducing emissions since many equipment types are not yet ready for electrification or hydrogen due to technical or operational barriers. Hydrogen, in particular, faces important challenges to widespread adoption, lack of available models, high costs, and uncertain feedstock availability—making it unlikely to play a meaningful role in construction decarbonization in the near term.

Renewable diesel offers an immediate, drop-in solution to reduce lifecycle emissions without requiring equipment changes. Use of renewable diesel or biodiesel in larger equipment should be prioritized as fuel may be limited by feedstock availability and electrification is possible for smaller equipment.

The Equipment

The equipment this would be most appropriate for includes mid- and heavy-duty excavators, large cranes, large-scale wheel loaders, large-scale earthworks equipment, pavers, concrete mixers, marine/work boats and generators.

While often grouped together, biodiesel and renewable diesel differ in performance and application. Biodiesel, commonly blended with conventional diesel, is widely available but can pose challenges related to engine compatibility, cold-weather performance, and storage stability—particularly at higher blend levels. Renewable diesel, on the other hand, is chemically similar to petroleum diesel, offering seamless engine compatibility and strong performance even in cold climates. However, it remains less widely available and more expensive, making coordinated procurement strategies and supply development key to enabling its broader use in construction.

Key Benefits

- Drop-in fuel requiring no equipment change
- High behavioural acceptance
- Suitable for equipment with limited electrification readiness

Issues to Address

- Cost of fuel compared with fossil alternative (in Ontario and BC it is possible to achieve cost parity)
- Challenges in securing feedstock
- Policy and incentive gaps

The Impact

As noted elsewhere in this report, moving to renewable or biodiesel can have a very large impact on lifecycle emissions of the fuel – often decreasing emissions by 40-80%.

Construction Companies	• **Analyze aggregate demand and form a coalition of buyers** to send strong demand signals, pool procurement power, and negotiate better terms with fuel suppliers. • **Prioritize high-usage equipment** for rollout, such as excavators, haulers, and cranes. These should be prioritized where electrified alternatives are not yet available / too costly. • **Engage project owners and clients** to include renewable fuel adoption in procurement scoring or ESG metrics.
Equipment Manufacturer & Equipment Rental Companies	• **Certify equipment compatibility** with renewable diesel, especially for newer engines that can use 100% renewable diesel without voiding warranty. • **Update maintenance procedures** and manuals to reflect best practices when using renewable fuels. • **Bundle fuel and service packages** that promote lower-emission operation (e.g. training, telematics, optimization).

Fuel Distributors	• **Educate customers and contractors** about the advantages of renewable diesel and how it differs from biodiesel. • **Secure long-term supply contracts** with renewable diesel producers (domestic and international) to guarantee availability for construction markets. • **Expand distribution infrastructure** to deliver renewable diesel to both urban depots and remote / seasonal job sites.
Governments & Regulators	• **Offer incentives or credits** for switching to renewable diesel, such as per-litre rebates, carbon intensity scoring or procurement benefits. • **Develop and enforce fuel quality standards** to ensure renewable diesel meets performance and emissions benchmarks. • **Support domestic production** of renewable diesel to reduce import dependency and create economic opportunities.

Action 4. Deploy Grid-Connected and Hybrid Power Solutions for Temporary Energy Needs

Diesel generators are a major emissions source during construction. Grid hookups, hybrid gensets, and solar-battery systems offer cleaner, quieter, and more efficient alternatives.

The Equipment

Electrical generators or electrical grid connection.

Key Benefits

- Reduced emissions and operating costs
- Lower noise and improved site safety
- Increasing availability of battery hybrid solutions

Issues to Address

- Limited timelines provided to developers for securing grid access approvals
- Higher upfront capital for hybrid or fully electric generators

The Impact

Diesel generators are assumed to be used only for a small proportion of projects that are unable to connect to the electrical grid. However, for those projects, generators are a large source of emissions and moving to other solutions would have a high impact. In the overall data set diesel generators made up approximately 21% of the diesel usage. For deployment of grid connection or fully electric generators 1.8 tonnes of CO_2e per million dollars of project spend, or approximately 14% of total project lifecycle emissions are eliminated. For hybrid generators the effect is slightly less with the lifecycle elimination of 1.1 tonnes of CO_2e per million dollars or 6.9%.

Construction Companies	• **Mandate early grid hookups** during preconstruction to reduce use of diesel gensets. • **Deploy solar + battery or hybrid gensets** for temporary facilities like trailers and lighting towers. • **Monitor energy use** with smart metering to optimize loads and avoid oversizing.
Project Owners & Developers	• **Plan for electricity access from the outset** by including site electrification requirements in project designs and construction contracts. • **Advocate** with utilities and local governments to streamline grid access approvals and timelines. • **Coordinate schedules** to allow sufficient lead time for utility hookups or BESS installations.
Technology Vendors	• **Provide bundled hybrid power solutions**, integrating gensets, batteries and load controllers. • **Offer on-site commissioning and training** to ensure proper deployment and maintenance. • **Enable real-time monitoring** through dashboards and alert systems.

Utilities & Microgrid Providers	• **Offer rapid hookup services** with modular interconnects for temporary power supply. • **Develop containerized microgrid packages** for rental or turnkey deployment. • **Engage proactively with developers and municipalities** to anticipate future load needs, clarify grid-access timelines, and simplify approval processes.

Action 5. Incorporate Hybrid and Electric Solutions for Excavation & Earthworks

Excavation and earthworks machinery is a source of emissions across all project archetypes. Hybrid systems are ready for deployment and can reduce fuel use by 15-20%. Electric versions are emerging for compact and medium use cases. Hybrids can offer the opportunity for companies to gain hands-on experience and become more familiar with electric technologies when fully electric options are not yet optimal.

The Equipment

The equipment this would be most appropriate for includes compact electric excavators, wheel loaders, skid-steers, and tandem rollers.

Key Benefits

- Substantial fuel and maintenance savings.
- Reduced noise and emissions in dense areas.
- Hybrid models available for many classes.

Issues to Address

- Limited availability of models.
- Higher upfront capital.
- Lack of available and adapted charging infrastructure.
- Battery duration and planning for associated time to charge or change.

The Impact

The potential impact of implementing Action 3 has been split into two scenarios. Using hybrid equipment, the average project could expect a net emissions decrease of 0.2 tonnes of CO_2e per million dollars of project spend, approximately 1% of total project lifecycle emissions. With electric equipment, the net emissions decrease would be 1.3 tonnes of CO_2e per million dollars of project spend, approximately 8% of total project lifecycle emission. Excavation and earthworks were assumed to represent 50% of category B emissions for this analysis, or 9% of the total project emissions.

Construction Companies	• **Pilot hybrid dozers, excavators, and loaders** on suitable projects to evaluate fuel and cost savings. • **Use electric compact equipment** (e.g. mini-excavators, skid steers) for urban and indoor worksites. • **Track total cost and performance data** to support scaling and grant applications.
Equipment Manufacturer & Equipment Rental Companies	• **Stock hybrid and electric models** in Canada with flexible rental terms to reduce customer risk. • **Provide performance and ROI calculators** to help justify investments. • **Train mechanics and operators** on high-voltage equipment and battery care.

Fuel & Energy Providers	• **Design dual-fuel and charging setups** for mixed fleets. • **Coordinate with contractors** on energy plans that account for peak usage and load-sharing.
Governments & Industry Groups	• **Support hybrid equipment pilots** through grants or demonstration programs. • **Recognize hybrid and electric solutions** for public procurement scoring and emissions reporting. • **Expand capital cost allowances** or tax credits to include hybrid systems.

Total Impact of Implementation

Full implementation of these five actions could reduce lifecycle emissions from construction activity by approximately 75%.

Pragmatic Implementation Timeline

By 2030 (Next 5 Years)

Total Achievable Emission Reductions: up to 25%

Strategy	Implementation Rate	Emission Reduction Contribution
Light Duty Vehicles & Other Electrification	25-30% of total fleet	5%
Optimize and Electrify Heating	70-80% adoption	5%
Renewable Diesel Adoption	30-40% of diesel use	10%
Grid Connection and Hybrid or Electric Generators	30-40% of projects	5%

By 2035 (Next 10 Years)

Total Achievable Emission Reductions: up to 55%

Strategy	Implementation Rate	Cumulative Emission Reduction
Light Duty Vehicles & Other Electrification	50-60% of total fleet	10%
Optimize and Electrify Heating	90-100% adoption	10%
Renewable Diesel Adoption	60-70% of diesel use	20%
Grid Connection and Hybrid or Electric Generators	70-80% of projects	10%
Electric/Hybrid Excavation Equipment	30-40% of equipment	5%

By 2040 (Next 15 Years)

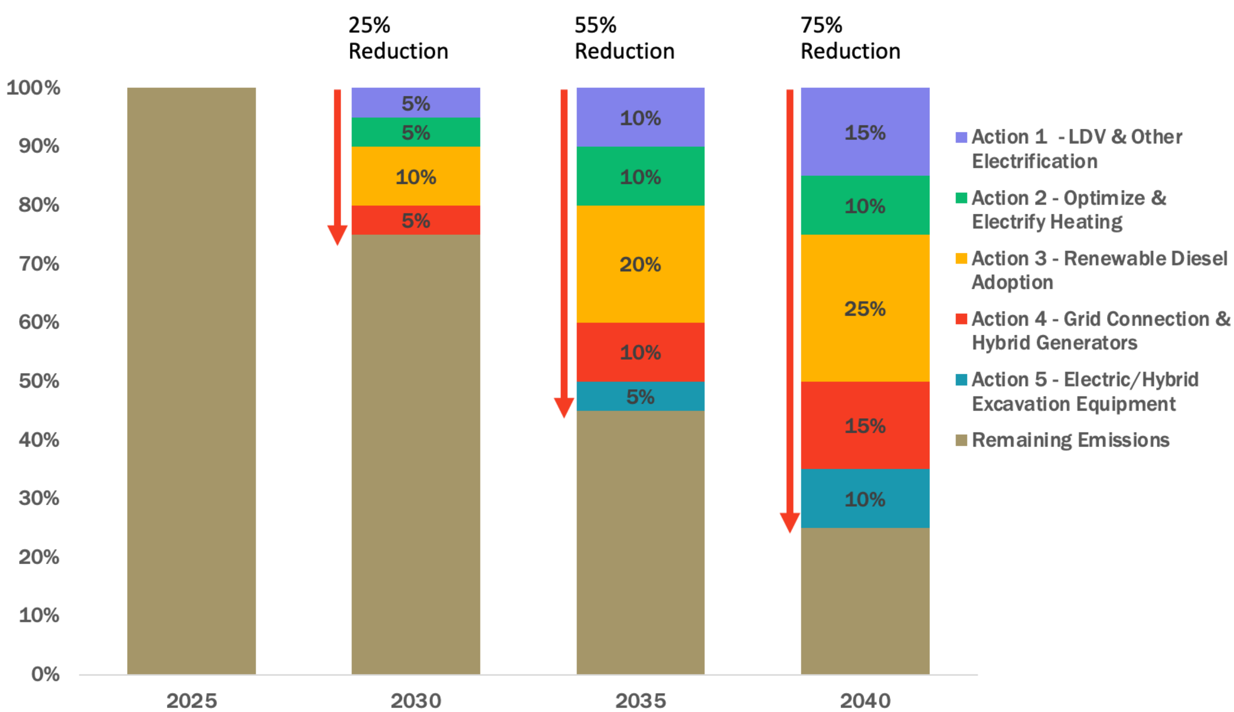
Total Achievable Emission Reductions: up to 75%

Strategy	Implementation Rate	Cumulative Emission Reduction
Light Duty Vehicles & Other Electrification	90-100% of fleet	15%

Strategy	Implementation Rate	Cumulative Emission Reduction
Optimize and Electrify Heating	95-100%	10%
Renewable Diesel Adoption	90-100%	25%
Grid Connection and Hybrid or Electric Generators	90-100%	15%
Electric/Hybrid Excavation Equipment	60-80%	10%

This chart below demonstrates how five targeted strategies can reduce construction emissions by 75% over 15 years, progressing from a 2025 baseline to significant decarbonization by 2040.

- **Renewable diesel adoption drives the largest impact**, contributing 25% of total reductions by 2040. This reflects construction's heavy dependence on diesel equipment and the immediate availability of renewable diesel as a drop-in replacement fuel.
- **Early electrification wins** come from light duty vehicles and grid connections, each delivering 15% reductions by 2040. These strategies benefit from mature technologies and existing infrastructure, making them ideal for near-term implementation.
- **Heating optimization** provides steady 10% reductions across all timeframes through equipment upgrades and electrification—representing achievable efficiency gains with proven technology.
- **Heavy equipment electrification** starts later but contributes 10% by 2040, reflecting the current development stage of electric excavators and similar machinery.



The intention of these estimates is to provide directional understanding of the order of magnitude of various strategies that will align the sector as a whole towards emission reductions. These projections establish appropriate transitional actions for sector-wide decarbonization. While this analysis creates foundational groundwork for strategic planning, company-specific data and circumstances may differ significantly from these sector-level estimates.

The emission reduction projections presented in this report reflect a pragmatic assessment that balances technical feasibility, economic viability, operational constraints, and organizational readiness for change. These projections are based on realistic fleet turnover cycles, gradual technology adoption curves, and typical infrastructure development timelines within the construction industry.

However, **more ambitious emission reductions can be achieved by accelerating the implementation rates of the underlying measures.** Companies with aggressive sustainability commitments, such as those aligned with Science-Based Targets initiative (SBTi), may choose to pursue faster implementation through:

- **Accelerated fleet turnover** - replacing diesel vehicles and equipment ahead of normal replacement cycles
- **Higher renewable diesel adoption rates** - achieving 60-80% usage by 2030 rather than the projected 30-40%
- **Expedited grid connections** - prioritizing electrical hookups for 60-80% of projects by 2030 instead of 30-40%
- **Faster heating system transitions** - achieving near-complete electrification by 2030 rather than gradual adoption
- **Early adoption of electric excavation equipment** - beginning substantial deployment before 2035

While these accelerated approaches may require higher upfront capital investment, strategic fleet management, and organizational change management, they can bridge the gap between the pragmatic projections in this analysis and the more ambitious targets that leading construction companies have committed to achieve.

The five core strategies remain the same - the difference lies in the speed and scale of implementation.

Improving Emissions Data Collection

Comprehensive emissions tracking across the construction sector presents significant logistical challenges. Our analysis revealed substantial data gaps and inconsistencies that would be impractical to address across all projects simultaneously. Rather than attempting universal implementation of detailed tracking—which could create excessive administrative burden—we recommend a strategic approach using representative sample projects to establish reliable benchmarks. This focused methodology balances the need for quality emissions data with the practical realities of construction operations.

Representative Project Selection

Instead of tracking detailed emissions data for every project, companies should:

1. Identify 3-5 representative projects for each major archetype (residential buildings, commercial buildings, industrial facilities, etc.)
2. Apply thorough monitoring and data collection to these sample projects
3. Use these detailed case studies to establish emission benchmarks for similar projects

This approach balances data quality with practical implementation constraints.

Core Data Requirements for Sample Projects

For representative projects, collect:

- **Basic Information**: Project name, type, cost, timeline, and location
- **Energy Data**: Complete records of all fuel (diesel, gasoline, propane, natural gas) and electricity usage
- **Project Parameters**: Gross floor area (for buildings) or length (for linear projects)
- **Equipment Usage**: Detailed tracking of equipment types and operating hours

Addressing Common Data Gaps

For representative projects, implement these targeted solutions that can enable more formalized standardization and comparability:

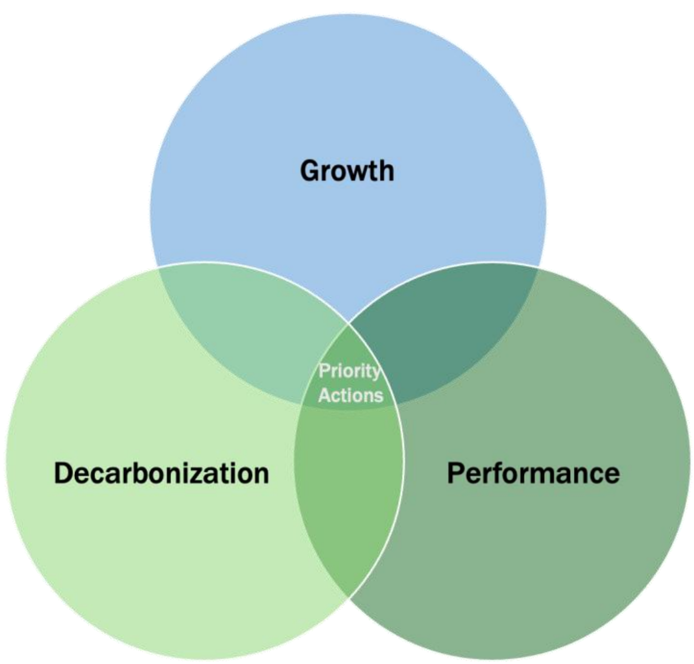
1. **For Utility Data**: Establish formal information sharing with project owners to access electricity and natural gas consumption data
2. **For Subcontractor Activities**: Include specific fuel reporting requirements in subcontracts for sample projects
3. **For Equipment Tracking:** Use digital tools (asset tracking systems, QR codes, mobile apps) to streamline equipment-level data collection on sample projects

This representative sampling approach provides high-quality baseline data that can inform emissions estimates for similar projects while avoiding the administrative burden of comprehensive tracking across all construction activities. The resulting benchmarks will support more accurate decarbonization planning while remaining practical for implementation.

The Strategic Value of Coordinated Action

The five high-impact actions outlined in this report represent more than individual initiatives—they form a **coordinated strategy** that amplifies the construction sector's competitive advantages while achieving substantial emissions reductions.

How the Five Actions Work Together Strategically



The strategic power of these actions lies in their intersection across three critical business dimensions:

1. Construction Company Growth

- Actions create new market opportunities and competitive positioning
- Early adoption establishes leadership in emerging low-carbon markets
- Collective implementation drives industry transformation

2. Decarbonization of Operations

- Up to 55% emissions reduction achievable by 2035
- 60-75% reduction achievable by 2040
- Positions sector to meet evolving climate requirements

3. Project Performance Excellence

- **Cost Control:** Lower operating costs through fuel efficiency and reduced maintenance
- **Schedule Reliability:** Improved project timelines through optimized equipment and reduced downtime
- **Quality Assurance:** Precise control systems and remote monitoring for superior workmanship
- **Safety Leadership:** Cleaner air, reduced noise, and elimination of fuel storage risks

Strategic Business Benefits of Coordinated Implementation

Supply Chain Leadership: By acting collectively, construction companies send strong market signals that accelerate the development of low-carbon technologies, improve equipment availability, and reduce costs through economies of scale.

Competitive Differentiation: Companies implementing these actions gain advantages in:

- **Talent Attraction**: Sustainability-focused projects attract younger workers in tight labor markets
- **Client Preference**: Proven decarbonization capabilities increasingly win competitive bids
- **Financial Access**: Enhanced access to preferential financing and specialized funding sources

Performance Excellence:

- **Operational Efficiency**: Reduced fuel costs, lower maintenance requirements, and improved equipment reliability
- **Quality Improvements**: Smart monitoring systems and precise controls enhance workmanship standards
- **Safety Enhancements**: Cleaner work environments, reduced noise levels, and elimination of hazardous fuel handling
- **Risk Mitigation**: Protection against fuel price volatility, supply disruptions, and regulatory changes

Risk Mitigation:

- **Regulatory Readiness**: Proactive adoption avoids costly future retrofits as standards evolve
- **Supply Chain Resilience**: Reduced dependence on volatile fossil fuel markets

- **Cost Stability**: Protection against fuel price fluctuations and supply disruptions

The Amplification Effect

When implemented as a coordinated approach rather than isolated initiatives, these actions create an amplification effect:

1. **Market Transformation**: Collective demand signals accelerate technology development and cost reductions
2. **Knowledge Sharing**: Shared experiences and best practices accelerate adoption across the sector
3. **Policy Influence**: United industry voice creates stronger advocacy for supportive policies and incentives
4. **Client Confidence**: Demonstrated sector-wide commitment builds client trust in low-carbon construction capabilities

From Individual Actions to Industry Leadership

By viewing decarbonization not as a regulatory burden but as a **strategic opportunity for business enhancement**, Canada's construction sector can:

- **Lead the North American market** in low-carbon construction capabilities
- **Attract investment** in Canadian construction technology and innovation
- **Export expertise** to other markets pursuing similar transitions
- **Build a resilient, competitive industry** prepared for the demands of a low-carbon economy

The five actions provide the foundation, but their true strategic value emerges when the industry moves forward together—transforming what could be seen as individual company challenges into a collective competitive advantage for Canadian construction.

Strategic Implementation Considerations

Leverage the Current Context

The current political emphasis on "building" by all levels of government in Canada, especially with respect to housing and energy infrastructure, provides a timely opportunity. The construction sector should engage with the new federal government as it starts implementing mandates, plan for a fall budget and develop regulatory proposals to advance common low-carbon building objectives.

Address Affordability Concerns

Following a period of elevated inflation, any decarbonization action that entails a cost premium could face challenges. Focus initial implementation on actions with clear economic payback periods (like light-duty vehicles and electric heating in applicable regions) to build momentum and demonstrate value.

Collaborate Vertically Across the Value Chain

The horizontal coalition of Canadian construction companies should use its critical mass and central position to collaborate both upstream and downstream:

- **Upstream**: Use collective buying power to stimulate supply from OEMs, utilities, vendors, and equipment rental companies by reducing costs through scale and/or enabling investments by reducing risk.

- **Downstream**: Serve as a knowledge hub on decarbonization to influence developers, financial institutions, and governments who set policies and standards.

Government Engagement Strategy

Work with existing federal tools and programs that could support the proposed decarbonization actions:

- Transport Canada's iZEV program (currently paused)
- Greening Government Strategy for new building and infastructure projects
- The Clean Technology Investment Tax Credit
- Engage with the Clean Growth Hub as a "one-stop shop" for information about funding and services

Public Sector Procurement Leadership

Government clients control hundreds of billions in construction spending and can accelerate decarbonization through strategic procurement practices.

Contract Requirements: Include specific targets for electric equipment usage, renewable fuels, or emissions reductions in RFPs. Award scoring that favors low-carbon approaches rewards prepared contractors.

Infrastructure Coordination: Plan permanent electrical connections during project development to eliminate diesel generators and enable electric equipment from project start.

Leading by Example: Expand federal commitments like the Greening Government Strategy beyond building materials to include construction process requirements.

Public sector procurement power represents the most direct path to creating market demand for low-carbon construction practices while demonstrating their viability at scale.

Address Supply Chain Shifts

The construction sector should monitor how recent protectionist trade measures affect building materials and equipment. While tariffs could serve as a barrier to actions relying on imported equipment and fuel, "Buy Canadian" efforts could stimulate domestic production and relieve supply constraints.

Knowledge Sharing

Municipal governments may lack capacity in developing and implementing low-carbon construction projects. The construction sector coalition should share best practices and promote its decarbonization actions with these partners. Similarly, as provinces and territories develop energy roadmaps as recommended by the Canada Electricity Advisory Council, there is an opportunity to help align these plans with the construction sector's decarbonization actions, which rely heavily on electrification.

Workforce Development and Training

Successful implementation requires targeted workforce training for new technologies and practices. Construction companies should prioritize three key areas:

Equipment and Safety Training: Partner with manufacturers for certified programs covering electric/hybrid equipment operation, high-voltage safety protocols, and battery management.

Energy Management: Train site supervisors on smart heating controls, grid connections, and load optimization to avoid peak demand charges and equipment downtime.

Implementation Best Practices: Develop internal champions for each technology area and create standardized protocols that scale across projects.

Strategic workforce development transforms implementation challenges into competitive advantages, building expertise while positioning companies as employers of choice in a tight labor market.

Early Wins Strategy

To build momentum and demonstrate the viability of the approach, prioritize actions that:

1. Have the shortest payback periods (like light-duty vehicle electrification and smart heating controls)
2. Require minimal changes to existing operations (like renewable diesel adoption)
3. Can be implemented at scale quickly (like LED lighting and small equipment electrification)
4. Provide co-benefits such as noise reduction, improved air quality, and worker comfort

Supply Chain Development

As in the case for renewable diesel, analyze aggregate demand and form buyer coalitions to send strong demand signals for critical technologies and fuels. This collective approach can:

- Reduce per-unit costs through volume purchasing
- Encourage manufacturers to expand product lines or increase production
- Incentivize distributors to improve infrastructure for renewable diesel delivery
- Support bulk purchasing programs for smaller contractors or industry associations

Pilot Project Network

Establish a coordinated network of demonstration projects across different construction archetypes (buildings, industrial facilities, etc.) to:

- Test technologies in different operational contexts
- Generate real-world performance data
- Create case studies and ROI calculations
- Train operators and maintenance staff
- Showcase successes to clients and stakeholders

Industry Standards and Practices

Work with industry associations to develop:

- Standard protocols for emissions tracking and reporting
- Best practices for equipment selection and operation
- Procurement templates that incorporate low-carbon requirements
- Training programs for site superintendents and operators

The five high-impact actions outlined in this chapter represent practical, economically viable steps that can be implemented today while laying the groundwork for deeper decarbonization in the future. While each action offers significant benefits on its own, their true power comes from implementing them as part of a coordinated strategy.

By taking a systematic approach to implementing these actions, the construction sector can achieve up to 75% emission reduction over the next 15 years. This represents a substantial contribution to Canada's climate goals while simultaneously addressing key business challenges facing the sector.

Implementation should be guided by a pragmatic timeline that accounts for equipment lifecycle, technological readiness, and organizational capacity. The roadmap provided offers a realistic progression from near-term actions with immediate payback to medium and longer-term transformations as technologies mature and markets evolve.

As construction companies move forward with these actions, they should view them not as isolated environmental initiatives but as core business improvements that enhance efficiency, reduce operating costs, improve working conditions, and strengthen competitive positioning. By framing decarbonization within this broader context of business value, companies can build the internal momentum and stakeholder support needed for successful implementation.

The market transformation needed to fully realize these opportunities will require collaboration across the entire value chain. By working together—construction companies, equipment manufacturers, energy providers, technology vendors, clients, and policymakers—the sector can accelerate progress and unlock the full potential of low-carbon construction in Canada.

VI. Conclusion

Canada's construction sector stands ready to lead a transformation that delivers both business success and environmental progress. The five high-impact actions outlined in this report provide a practical roadmap for achieving up to 55% emissions reductions by 2035 while enhancing operational efficiency and competitive positioning.

The Key Industry-Wide Actions

Take Immediate Action on Proven Technologies: Electrify light-duty vehicles and small equipment, optimize heating systems with smart controls, and mandate early grid connections for projects. These steps deliver quick wins with mature technology and clear ROI.

Form Strategic Coalitions: Create buyer coalitions for renewable diesel procurement, share pilot project learnings across companies, and coordinate with equipment manufacturers to accelerate technology development and reduce costs through collective demand.

Invest in Workforce Capabilities: Train operators on electric and hybrid equipment, certify maintenance staff for high-voltage systems, and develop internal champions who become technology experts across the organization.

Lead Through Demonstration: Track and share performance data from decarbonization initiatives, showcase successful projects to clients and stakeholders, and position early adoption as a competitive advantage in bid processes.

The Collective Opportunity

When Canada's largest construction companies act together, they create a market transformation that benefits the entire industry. Collective implementation amplifies individual company efforts by:

- **Driving down costs** through economies of scale and shared learning
- **Accelerating technology development** through unified demand signals
- **Creating industry standards** that level the playing field for all participants
- **Influencing policy** through coordinated advocacy for supportive regulations and incentives

The Path Forward

The construction industry has everything needed to begin this transformation immediately: proven technologies, viable business cases, willing partners, and growing client demand. The question is not whether to act, but how quickly the industry can move together.

By 2030, companies implementing these five actions will have gained competitive advantages, reduced operational costs, and positioned themselves as leaders in Canada's growing low-carbon economy. By 2035, coordinated industry action can achieve nearly half of all possible emissions reductions while building the foundation for deeper decarbonization in the decades ahead.

The time for action is now. Canada's construction industry can build a better future by embracing the practical, profitable path to decarbonization outlined in this report—and the major contractors in the industry are ready to make it happen.

Appendix 1: Evaluation of Options by Equipment Type

This Appendix presents detailed information on the viability and fit of emissions reduction approaches for the different classes of equipment used on construction sites.

For each class of equipment, performance is described and rated across **four dimensions** (technical, economic, operational and behavioural) for the primary **emissions reduction approaches** (electrification, electric hybrids, renewable fuels, hydrogen) that is a feasible alternative for that equipment class.

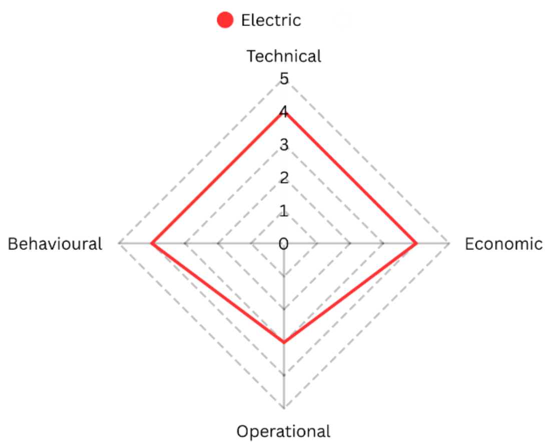
Each combination of equipment / emissions reduction approach / dimension is assigned a numerical value, from 1 to 5. The scores assigned reflect informed judgment based on the experience, contextual understanding, and professional expertise of the report authors. The intention is to allow comparison across different emissions reduction approaches and equipment types.

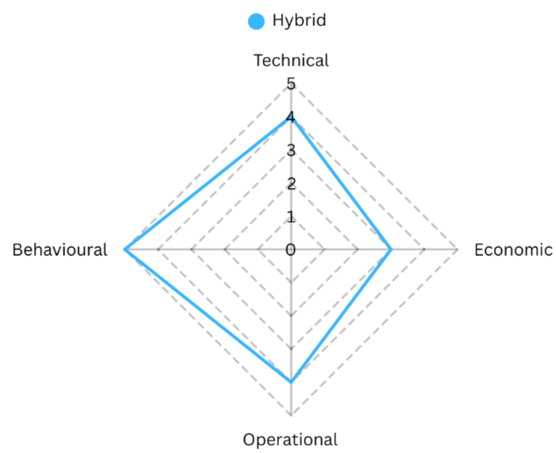
A score of 1 indicates very low readiness or significant challenges and 5 a high level of readiness or ease in that regard. For example, a score of 5 in Technology means the solution is proven and commercially available for immediate use, whereas a 1 would mean it is in early development or faces major technical hurdles. Similarly, a high score in Economic suggests affordable upfront cost, lifecycle savings, or strong incentives, while a low score indicates high costs or weak economic feasibility. No summary value is provided, as different companies may place different values or weight on some attributes over other ones.

Equipment categories in this Appendix:

A.1 Light Duty Vehicles

		Emissions	Technology	Economic	Operational	Behavioural
A1 Light Duty Vehicles	**Battery Electric Vehicles**	100% of direct emissions	4	4	3	4
			300-400km range	Higher upfront cost, lower operational	Overnight charging compatible	Range anxiety, unfamiliarity
	Plug-in Hybrid	50-75% depending on usage	4	3	4	5
			Mature technology	10-30% premium	Flexible operation	Proven technology





The only feasible fuel alternative for gasoline and diesel for light duty vehicles (pickup trucks, vans, and passenger vehicles) is electrification—changing to an electric vehicle (EV), whether fully battery electric (BEV) or a hybrid (containing both a small battery and a combustion engine). This is discussed below.

Electrification (EVs and hybrids)

Technical

EV technology for light-duty fleet vehicles is mature in 2025. A wide variety of vehicle models are available made by familiar automakers such as Ford and GM, and in optimal conditions can get well above 500 kilometers of range on a single charge. Factors such as payload, towing, and/or cold weather conditions affect the effective range—although they do for combustion engines as well.

EVs are also substantially lower in emissions. Table 3 shows the spread between oil and diesel-powered light duty vehicles vs. fully electric or hybrid vehicles. The per-kilometer emissions difference is substantial and adds up quickly with vehicle use.

Table 3: Tailpipe emissions from different fuel types used in light duty vehicles[24]

Fuel Type	Kilograms of CO_2e emissions per kilometer
Diesel	0.17
Gasoline	0.16
Battery Electric	0.00
Plug-in Hybrid	0.07
Hybrid	0.13

Economic

Though EVs have higher upfront costs than combustion engine vehicles (20-40% higher for most EVs and 15-25% higher for most hybrids), they offer significantly lower operating costs. A 2024 report from Clean Energy Canada found that fueling with electricity is cheaper per kilometer and is equivalent to paying about $0.40 per liter of gas.[25] Below are examples of routes the study used for their findings:

From	To	Cost of Gasoline	Cost of Charging
Vancouver	Kelowna	$57	$10
Victoria	Nanaimo	$16	$3
Edmonton	Calgary	$32	$17
Winnipeg	Regina	$69	$21
Montreal	Toronto	$70	$17
Toronto	Ottawa	$54	$16
Halifax	Moncton	$33	$9

Further, a survey of 16,000 EV owners found the average BEV owner saves about 40% to 50% in maintenance compared to a gas-powered vehicle as a result of having no engine oil, fewer moving parts, and reduced brake wear due to regenerative braking.[26] These savings have made EVs cost competitive, with a 2023 study by Vincentric finding that 38 of 40 EV models assessed had lower total five-year ownership cost than gasoline equivalents.[27] In comparison, a hybrid light-duty vehicle would still require standard maintenance alongside the addition of electrical and battery considerations.

24 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023
25 https://cleanenergycanada.org/wp-content/uploads/2024/07/Report_2024_EVSavings-V5-1.pdf
26 https://evbuyersguide.caa.ca/content/costs
27 https://vincentric.com/Portals/0/Market%20Analyses/2023%20Canada%20EV%20Analysis/2023%20Vincentric%20Canada%20EV%20Cost%20of%20Ownership%20Analysis.pdf

A number of financial incentive programs are available that reduce up-front purchase costs for EVs and hybrids.

*Table 4: Financial Incentive Programs Applicable to Light Duty Vehicles**

Program Name	Jurisdiction	Type	Eligibility	Incentive per vehicle
Incentives for Zero-Emission Vehicles (iZEV)	Federal	Rebate	New BEVs, PHEVs, FCEVs	$2,500 - $5,000 *Note: the federal program is paused as of March, 2025 but may resume in the future*
CleanBC Go Electric Vehicle Rebate (Fleet Eligible)	British Columbia	Rebate	New BEVs, PHEVs, FCEVs	$1,500 - $3,000
Yukon Good Energy EV Rebate	Yukon	Rebate	New BEVs, PHEVs, FCEVs	$3,000 - $5,000
NWT EV Rebate (Arctic Energy Alliance)	Northwest Territories	Rebate	New BEVs and PHEVs	Up to $5,000
Manitoba Electric Vehicle Rebate Program	Manitoba	Rebate	New and used BEVs and PHEVs	$2,500 - $4,000
Québec “Roulez vert” New Vehicle Rebate	Quebec	Rebate	New BEVs, PHEVs, FCEVs	$4,000 - $7,000
New Brunswick “Plug-In NB” EV Rebate	New Brunswick	Rebate	New and used BEVs and PHEVs	Up to $5,000
Nova Scotia “Electrify Nova Scotia” Rebate	Nova Scotia	Rebate	New and used BEVs and PHEVs	$1,000 - $3,000
Prince Edward Island EV Incentive	PEI	Rebate	New and used BEVs and PHEVs	$2,500 - $5,000
NL Hydro EV Rebate Program	Newfoundland	Rebate	New and used BEVs and PHEVs	$1,500 - $2,500

** Programs are subject to change. Incentive level may be tied to vehicle range, purchase price, power type, new vs. used or where the vehicle is built.*

Operational

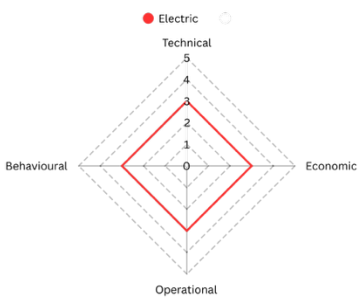
On the whole, EVs and hybrids score high for operational considerations. Minimal special training is needed to operate EVs, aside from basic electrical safety and charger use. However, charging infrastructure is required, as well as planning to ensure that vehicles are charged and available when needed. Most light-duty fleet EVs can charge overnight on Level 2 (240V) chargers at depots or jobsite trailers or use DC fast charging (public or on-site). Projects in remote areas without grid access may need portable generators or battery banks to recharge vehicles, which requires coordination and generator solutions. Further, staff must adapt to planning around charge schedules. In cold climates, range can drop by 20-30% due to battery efficiency and heating needs, making route planning and battery pre-heating (while plugged in) important operational adjustments.

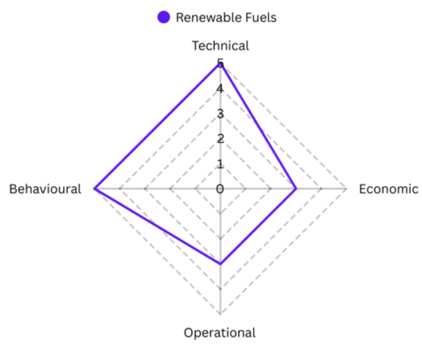
Behavioural

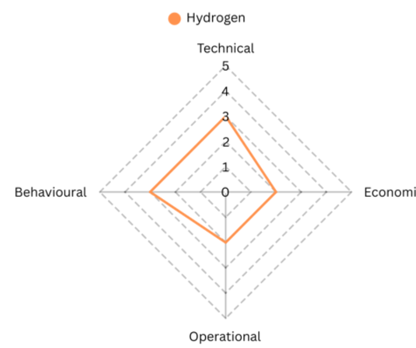
Successfully integrating EVs into a fleet requires shifts in workplace culture and updated management approaches to address new operational needs. Resistance often stems from practical concerns such as range anxiety, longer charging times, and uncertainty about the reliability of EV technology. To encourage broader adoption, developers can address these concerns through education, communication, and providing reliable charging infrastructure. Hybrid technology that uses both battery and fuel technology may be less likely to face resistance.

A.2 Medium and Heavy-Duty Trucks

		Emissions	Technology	Economic	Operational	Behavioural
A.2 Medium/Heavy Duty Vehicles	**Battery Electric**	100% of direct emissions	3	3	3	3
			Range limited	High premium	Infrastructure needed	
	Renewable or Biodiesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited availability	
	Hydrogen	Up to 100% of lifecycle emissions	3	2	2	3
			Commercial or demo phase	2-3x diesel trucks	Infrastructure limited	







Three viable options exist for low-emissions medium and *heavy-duty* trucks: electrification (EV), using renewable diesel in place of conventional diesel, and using hydrogen as a fuel.

Electrification (EVs)

Technical

Electric options for Class 6-8 trucks are increasingly available in Canada and internationally. Manufacturers are producing them (like Volvo's FE Electric and Freightliner's eCascadia) and companies are starting to use them (Sysco and Loblaw are using eCascadia Class 8 electric semis in British Columbia[28] and Lafarge Canada added electric trucks to its B.C. operations[29]). As of 2024, there are 27 different types of zero-emission medium- and heavy-duty trucks available in Canada, with ranges varying from 95 km to 425 km,[30] which is suitable for urban hauls. Long-haul heavy-duty BEVs are in early stages of development.[31] Hybrid electric truck solutions are also in development and near-commercial stages in Canada, with a notable

[28] https://electricautonomy.ca/fleets/commercial-electric-vehicles/
[29] https://electricautonomy.ca/fleets/2023-08-29/lafarge-canada-electrification-vicinity-motor-trucks/
[30] https://cleanenergycanada.org/wp-content/uploads/2024/05/ZEMHDV-AvailabilityCatalogue-V7-Online-1.pdf
[31] https://link.springer.com/article/10.1007/s38311-023-1504-0

example being B.C.-based Edison Motors' new L500 hybrid semi, which can reduce diesel fuel consumption by at least 70%.[32]

Economic

As with other vehicle classes, EVs and hybrid trucks and buses have a higher upfront cost than conventional diesel and gasoline vehicles, as shown below. However, both provincial and federal government incentive programs are available that can offset some of this difference. EVs also offer significant fuel and maintenance savings that improve total cost of ownership. Maintenance costs for battery-electric trucks can be up to 50% lower than for diesels[33] and fuel savings are also substantial.

Table 5: Purchase price for medium and heavy-duty vehicles

Vehicle Type	Cost
Diesel Class 6-8	$80,000 to $200,000+
Electric Class 6-8	$159,000 to $427,000+
Diesel Bus	$200,000 to $600,000+
Hybrid Bus	$789,000+
Electric Bus	$813,000+

Table 6: Financial Incentive Programs Applicable to Medium and Heavy-Duty Vehicles*

Program Name	Jurisdiction	Type	Eligibility	Incentive per vehicle
iMHZEV – Incentives for Medium- and Heavy-Duty ZEVs	Federal	Rebate	BEV, FCEV, or PHEV commercial vehicles classes 2B through 8	$10,000 – $200,000 per vehicle
Accelerated Investment Incentive (ZEV Depreciation)	Federal	Tax incentive (accelerated CCA)	ZEVs used for business	100% first-year depreciation of ZEV purchase cost
CleanBC Go Electric Rebates (Fleets Program)	British Columbia	Rebate	BEV and PHEV, on-road classes 2B through 8 and charging infrastructure	33% of purchase cost, maximum $150,000
Québec "Écocamionnage" Program	Quebec	Rebate	BEV or PHEV, Class 5–8 trucks	Up to $175,000
Electrify Nova Scotia – MHZEV Rebate	Nova Scotia	Rebate	ZEVs, classes 2B through 8	$10,000 – $50,000
Yukon Good Energy Program – Commercial EV Rebate	Yukon	Rebate	ZEVs, classes 2B and up	$10,000
Arctic Energy Alliance EV Rebate	Nova Scotia	Rebate	BEV and PHEV	$5,000

** Programs are subject to change. Incentive level may be tied to vehicle range, purchase price, power type, new vs. used or where the vehicle is built.*

[32] https://sustainablebiz.ca/edison-motors-set-to-begin-building-hybrid-electric-semi-trucks-in-bc

[33] https://cdn.motor1.com/pdf-files/202210-te-trucks-briefing-final.pdf

Operational

Adopting low-emission trucks requires operational adjustments, particularly regarding charging infrastructure and route management. Electric trucks depend on reliable access to charging facilities, either installed at project sites or fleet depots, and routes must be planned to align with the vehicles' range capabilities. Hybrid trucks involve fewer infrastructure changes but require strategic route management to fully utilize their electric efficiency, particularly in urban or on-site operations. Maintenance teams will need specific training on high-voltage systems and battery health management, although overall maintenance needs typically decrease. Implementing telematics and data analytics allows operators to closely monitor vehicle performance, optimize routes, and streamline charging schedules. Additionally, proactive coordination with suppliers and subcontractors is essential to align charging logistics and ensure reliable project delivery without disruptions.

Behavioural

Drivers accustomed to diesel trucks may question the reliability of electric vehicles, worry about range limitations, or feel uneasy with new maintenance requirements. Some may view changes in driving behavior, such as anti-idling policies or eco-driving techniques, as inconvenient or unnecessary. However, experience shows these concerns tend to fade quickly as drivers gain firsthand experience with the new technologies and see practical benefits like quieter, cleaner, and smoother truck operation.

Hydrogen

Technical

Medium- and heavy-duty hydrogen fuel cell electric vehicles (FCEVs) are an emerging zero-emission option for freight transport. An advantage is their long range and quick refueling with current models exceeding 800 km and refuel time of 15 to 20 minutes,[34] making them suitable for long-haul operations comparable to diesel counterparts. Several manufacturers have pilot or early commercial FCEV trucks on the market, such as Nikola's Tre and Hyundai's XCIENT FCEL.[35,36] In Canada, hydrogen truck deployments are beginning with the company HTEC announcing plans to roll out 100 hydrogen fuel-cell trucks and 20 refueling stations in British Columbia.[37] Other models like the Toyota-Kenworth fuel cell truck and offerings from Hyzon Motors have also been tested in ports and freight corridors.

Hydrogen trucks, if fueled with low-carbon hydrogen, can reduce GHG emissions by 90 to 92 percent.[38] For instance, Nikola's hydrogen Class 8 truck is projected to eliminate about 97 tonnes of CO_2 per year versus an equivalent diesel rig.[39]

Economic

Hydrogen fuel cell trucks remain significantly more expensive upfront than their diesel counterparts. Low production volumes and costly fuel cell systems mean FCEV purchase prices are roughly two to three times higher than diesel trucks.[40,41]

[34] https://cice.ca/projects/zero-emissions-h2-fuel-cell-electric-truck/
[35] https://ecv.hyundai.com/global/en/products/xcient-fuel-cell-truck-fcev
[36] https://www.reuters.com/business/autos-transportation/nikolas-hydrogen-powered-truck-deliveries-dealers-rise-22-q3-2024-10-02/
[37] https://www.htec.ca/100-fuel-cell-electric-trucks-a-reality-for-bc-through-htecs-h2-gateway-program/
[38] https://www.htec.ca/100-fuel-cell-electric-trucks-a-reality-for-bc-through-htecs-h2-gateway-program/
[39] https://www.powerprogress.com/news/a-first-for-nikola-hydrogen-fcev-in-canada/8038109.article?zephr_sso_ott=0fvBUm
[40] https://theicct.org/wp-content/uploads/2022/02/purchase-cost-ze-trucks-feb22-1.pdf
[41] https://www.trucknews.com/equipment/hydrogen-powered-trucks-in-midst-of-tests-and-proving-worth/1003174345/

Truck Type	Cost
Diesel Class 8	$180,000 to $250,000+
Hydrogen FCEV Class 8 Truck (Nikola, Hyundai, Toyota/Kenworth, etc.)	$470,000 to $800,000+

In addition to purchase price, long-term maintenance costs remain a concern despite FCEVs having smaller battery buffers that largely avoid the expensive battery replacement. Fuel cell stacks and hydrogen storage tanks have their own lifespans with components requiring periodic service or replacement, which could be costly. Though not directly comparable, the replacement frequency of hydrogen fuel cells in smaller vehicles such as the Hyundai Nexo is estimated to be every 5,000 operating hours[42] with recent costs exceeding the price of a brand-new vehicle.[43]

Further, hydrogen fuel is currently more expensive per kilometer than diesel with a current price of $14.70 per kg in British Columbia.[44] As an example, Nikola Tre's 70kg storage capacity would cost $1,029 for a full 800 km tank (or roughly $1.28 per km). In comparison, a diesel Class 8 truck holds a 450 to 560L tank and with an average diesel cost of $1.84, a full tank would cost $828 to $1,030. With an average fuel efficiency of 40L/100km or 2.5L/km,[45] a diesel truck can travel 1,125 to 1,400 km before refuelling.

Truck type	Cost per km
Diesel	~$0.73
Hydrogen	~$1.28

While both upfront and refuel costs are higher with hydrogen fuel cell trucks, both federal and provincial incentives described earlier may assist with reducing cost of ownership. Additionally, to reduce costs of hydrogen refueling, initiatives such as the Charging and Hydrogen Refueling Infrastructure Initiative (CHRI) aims to reduce transportation sector's GHG emissions by accelerating the private sector's rollout of large-scale zero-emission vehicle chargers and hydrogen refueling stations using $500 million in federal funding.[46]

Operational

Deploying hydrogen trucks in the field comes with practical challenges revolving around fuel infrastructure. Unlike diesel, hydrogen refueling stations are very limited across Canada with only a few public heavy-duty hydrogen stations operational. As of the end of 2024, Canada had 18 active hydrogen refueling stations in total[47] primarily located in British Columbia and Quebec. The lack of infrastructure makes it operationally challenging for organizations and businesses to adopt hydrogen technologies.

Another operational consideration is the need for specialized training and safety protocols. Hydrogen is stored at very high pressure and requires properly sealed systems. Maintenance staff and drivers therefore must be trained in handling hydrogen safely, refueling procedures, and the basics of fuel cell system operation. Many fleets currently lack this expertise, so adopting FCEV trucks means investing in training programs for technicians and educating drivers on new standard operating procedures.

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42 https://www.thedrive.com/news/hyundai-tucson-fcev-owner-shocked-by-113k-repair-bill-for-hydrogen-fuel-cell

43 https://www.drive.com.au/news/hyundai-ix35-hydrogen-fuel-cell-repair-germany/

44 https://www.htec.ca/faqs/

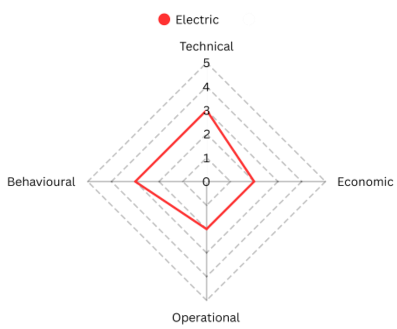
45 https://natural-resources.canada.ca/energy-efficiency/transportation-energy-efficiency/fuel-efficiency-benchmarking-canada-s-trucking-industry

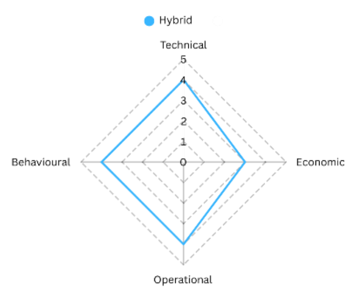
46 https://cib-bic.ca/en/charging-and-hydrogen-refuelling-infrastructure-initiative/

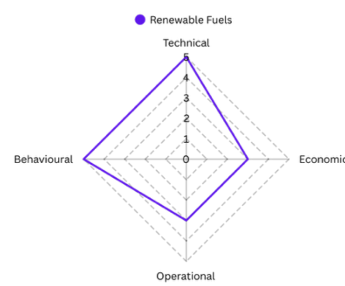
47 https://www.evcandi.com/news/nearly-80-global-hydrogen-refueling-stations-are-located-just-five-countries

B.1 Excavation and Earthworks

		Emissions	Technology	Economic	Operational	Behavioural
B1. Excavation/Earthworks	Electric	100% of direct emissions	3	2	2	3
			Limited availability	High premium	Charging difficulties	Reliability anxiety
	Hybrid Systems	20-40% fuel reduction	4	3	4	4
			Proven technology	15-30% premium	Similar operation	Proven and accepted
	Renewable Diesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited availability	No changes







Electrification (Battery Electric and Hybrid)

Technical

The development of battery-electric heavy equipment is underway, especially in smaller classes. Compact electric excavators are commercially available with Volvo's ECR25 Electric[48] and JCB's 19C-1E[49] as early examples. Aecon Group piloted the Volvo ECR25 on a Toronto project, becoming the first in Canada to use a zero-emission excavator on site.[50] Their findings suggested comparable performance to the diesel counterpart, offering lower noise and zero exhaust emissions.[51] While these eliminate fuel use and A5 emissions, their usage is currently best suited for small-to-medium jobs due to battery capacity limits. Mid-sized and heavy excavator development is still ongoing, with some models in the pilot testing phases. Larger hybrid excavators, such as the Komatsu HB215LC, which combine diesel engines with electric components

48 https://www.volvoce.com/united-states/en-us/products/electric-machines/ecr25-electric/

49 https://www.jcb.com/en-us/products/compact-excavators/19c-1e

50 https://www.aecon.com/press-room/news/2021/10/14/aecon-pilots-volvo-electric-excavator-in-support-of-ghg-emissions-reduction-targets---first-construction-company-in-canada-to-use-the-zero-emission-excavator-on-site-1

51 https://www.aecon.com/press-room/news/2021/10/14/aecon-pilots-volvo-electric-excavator-in-support-of-ghg-emissions-reduction-targets---first-construction-company-in-canada-to-use-the-zero-emission-excavator-on-site-1

and generated energy, are available commercially and offer carbon intensity reductions between eight and 41 percent.[52] [53]

Similarly, electric wheel loaders such as the Volvo L25 Electric and electric skid-steer/track loaders like the Bobcat T7X have been introduced with up to four hours of continuous operation time using a 62-kWh battery. Alternatively, hybrid wheel loaders, such as John Deere's 944K Hybrid, offer up to 38 percent reduction in emissions. Electric backhoe loaders remain limited in commercial availability with only few available, such as the Case 580EV. Otherwise, there are eco model backhoe loaders available, such as the JCB 3CX Eco, that, although not specifically hybrid, offer reduced emissions up to 16 percent through Tier IV diesel engines. Electric skid-steer loaders, such as the FirstGreen Industries Elise 1200 are also commercially available.

Both hybrid and electric articulated trucks remain in testing phases, with some models set to be available in 2026. Scania's electric articulated truck is expected to travel up to 450km with a 45-minute recharge time while Volvo's FH Electric articulated truck is expected to travel up to 600km on a single charge.

Electric, hybrid, and hydrogen-based trench rollers and smooth drum rollers remain in development and commercially unavailable. Alternatively, HAMM has introduced the "power hybrid" concept in their HD+ 90i PH tandem rollers.[54] The power hybrid system continues to use diesel to provide continuous base power but holds an electric hydraulic accumulator that provides 20 kW for peak loads and recharges afterward – requiring a 55.4 kW engine over the standard 85 kW.[55]

Electric drilling rigs remain in the prototype and testing phases, with few rigs demonstrated in Europe, including the Liebherr LB 16[56] and BAUER eBG 33.[57]

Economic

Electrifying excavation and earthworks equipment involves notable upfront investment. Below is a comparative overview of costs and upfront premiums associated with diesel, hybrid, and electric models (as available):

Equipment Type	Diesel Price Range	Hybrid Premium	Electric Premium
Excavators	$200,000 to $1,500,000+ [58]	20% savings (John Deere 644K vs. 644K Hybrid) [59]	40 to 100% premium [60]
Dozers	$100,000 to $1,000,000+ [61]	Up to 20% premium (CAT D7E) [62]	40 to 100% premium [63]

52 https://www.iploca.com/member-news/volvo-ce-brings-hybrid-technology-to-new-generation-excavators
53 https://www.sciencedirect.com/science/article/abs/pii/S0048969718311689
54 https://www.wirtgen-group.com/en-us/products/hamm/technologies/power-hybrid/
55 https://www.wirtgen-group.com/en-us/products/hamm/technologies/power-hybrid/
56 https://www.liebherr.com/en-ca/p/lb16unplugged-4079621
57 https://equipment.bauer.de/en/drilling-rig-ebg-33-electric-drive
58 https://heavyequipmentappraisal.com/excavator-cost/
59 https://construction.papemachinery.com/blog/can-hybrid-construction-equipment-stand-up-against-diesel
60 https://www.idtechex.com/en/research-article/total-cost-of-ownership-will-fuel-the-ev-construction-industry/31876
61 https://heavyequipmentappraisal.com/bulldozer-cost/
62 https://www.enr.com/articles/9256-cat-reveals-pricing-of-world-s-first-hybrid-dozer
63 https://www.idtechex.com/en/research-article/total-cost-of-ownership-will-fuel-the-ev-construction-industry/31876

Articulated Hauling Trucks	Up to $300,000+	*Not commercially available (goal to achieve cost parity by 2031)* [64]	*Not commercially available (goal to achieve cost parity by 2031)* [65]
Skid-Steer Loaders	$15,000 to $30,000	-	$20,000 to $45,000
Drum Rollers	$30,000 to $225,000+	-	-
Wheel Loaders	Up to $500,000+	-	-

Despite these higher upfront costs, hybrids dozers offer up to 30% savings in operating and ownership (O&O) expenses, primarily due to reduced fuel consumption, enhanced productivity, and lower maintenance requirements – resulting in a payback period of three years.[66] For example, electric skid-steer loaders have seen operational cost savings of up to 70 percent.[67] Further, both federal and provincial incentives are in place for excavation and earthworks, primarily in favour of articulated hauling trucks and excavation/earthworks vehicles that function as both on-road and off-road vehicles:

Table 7: Financial Incentive Programs Applicable to Excavation and Earthworks Equipment*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Clean Technology Investment Tax Credit (ITC)	Federal	Refundable tax credit	New off-road zero-emission equipment	30% of purchase cost
Accelerated CCA for Off-Road ZEV Equipment (Class 56)	Federal	Tax deduction (CCA)	New off-road zero-emissions vehicles and equipment	First-year depreciation of 55%-100%
CleanBC Go Electric – Commercial Vehicle Pilots (CVP)	British Columbia	Grant (cost-share)	Commercial ZEVs, including off-road heavy equipment and on-road medium/heavy-duty fleet vehicles and charging infrastructure	Up to 1/3 of project costs (vehicle and infrastructure)
Programme Écocamionnage	Quebec	Rebate	New BEV or PHEV Class 3-8 trucks and heavy off-road vehicles used for freight or construction	Up to $175,000. 15% bonus for Quebec-made vehicles. *Program under review as of April, 2025*
Electrify Nova Scotia Medium/Heavy Vehicle Rebate	Nova Scotia	Rebate	Medium- and heavy-duty on-road EVs	$10,000–$50,000
Yukon Commercial EV Rebate	Yukon	Rebate	Commercial zero-emission vehicles class 2B and above	$10,000
Yukon "Super Green Credit" (Business Carbon Rebate)	Yukon	Tax credit / rebate	Any technology or equipment that reduces emissions	Variable

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

64 https://www.thetimes.com/uk/environment/article/starmer-wants-e-trucks-on-the-road-but-manufacturers-are-stalling-times-earth-zvf8902zc
65 https://www.thetimes.com/uk/environment/article/starmer-wants-e-trucks-on-the-road-but-manufacturers-are-stalling-times-earth-zvf8902zc
66 https://www.enr.com/articles/9256-cat-reveals-pricing-of-world-s-first-hybrid-dozer
67 https://voltequip.com/news/why-not-electric/

Operational

Electric earthmoving equipment is currently effective in smaller-scale operations. As battery runtime falls short of a full workday (i.e., up to 4 hours for electric loaders), half-day operations are insufficient and require scheduling that incorporates dedicated charging periods or facilitates battery swapping on modular equipment – significantly extending operational uptime and project length while also requiring additional infrastructure and modular equipment. This is especially true with colder climates reducing battery life. Since excavation and earthworks equipment remains monolithic, construction projects in urban settings require temporary grid connections and remote sites require generators to maintain emissions benefits. Operationally, hybrid earthmoving equipment is most practical as fuel can be used when charging infrastructure is unavailable.

Minimal operator training is required with a focus on electric equipment characteristics such as torque management and regenerative braking systems. Maintenance protocols, on the other hand, can extend project cost and uptime through ensuring temperature management, particularly in colder climates. While many earthmoving equipment is kept on-site overnight, battery-electric equipment may require heated storage solutions to retain battery performance.

Behavioural

Behavioural factors influence staff perceptions regarding the adoption of electric and hybrid earthmoving and excavation equipment on construction sites. Staff may initially perceive electric machinery as less reliable or powerful compared to traditional diesel equipment. Concerns of battery longevity, equipment downtime, performance during demanding tasks, and inability to leave vehicle idle during short breaks may present challenges. Hands-on demonstrations and education will be necessary. There may be concerns with additional responsibilities including monitoring battery levels and adapting to new safety protocols involving high-voltage systems. Hybrid equipment adoption is less likely to present challenges associated with reliance on fully electric equipment.

Renewable Fuels

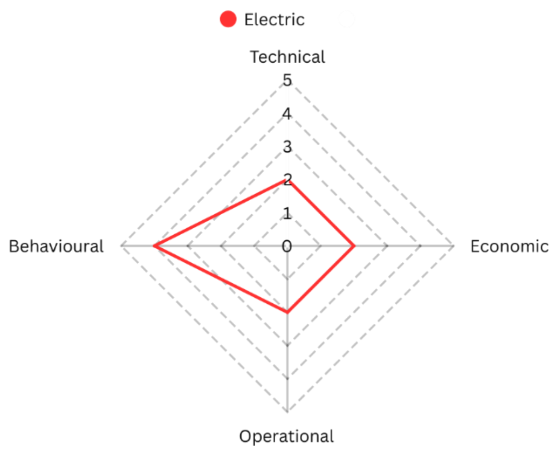
Technical

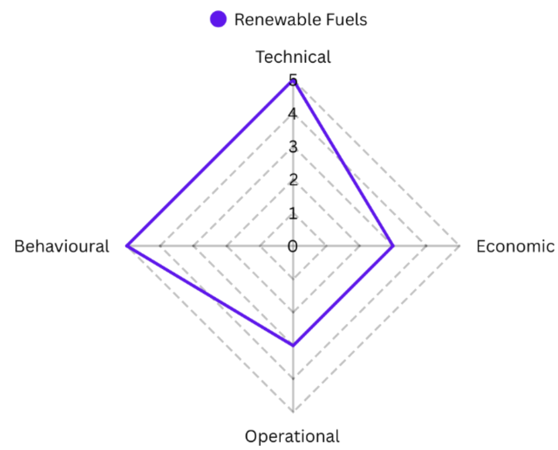
During the period while many earthmoving equipment remain diesel-reliant, using low-carbon fuels can cut emissions. Many newer model equipment is compatible with biodiesel blends (B20), and some can use renewable diesel as a direct replacement for diesel. While not necessarily relevant to reducing A5 emissions, these fuels yield large net CO_2 reductions without the need for new equipment. One study found life-cycle emissions reductions for producing biodiesel and renewable diesel from oilseeds and waste grease range from 40 to 86 percent.[68]

[68] https://pubs.acs.org/doi/10.1021/acs.est.2c00289

B.2 Concrete and Asphalt

		Emissions	Technology	Economic	Operational	Behavioural
B2. Concrete/Asphalt	Electric Equipment	100% for applicable sizes	2	2	2	4
			Size limited	High cost	Power infra needed	
	Renewable or Biodiesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited supply	No changes





Electrification

Technical

Electric pavers and curb machines have recently become commercially available with very limited options. Gomaco has developed the CC-1200e slipform curb machine, which is the only one of its kind that can operate for a full workday on a single charge.[69] Gomaco also offers their GT-3600 Hybrid curb paver. Leeboy's 8520C Electric paver, on the other hand, is the first fully electric asphalt paver in commercial paving.[70] However, availability across Canada remains limited with Leeboy dealers primarily located in Alberta and Saskatchewan with limited availability in other provinces[71] and Gomaco's reliance on a single third-party distributor per province.[72] Progress is also evident in concrete mixing and delivery trucks. In 2023, Lafarge Canada deployed two all-electric VMC 1200 mixer trucks in British Columbia,[73] which are

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[69] https://www.gomaco.com/Resources/cc1200e.html
[70] https://www.leeboy.com/products/8520c-electric/
[71] https://www.leeboy.com/find-a-dealer/
[72] https://www.gomaco.com/Resources/distributors/canadalookup.html
[73] https://www.lafarge.ca/en/lafarge-canada-pioneers-all-electric-trucks-setting-bar-sustainable-operations-north-america

Class 3 trucks with 240km of range on a single charge. Revolution Concrete Mixers are also in development stages of both hybrid and electric mixers.

Technical data on performance and emissions for electric concrete/asphalt machines remains unavailable as there is currently no published carbon intensity or fuel efficiency data for full-size electric pavers or heavy electric mixer trucks in operation – mainly because they are in prototype or early stages. Initial results, however, are promising. For example, in a multi-partner pilot, electric construction machines were found to perform similarly to diesel counterparts with reduced emissions.[74]

Economic

The purchase price of full-sized electric and hybrid concrete pavers or heavy electric mixer trucks is currently not well-documented since they are relatively new. In the absence of published prices for electric and hybrid pavers and mixers, early pricing discussions with Leeboy and Gomaco distributors and research of smaller mixers revealed the following:

Equipment Type	Cost
Leeboy 8520 (Diesel) Paver	$365,000 to $410,000[75]
Leeboy 8520C (Electric) Paver	$495,000 to $587,000[76]
Gomaco GT-3600 (Diesel) Curb Paver	$170,000 to $325,000[77]
Gomaco GT-3600 Hybrid Curb Paver	$288,000 to $363,000[78]
Gomaco CC-1200e (Electric) Curb Paver	$340,000 to $420,000[79]
Multiquip MC94PH8 (Gasoline) Mixer	$10,000 to $25,000
Multiquip EM120 (Electric) Mixer	$5,000 to $20,000

Like the other types of vehicles and equipment examined above, the operating costs are expected to be lower than for fossil fuel-powered equipment. Based on recent diesel prices and the average consumption of fuel by pavers and mixers and assuming the use of equipment for a full 8-hour working day for 251 business days in the year, the cost savings associated with using a fully electric paver would be an estimated $15,107 to $46,397 less the cost of charging. The cost savings associated with using an electric ready-mix truck depends on numerous factors, including project size, frequency of use, and location/distance. However, the cost of $0.56 to $1.86 per km travelled can be utilized by developers to estimate cost savings.

74 https://www.volvoce.com/global/en/news-and-events/news-and-stories/2024/study-proves-viability-of-urban-electric-construction
75 Prices acquired from Cubex (distributor) in Vancouver
76 Prices acquired from Cubex (distributor) in Vancouver
77 https://www.machinerytrader.com/listings/for-sale/gomaco/construction-equipment?srsltid=AfmBOopwnev-6pH_LW3nVRkrnuV6f_hltWYV6L1WEYxn28fckERCl2mT
78 Prices acquired from HMA Equipment Company (distributor) in Ontario
79 Prices acquired from HMA Equipment Company (distributor) in Ontario

Equipment	Data Source	Average Litres burned	Cost of fuel/savings per 8-hour day (assuming 167.2 / L average)[80]
Paver	Caterpillar (CAT)[81]	4.50 to 13.82 L/hour	$60.19 to $184.85 per day
Concrete Pump	Luton Machinery[82]	12.90 to 31.80 L/hour	$172.55 to $425.36 per day
Ready-Mix Truck	Energy Star[83]	0.34 to 1.11 km/L	$0.56 to $1.86 per km

Currently, no federal or provincial incentives are specifically designated for electric concrete pavers and mixer trucks. However, the table below shows incentive and rebate programs that may apply to some equipment.

Table 8: Financial Incentive Programs Applicable to Concrete and Asphalt Equipment*

Program Name	Jurisdiction	Type	Eligibility	Incentive
iMHZEV – Incentives for Medium- and Heavy-Duty ZEVs	Federal	Rebate	BEV, FCEV, or PHEV commercial vehicles classes 2B through 8	$10,000 – $200,000 per vehicle
Federal Accelerated Investment Incentive for ZEVs	Federal	Tax credit	Eligible zero-emission vehicles used in business	First-year depreciation of 55%-100%
Clean Technology Investment Tax Credit	Federal	Tax credit	New heavy-duty electric or hydrogen mining and construction equipment	30% of purchase cost
CleanBC Go Electric Rebates – MHD Specialty Use	British Columbia	Rebate	On-road medium- and heavy-duty zero-emission vehicles (Class 2B–8 trucks, vocational trucks like mixers)	33% of purchase price, up to $150,000
CleanBC Go Electric – Commercial Vehicle Pilots (CVP)	British Columbia	Grant	Commercial ZEVs, including off-road heavy equipment and on-road medium/heavy-duty fleet vehicles and charging infrastructure	Up to 1/3 of project costs (vehicle and infrastructure)
Programme Écocamionnage	Quebec	Rebate	ZEV freight trucks, including Class 7-8 and concrete mixer trucks	Up to $175,000. 15% bonus for Quebec-made vehicles. *Program under review as of April, 2025*
Electrify Nova Scotia – MHZEV Rebate Program	Nova Scotia	Rebate	On-road ZEVs, Class 2B and above	$10,000–$50,000
Yukon Good Energy Program – Commercial EV Rebate	Yukon	Rebate	ZEVs, classes 2B and up	$10,000

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

80 https://www2.nrcan.gc.ca/eneene/sources/pripri/prices_byyear_e.cfm?ProductID=5&_gl=1*z0uor3*_ga*MzU3MDAxMzA3LjE3Mzk0NjY1NTg.*_ga_C2N57Y7DX5*MTc0MzUzOTc3MC45LjAuMTc0MzUzOTc3MC4wLjAuMA..

81 https://wheelercat.com/wp-content/uploads/2023/01/Cat-Performance-Handbook-from-VST-fuel-consumption-2022-12-09T21-20-09.pdf

82 https://lutonmachinery.com/fuel-consumption-of-concrete-pump/

83 https://www.energystar.gov/sites/default/files/buildings/tools/Concrete_Quick_Guide_09052013.pdf

Operational

Electric concrete and asphalt equipment requires additional operational planning due to infrastructure demands. Charging solutions must be integrated into jobsite layouts, including either reliable grid access or the installation DC fast-charging charging stations. Since concrete pavers and mixer trucks often operate continuously throughout the day, scheduling must accommodate dedicated charging periods, which can extend project timelines. This is particularly true in cold climates, where lower temperatures reduce battery performance and overall efficiency. Given the limited commercial availability of larger electric concrete machinery, hybrid models or renewable fuels may present a more immediately practical solution, providing operational flexibility through continued diesel use.

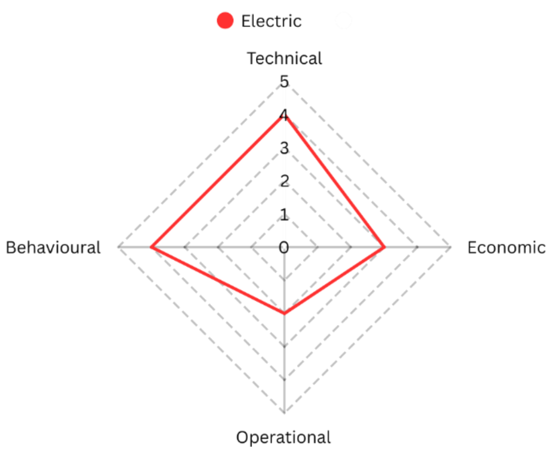
Like other pathways, minimal training is required for operators with electric equipment apart from power management, battery monitoring, and basic operational adjustments. However, maintenance requirements may involve added complexities, such as temperature-controlled storage to protect battery lifespan and ensure reliable operation.

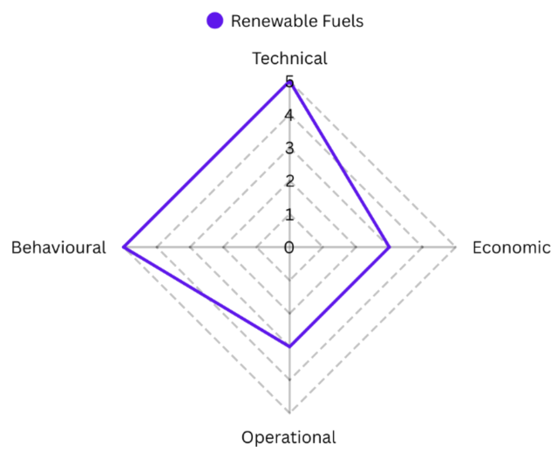
Behavioural

Staff may initially perceive large electric machinery as less reliable or powerful compared to traditional diesel equipment. However, smaller plug-in electric concrete and asphalt equipment are common and well-accepted for use in smaller projects. For larger projects, hybrid equipment adoption is less likely to present challenges associated with reliance on fully electric equipment.

B.3 Miscellaneous Equipment - Land

		Emissions	Technology	Economic	Operational	Behavioural
B3. Misc. Equipment - Land	Electric Equipment	100% direct emissions	4	3	2	4
			Commercially available	50-100% more upfront	Power infra needed	
	Renewable Diesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited availability	





"Miscellaneous Equipment - Land" covers a broad range of other non-road construction equipment used on land-based sites that do not fall into the earlier categories. For this disparate equipment group, decarbonization involves applying general strategies of electrification, fuel switching, and efficiency on a case-by-case basis.

Electrification

Technical

Electric drive technology is widely established in forklifts and primarily adopted in warehouses and industrial settings. Toyota alone has developed seven different forklifts that cover various lifting capacities and operational needs, from a 3-wheel to turret to pneumatic. Side-by-side utility vehicles (UTVs) offer several options from Polaris' Ranger Zero series to Kandi's Innovator e10K. In smaller equipment, some manufacturers are piloting solar-assisted and battery-electric equipment.

Economic

Electric equipment comes with higher upfront costs than diesel-powered models. Below is a detailed comparison highlighting these differences:

Equipment Type	Diesel/Propane Price Range	Electric Price Range
Forklifts	$27,000 to $70,000	$35,000 to $60,000
Side-by-Side (UTVs)	$20,000 to $45,000	$20,000 to $50,000

While differences in upfront costs remain an obstacle, electric models allow for significant operational savings over time. Electric forklifts and UTVS have reported operational cost savings of up to 75 percent,[84] and 70 percent,[85] respectively.

Table 9: Financial Incentive Programs Applicable to Misc. Equipment – Land*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Accelerated CCA for Off-Road ZEV Equipment (Class 56)	Federal	Tax deduction (CCA)	New off-road zero-emissions vehicles and equipment	First-year depreciation of 55%-100%
CleanBC Go Electric Specialty Use Vehicle Incentives (SUVI)	British Columbia	Rebate	Off-road and specialty ZEVs not covered by standard EV programs. Includes industrial material-handling equipment	$2,000 - $150,000
Yukon "Good Energy" E-Transportation Rebate	Yukon Territory	Rebate	Electric recreational & utility vehicles	$750-$2,500
Arctic Energy Alliance EV Rebate (Electric Vehicles Program)	Northwest Territories	Rebate	Highway-capable EVs and as of 2023, certain off-road electric vehicles used in NWT communities	Up to $5,000 per vehicle for fully electric vehicles

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

Operational

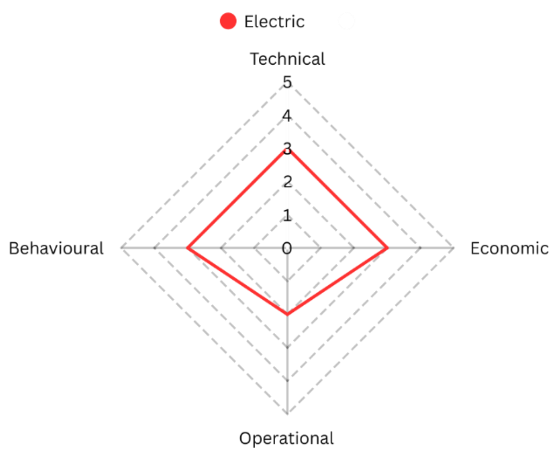
Transitioning to electric equipment requires careful operational planning, particularly for charging infrastructure. This equipment typically remains on job sites, which requires dedicated Level 2 charging stations or designated charging areas to minimize downtime. Portable generators or battery banks might be used in remote locations lacking grid access. Operators will require minimal training in battery management practices, such as monitoring battery life, adhering to charging schedules, and understanding runtime expectations. Ensuring site managers schedule charging efficiently can optimize workflow and equipment availability.

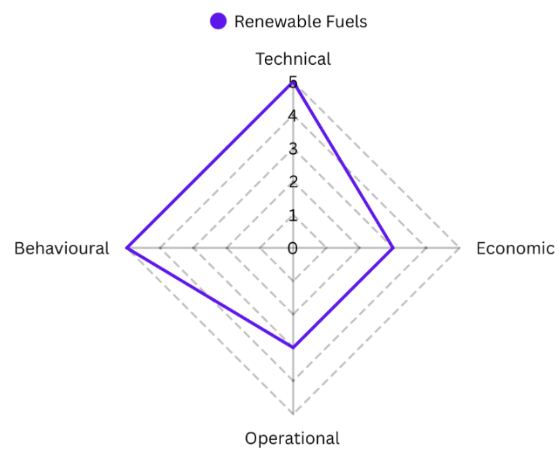
84 https://www.toyotamhs.com/wp-content/uploads/2019/12/Forklift-Decisions-and-Responding-to-the-Electric-Trend-Whitepaper-2019.pdf

85 https://www.polarisaustralia.com/news/detail/7-reasons-why-an-electic-utv-is-smart-for-business.html

B.4 Miscellaneous Equipment – Marine

		Emissions	Technology	Economic	Operational	Behavioural
B4. Misc. Equipment - Marine	**Electric boats**	100% direct emissions	3	3	2	3
			Commercially available	20-50% more upfront	Power infrastructure needed	
	Renewable Diesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited availability	





Electrification

Technical

Modern fully electric and hybrid marine vessels are becoming more available for workboat applications but are primarily in pilot and developmental stages. Further, Canadian access remains extremely limited unless internationally obtained. For example, in the UK the Coastal Workboats E-LUV electric landing utility vessel is in development[86], and Estonia's Baltic Workboats has a contract to deliver hybrid-electric Pilot 17 WP[87] harbour pilot boats by the end of 2025. The only Canadian manufacturer of electric marine vessels, British Columbia's Templar Marine, produces 100% electric 26-foot boats for water taxi and tour applications[88], but is currently listed for sale.

While diesel engines in marine vessels differ from those in on-road vehicles, which may alter GHG emission values, data related to the carbon intensity of marine vessels and workboats are not readily available. However, diesel engines emit an estimated 2.7kgCO_2 per litre of fuel consumed. By contrast, a fully electric vessel has zero tailpipe emissions (CI = 0) when running on battery power. Hybrid vessels generally produce

[86] https://www.coastalworkboats.co.uk/e-luv
[87] https://workboat365.com/baltic-workboats-secures-contract-for-two-hybrid-pilot-boats/
[88] https://www.templarmarine.com/

lower GHG emissions than exclusively diesel vessels, though their exact carbon intensity depends on the duty cycle and charging source.

Economic
Because much of the technology to electrify marine operations is in the early stages of commercialization, the cost is unknown. However, various government incentive programs may apply.

Table 10: Financial Incentive Programs Applicable to Misc. Equipment – Marine*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Programme d'aide à l'amélioration de l'efficacité du transport maritime, aérien et ferroviaire (PETMAF)	Quebec	Grant	Commercial maritime vessels and related equipment	Up to 65% of eligible project costs
CleanBC Go Electric Specialty Use Vehicle Incentives (SUVI)	British Columbia	Rebate	Off-road and specialty zero-emission vehicles not covered by standard EV programs. Includes industrial material-handling equipment	$2,000 - $150,000
CleanBC Go Electric – Commercial Vehicle Pilots (CVP)	British Columbia	Grant (cost-share)	Commercial ZEVs, including off-road heavy equipment and on-road medium/heavy-duty fleet vehicles and charging infrastructure	Up to 1/3 of project costs (vehicle and infrastructure)
Yukon "Good Energy" E-Transportation Rebate	Yukon Territory	Rebate	Electric recreational & utility vehicles	$750-$2,500

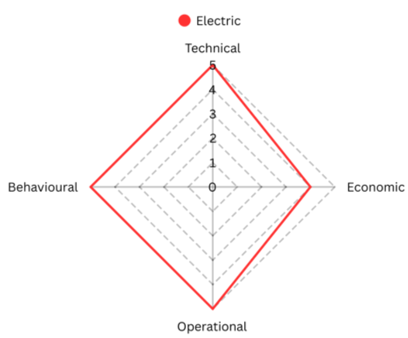
** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

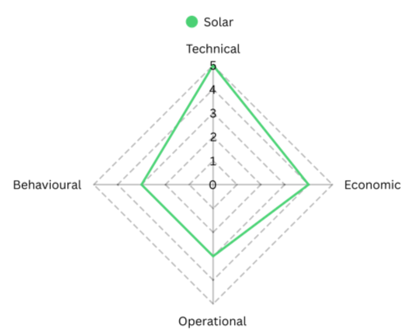
Operational
Many electric marine vessels are currently manufactured outside of Canada, a factor that can impact their availability and procurement costs domestically. Additionally, marine-specific charging infrastructure remains limited, with only a handful of fast-charging shore power stations being developed globally, primarily at major international ports. Canada's progress in this area has been relatively slow, potentially constraining the adoption of electrified marine vehicles within the country. The transition to electric propulsion requires specialized training for operators to manage critical aspects such as energy management and charging logistics effectively. Comprehensive training programs are therefore essential for operators to fully grasp the operational benefits, limitations, and practical considerations associated with electric propulsion systems in marine environments.

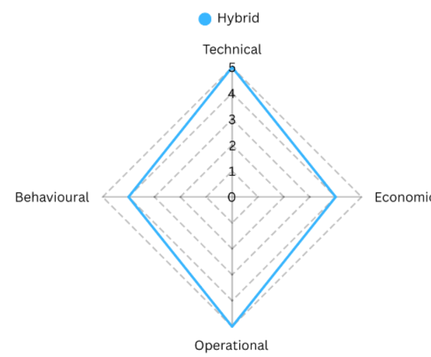
Behavioural
Behavioral factors may influence the adoption of electrified marine vehicles. Key concerns include consistency of power output, battery longevity, and potential vulnerabilities such as water damage to sensitive electrical components. Additionally, there may be resistance stemming from established operational routines and a preference for familiar, proven technologies. Overcoming these behavioral hurdles requires targeted education and clear demonstrations of reliability, safety, and cost-effectiveness to build confidence and encourage widespread acceptance of marine electrification.

C.1 Lighting

		Emissions	Technology	Economic	Operational	Behavioural
C1. Lighting	LED + Smart Controls – Electric	60-80% energy use, 100% reduction in direct emissions	5	4	5	5
			Mature technology	Quick payback	Simple retrofit	Familiar Solution
	Solar	100% reduction	5	4	3	3
			Mature technology	Quick payback	Limitations with weather	Reliability doubt
	Hybrid Diesel/Solar	Reduction of 70-80%	5	4	5	4
			Mature Technology	Quick payback	Works under all conditions	Some doubt but diesel support







Electrification

Technical

Fully electric lighting towers are common and commercially available in Canada, using grid power (or a solar array) to recharge. A typical battery tower, such as Atlas Copco's HiLight Z3+ can provide between 32 hours[89] to 75 hours[90] of lighting on a single charge, depending on usage and dimming settings, and can be recharged in 6-8 hours. With no onboard engine, electric light towers eliminate fuel use and emissions. Other available electric light towers include Generac's plug-in CTF-10[91] and MLTB battery light tower, and Multiquip's Globug series.[92]

Hybrid towers are also commercially available with the ability to have a battery supply power and a diesel engine to recharge the battery or support the load as needed. This load-leveling allows the engine to run

89 https://www.atlascopco.com/en-gr/construction-equipment/pfl-landings/templates/battery-light-tower-campaign
https://www.atlascopco.com/en-gr/construction-equipment/pfl-landings/templates/battery-light-tower-campaign
90 https://steadypower.com/product/generac-mobile-mltb-battery-light-tower/
91 https://www.generac.com/industrial-products/mobile-power-light-solutions/light-towers/light-tower-ctf-10-plug-in/
92 https://www.multiquip.com/multiquip/globug.htm

intermittently at optimal efficiency, running 8-16 hours before requiring a charge. For example, the HIMOINSA HBOX+ hybrid tower offers up to 16 hours of silent lighting[93] while on average cutting fuel consumption and emissions by 50-90%.[94] Other available hybrid light towers include Atlas Copco's BI+ 4, which runs for 20 hours on a single charge.[95]

As for solar-battery light towers, commercial availability in Canada is prominent with manufacturers including Wanco's WLTS-M-1600H[96] and Finning's SLT-6[97], which are primarily designed for remote and off-grid applications.

Atlas Copco's HiLight series (Z3+ battery, H5+ and H6+ hybrids) and Generac's Mobile series (i.e., the VT Solar and Hybrid LED towers) are two examples available through Canadian dealers. Further, local rental companies are also beginning to stock solar/battery light towers to meet demand from sustainable construction projects.

Economic

Electrified and hybrid lighting equipment typically require an upfront premium over their diesel counterparts. A standard diesel mobile 6kW LED light tower costs $12,000 to $15,000 to purchase new. In comparison, a Generac Mobile VT solar LED tower lists at about $22,000, and Atlas Copco's lithium battery towers are in a similar range (pricing ~1.5× a diesel unit). Hybrid diesel-battery towers fall in between – their cost premium is modest. While the capital cost is higher, the total cost of ownership often favors electric solutions over a few years of operation due to fuel and maintenance savings.

Lighting Tower Type	Fuel/Energy Use per hour[98]	Emissions per month[99]	Runtime (before refuel/recharge)[100]	Cost
Diesel	0.5 L diesel	336 kgCO2	200 hours	$12,000 to $15,000
Hybrid-Diesel	0.2 L diesel	171 $kgCO_2$	860 hours for fuel + 18 hours silent running per charge	$15,000 to $18,000
Battery Electric	5-10 kWh	0	8 to 32 hours per charge	$20,000 to $25,000
Solar-Battery	5-10 kWh	0	Up to 16 hours *(Sufficient sunlight required)*[101]	$30,000 to $70,000

While upfront premiums range from 25 to 108 percent for electric and diesel-hybrid towers, ownership and operating costs are reduced through the reduction of maintenance frequency and costs. For example, with Atlas Copco's HiLight electric towers, service intervals are reduced to every 600 hours[102] and 1,500

93 https://www.himoinsa.com/landing/hbox-hybrid-lighting-tower/142/eng.html
94 https://www.sunbeltrentals.co.uk/media/5ljbldia/109072-tower-light-comparison-chart-2022.pdf
95 https://www.atlascopco.com/en-au/construction-equipment/products/light-towers/battery-portable-light-towers/hybrid-hilight-bi-plus-4
96 https://www.wanco.com/product/programmable-hybrid-solar-light-towers/
97 https://www.finning.com/content/dam/finning/en_ca/22345%20-%20SLT%206%20ALt.pdf
98 https://www.sunbeltrentals.co.uk/media/5ljbldia/109072-tower-light-comparison-chart-2022.pdf
99 https://www.sunbeltrentals.co.uk/media/5ljbldia/109072-tower-light-comparison-chart-2022.pdf
100 https://www.sunbeltrentals.co.uk/media/5ljbldia/109072-tower-light-comparison-chart-2022.pdf
101 https://www.fs.usda.gov/sites/default/files/2022-07/GFT-BMP-Solar-Lt-n-Power.pdf
102 https://atlas-copco-images.s3.amazonaws.com/Brochure-HiLight-Range-English-v05.pdf

hours for their hybrid towers.[103] Solar towers, on the other hand, carry an upfront premium of 150 to 500+ percent. However, unlike diesel-hybrid or battery electric towers, operating costs of solar towers are further reduced by utilizing sunlight for charging rather than incurring electricity and/or diesel costs. Though solar panels only require replacement every 25 to 30 years[104], unexpected damages, especially in on-site settings, can lead to significant costs as each panel cost between $228 USD (~$323 CAD) to $1,492 USD (~$2,117 CAD).[105] [106]

Further, Canada and its provinces have introduced incentives that primarily relate to solar equipment but also cover some hybrid and electric light towers:

Table 11: Financial Incentive Programs Applicable to Lighting Equipment*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Clean Technology Investment Tax Credit (ITC)	Federal	Tax Credit	Renewable energy generation equipment, stationary battery storage (no fossil fuel use), and non-road ZEVs	30% of eligible equipment cost
Accelerated Capital Cost Allowance – Clean Energy / ZEV Equipment	Federal	Tax Deduction	Clean energy equipment eligible under Classes 43.1/43.2; and ZEV off-road vehicles under Class 56	First-year depreciation of 55%-100%
PST Exemption for Renewable Energy Equipment	British Columbia	Sales Tax Exemption	Solar, wind, and micro-hydro generation equipment	7% of equipment cost
Arctic Energy Alliance – Renewable Energy Rebate (Commercial)	Northwest Territories	Rebate	Off-grid renewable energy systems for businesses	50% of project costs up to $50,000 per project

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

Operational

The implementation of electric, hybrid, and solar light towers may necessitate additional training for operators and maintenance personnel. Given the technological differences from conventional diesel towers, staff may require training on proper operation, charging procedures, and preventative maintenance to ensure optimal performance and equipment longevity. Electric light towers depend on access to charging infrastructure or a reliable power source, such as portable generators, which can affect overall site layout and logistics since sufficient space and access is needed for charging stations or fuel supply setups.

In contrast, solar-battery light towers offer operational advantages in remote and off-grid settings. Since they utilize solar energy to charge onboard batteries, there is continuous, and autonomous operation without the need for grid, generator, or fuel resupply. This makes them particularly well-suited for remote and off-grid work sites, and environmentally sensitive areas.

Behavioural

The transition from diesel light towers to electric or hybrid alternatives will likely not involve resistance from staff as electric lighting is the standard. There may be minimal hesitation from a lack of familiarity with charging times, which can be overcome by demonstrations and hands-on training. There may also be

[103] https://www.atlascopco.com/en-au/construction-equipment/products/light-towers/battery-portable-light-towers/hybrid-hilight-bi-plus-4

[104] https://www.sciencedirect.com/science/article/pii/S2212827122001317

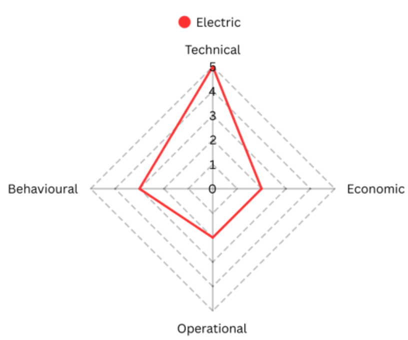
[105] https://www.angi.com/articles/how-much-does-it-cost-repair-solar-panels.htm

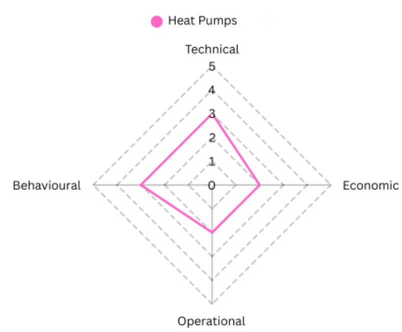
[106] https://www.sciencedirect.com/science/article/pii/S2212827122001317

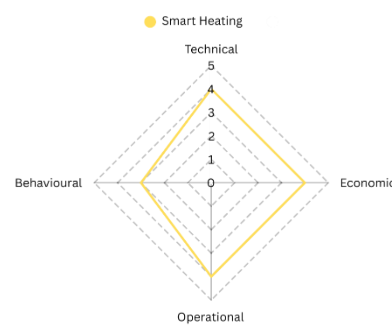
positive influence on user perception over time as electric and hybrid towers typically produce less noise and contribute to a quieter site especially during urban or overnight operations. The ease of use, reduced fuel handling, and lower maintenance requirements of electric light towers can also reduce recurring tasks for staff, allocating more time to other duties. As for solar-powered towers, there is expected resistance due to charging anxiety associated with insufficient sunlight charging during cloudy conditions or the winter season's shorter daylight.

C.2 Heating

		Emissions	Technology	Economic	Operational	Behavioural
C2. Heating	**Resistive Electric Heat (Switch from NG)**	Varies with grid mix, up to 100%	5	2	2	3
			Mature technology	High electricity costs	Dependent on access to grid hookup	
	Heat Pumps		3	2	2	3
			Size limited	High cost	Power needed	
	Smart Heating	Reductions of 10-50%	4	4	4	3
			High technical readiness	Strong business case	Feasible with some effort	Possible lack of trust with automated controls







Electrification

Technical

High-output electric on-site heaters are commercially available in Canada, including the Fostoria FES-1520-3E,[107] Heat Wagon P6000[108], and Frost Fighter E64QRH.[109] With respect to efficiency, electric units can provide clean heat with one hundred percent efficiency – all input energy being converted to heat – and produce no on-site emissions. Diesel and natural gas heaters, on the other hand, lose 10 to 20 percent of energy through exhaust in indirect setups. Since many heaters are utilized indoor/semi-indoor, an electric heater's elimination of combustion byproducts, such as CO_2, CO, NO_x, and soot require no venting or fresh-

[107] https://www.ameritempgroup.com/store/p53/Fostoria%C2%A0FES-1524-3E_15KW_240V_3Ph_Portable_Electric_Salamander_Heater.html?srsltid=AfmBOork8QQYtQhD37EERVOkqXEWmWelhngKq4PCY7P117HiKDm_mq_M
[108] https://heatwagon.com/products/electric-heaters/p6000/
[109] https://www.frost-fighter.com/heating-products/electric-heaters

air dilution.[110,111] However, most electrical heaters commercially available sit under 200,000 BTU with larger 400,000 BTU heaters still in developmental stages. Carbon intensity of fossil-fuel-powered heaters vary by type as some utilize diesel while others natural gas – diesel fuel has a carbon intensity of 74 kg CO_2e/GJ; natural gas is lower at 56 kg CO_2e/GJ.[112] Comparatively, an electric heater's carbon intensity is zero.

Heater Fuel	Carbon Intensity (kgCO2e/GJ)	Efficiency	Average fuel consumption (L/hr)
Diesel	73.96	~80-90%	10.4[113]
Natural Gas	55.98	~90%	17.02
Electric	0	100%	-

Economic

Upfront premiums of electric heaters are higher than their diesel counterparts depending on the type of fuel-powered heater (i.e., direct vs. indirect).

Heater Type	Diesel/Propane Cost	Electric Heater Cost
Direct	$600 to $5,000+	$3,000 to $7,000+
Indirect	$12,000 to $25,000+	

Table 12: Financial Incentive Programs Applicable to Heating Equipment*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Clean Technology Investment Tax Credit (ITC)	Federal	Tax Credit	Renewable energy generation equipment, stationary battery storage (no fossil fuel use), and non-road ZEVs	30% of eligible equipment cost
Accelerated Capital Cost Allowance – Clean Energy / ZEV Equipment	Federal	Tax Deduction	Clean energy equipment eligible under Classes 43.1/43.2 including air-source, ground-source and heat recovery heat pumps	First-year depreciation of 55%-100%
BC Hydro Industrial Fuel Switching & Electrification	British Columbia	Grant	Industrial/commercial electrification projects	Capital incentive amount determined per project
Energy Savings for Business (ESB)	Alberta	Grant	Energy-efficient equipment for businesses	Up to $250,000 per project

110 https://partnerrentals.com/guide-to-selecting-the-right-construction-site-heaters/
111 https://www.energy.gov/energysaver/small-space-heaters
112 https://www.epa.gov/sites/default/files/2015-07/documents/emission-factors_2014.pdf
113 https://cooperequipment.ca/rental-equipment/400000-btu-indirect-fired-diesel-heater

ÉcoPerformance Program	Quebec	Grant	Electric or dual-fuel heating systems for commercial, industrial, and institutional applications	Up to 75% of project cost
Business Rebate Program	New Brunswick	Rebate	Approved energy-efficient products for commercial use	25% of purchase cost
Business Energy Rebates (BER)	Nova Scotia	Rebate	Wide range of high-efficiency electrical equipment for businesses	Up to 75% of product cost
Business Energy Rebates Program	PEI	Rebate	Energy-efficient equipment for businesses and farms	Up to $25,000 per project
Good Energy Commercial Energy Rebates	Yukon	Rebate / Grant	Electric heating systems	Up to 40%

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

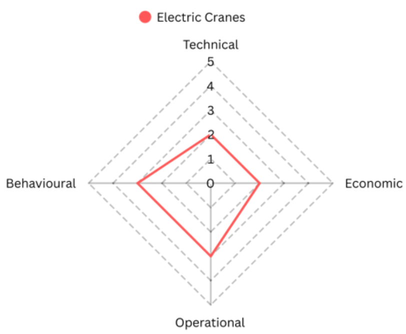
Operational

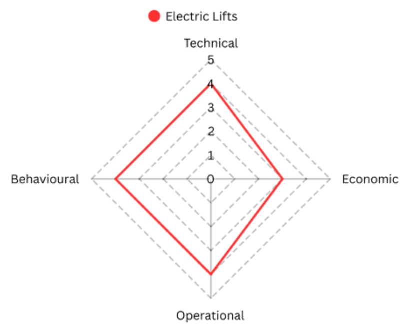
Electric heaters require consistent and reliable power either via grid access or on-site generators to be effective. However, their dependence on electricity presents operational challenges particularly in environments with limited power supply. In remote or large-scale construction sites, for example, where access to the electrical grid may be unavailable or limited, using electric heaters can present operational challenges unless generators are in place. Though even with generators, the high energy demand of industrial heaters may render smaller generators ineffective. For example, a 60-kW unit would draw 100 A at 480 V. Considering these limitations, electric heaters would likely not be suitable for large-volume heating or remote sites. Further, since a 400,000 BTU (117-kW) equivalent electric heater is not commercially available, multiple electric heaters would be needed to replace a single indirect heater, making it both operationally and economically challenging.

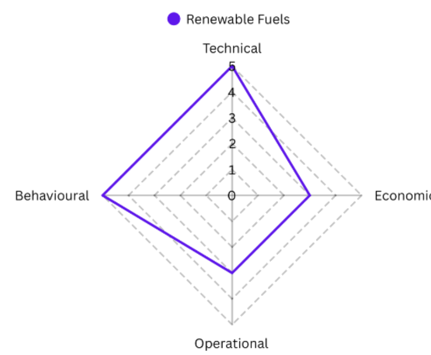
Electric heaters also offer operational advantages as they are typically quieter during operation, produce no on-site emissions, and reduce ventilation requirements. With the absence of open flames or fuel tanks, fire risk is reduced, and job-site safety planning is operationally less challenging.

C.3 Cranes and Lifts

		Emissions	Technology	Economic	Operational	Behavioural
C3. Cranes & Lifts	**Electric Cranes**	100% direct emissions	2	2	3	3
			Prototypes only	High upfront cost	Charging/electric connection needed	
	Electric Aerial Platforms	100% direct emissions	4	3	4	4
			Commercially available	Moderate premium	Standard operation	
	Renewable Diesel	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	30-50% fuel premium	Limited supply	







Electrification

Technical

Many lifts are already available in battery-electric versions or can be retrofitted with clean power sources. The market for electric and hybrid lifting equipment is rapidly expanding. Small-capacity lifts, such as Maeda's CC1485[114] and UNIC's ECO-095 and ECO-295[115] offer plug-in and battery power options. Recently, larger models have been emerging with Tadano introducing the GR-1000XLL EVOLT[116], a fully electric 100-ton rough-terrain crane. Liebherr has developed the LR 1200.1 Unplugged 200-ton crawler crane[117], the world's first battery-powered crawler crane, as well as the 250-ton model LR 1250.1[118]. Likewise, Sennebogen offers a 50-ton telescopic crawler crane that can run on battery or be plugged in[119].

114 https://www.maeda-minicranes.com/news/2021/11/deutz-and-maeda-unveil-fully-electric-crawler-crane.php
115 https://www.ggrgroup.com/products/mini-cranes/unic-eco/
116 https://group.tadano.com/uscan/en/lifting-equipment/rough-terrain-cranes/evolt-egr-1000xll-1/
117 https://www.liebherr.com/en-ca/p/lr1200unplugged-4678918
118 https://www.liebherr.com/en-ca/p/lr12501unplugged-4678918
119 https://www.sennebogen.com/en/products/telescopic-crane/sennebogen-653-e-electro-battery

Electric telehandlers, such as the JCB 505-20E[120] and Snorkel SR5719E[121] offer lift capacities up to 5,500 pounds and maximum lift heights of 20 feet, comparable to their diesel counterparts. Likewise, electric boom lifts such as the JLG E300AJP provide platform heights of about 29.5 feet.[122]

For aerial lifts, manufacturers such as Genie's Z-60/37 FE boom lift can run in full-electric mode for a full day on a charge, or in hybrid settings for up to one week[123]. Telehandlers are also going electric – JCB's 525-60E telehandler, for example, uses a 24-kWh lithium battery that can power an entire work shift on a single charge.[124]

Electric cranes and lifts carry larger battery packs to provide the high power needed for lifting and propulsion. Typical runtime on battery is 5-8 hours of continuous operation for heavy equipment. The Tadano EVOLT 100-ton crane, for instance, is equipped with six lithium-ion battery packs and can operate 5-7 hours on a single charge.[125] In comparison, electric boom lifts and telehandlers often achieve a full workday of intermittent use with Genie's hybrid boom running for a full workday.[126]

Economic

Electric and hybrid cranes and lifts generally have a higher upfront cost than traditional diesel models due to the battery systems and newer technology. Industry data indicates price premiums on the order of 20% to 50% for heavy electric equipment compared to diesel equivalents[127]. A major upside of electrification is the lower operating costs. For example, electric telehandlers like the Snorkel SR5719E have reported operational cost savings up to 60 percent compared to diesel counterparts[128]. Electricity is generally much cheaper per unit of work than diesel. One analysis showed a diesel forklift can cost five to ten times more in fuel than an electric forklift annually[129]. Tadano reports that its 100t electric crane will save about 35 percent in overall operating costs versus the diesel model[130].

To alleviate upfront costs, both federal and provincial governments in Canada have introduced and proposed incentives to accelerate the adoption of zero-emission heavy equipment in construction:

Table 13: Financial Incentive Programs Applicable to Cranes and Lifts*

Program Name	Jurisdiction	Type	Eligibility	Incentive
First-Year Capital Cost Allowance (CCA) Class 56 – Zero-Emission Equipment	Federal	Tax Deduction	Self-propelled off-road zero-emission equipment (fully electric or hydrogen-powered)	First-year depreciation of 55%-100%
Immediate Expensing for Zero-Emission Vehicles (Classes 54, 55, 56) (Proposed)	Federal	Tax Deduction	Proposed in Fall 2024 - Re-instating a 100% first-year write-off for medium- and heavy-duty zero-emission vehicles and equipment in Classes 54, 55, 56	100% first-year deduction

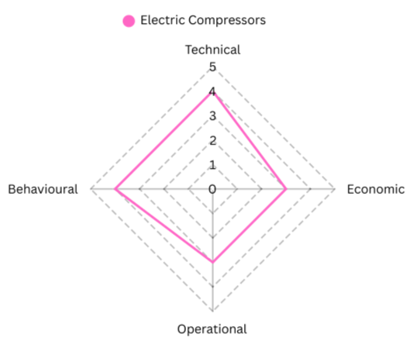
120 https://www.jcb.com/en-us/products/telescopic-handlers/505-20e
121 https://snorkellifts.com/equipment/sr5719e/
122 https://www.jlg.com/en-za/equipment/boom-lifts/articulating/electric-hybrid/e300-series/e300ajp
123 https://www.genielift.com/en-au/EWP-products/articulated-boom-lifts/z60fe
124 https://www.jcb.com/en-au/products/telescopic-handlers/525-60e-hi-viz
125 https://www.thecooldown.com/green-tech/tadano-evolt-crane-electric-rough-terrain
126 https://www.genielift.com/en-au/EWP-products/articulated-boom-lifts/z60fe
127 https://www.purchasing.com/construction-equipment/aerial-lifts/models-and-price-comparison/index.html
128 https://compactequip.com/aerial-lifts/lifting-electric-battery-powered-compact-telehandlers-are-on-the-rise-in-north-america/
129 https://www.conger.com/forklift-fuel/
130 https://electrek.co/2024/10/21/tadano-gr-1000xll-evolt-100-ton-electric-crane-is-coming-to-america-video/

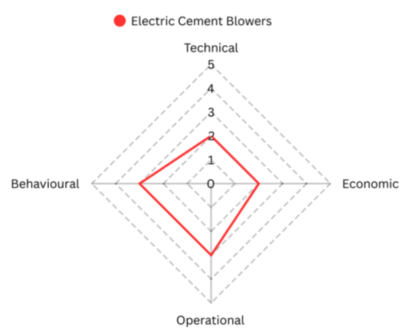
CleanBC Specialty-Use Vehicle Incentive (SUVI) Program	British Columbia	Rebate	Off-road and specialty commercial ZEVs, including electric forklifts, utility vehicles, etc.	Up to $5,000 per unit
Good Energy Commercial Medium/Heavy ZEV Rebate	Yukon	Rebate	Medium- and heavy-duty commercial ZEVs (Class 2B and above)	$10,000 per vehicle
Medium/Heavy-Duty ZEV Fleet Pilot Rebate	Yukon	Rebate	Medium- and heavy-duty zero-emission vehicles or equipment	Up to 75% of purchase cost

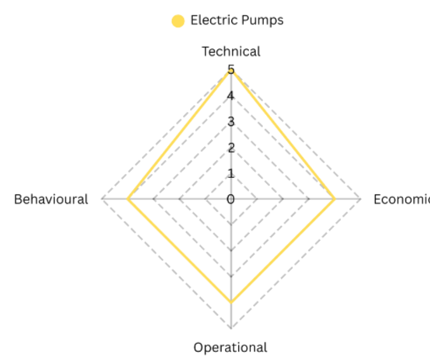
** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

C.4 Miscellaneous Equipment

		Emissions	Technology	Economic	Operational	Behavioural
C4. Misc. Equipment	**Electric Compressors**	100% direct emissions	4	3	3	4
			Wide availability	Moderate premium	Power connection	
	Electric Cement Blowers	100% direct emissions	2	2	3	3
			Limited options	High premium	Power/capacity limits	
	Electric Pumps	100% direct emissions	5	4	4	4
			Mature technology	Competitive cost	Simple setup	







Electrification

Technical

Fully electric and hybrid versions of compressors, pumps, cement blowers, fans, grout plants, and other equipment are increasingly available. For example, Atlas Copco's E-Air series of portable compressors provides the same CFM air output with zero-emissions[131] for smaller scale operations while the Kaeser M500-2[132] can be used for larger applications. Hybrid options also exist, including the Mattei XT65[133] and Atlas Copco GA200/GA250 VSD Hybrid. Electric hydraulic pumps, such as Power Team's PE172 and PE554S are readily available[134]. Specialty gear like grout plants and cement blowers are also available in fully electric and hybrid options. For example, Leadcrete's LGP350/80/70PI-E[135] for electric grout plants,

131 https://www.atlascopco.com/en-ca/construction-equipment/products/mobile-air-compressors-usa/electric-variable-compressors
132 https://us.kaeser.com/download.ashx?id=tcm:46-101770
133 https://www.matteigroup.com/en-us/products/custom-compressors/road-applications
134 https://www.motioncanada.ca/products/Hydraulics/Portable%20Hydraulic%20Lifting%20Systems/Pumps/Electric%20Hydraulic%20Pumps
135 https://www.leadcrete.net/products/grout-mixing-plant/electric-grout-plant.html

and Gardener Denver CycloBlower H.E. Series[136] and Swam's Super Helical Hybrid Blower[137] hybrid cement blowers. Industrial fans are typically produced as plug-in electric with diesel options being extremely uncommon.

Economic

Within miscellaneous equipment, upfront costs associated with electric/hybrid equipment and their diesel counterparts do not vary significantly:

Equipment Type	Fuel Source	Price Range
Blowers	Diesel	$20,000 to $30,000+
	Electric	$25,000 to $50,000+
	Hybrid	$25,000 to $45,000+
Compressors	Diesel	$5,000 to $30,000+
	Electric	$15,000 to $100,000+
	Hybrid	$10,000 to $80,000+
Grout Plants	Diesel	$12,000 to $19,000+
	Electric	$10,000 to $30,000+

Various incentive programs can help with the upfront premium of electrified equipment:

Table 14: Financial Incentive Programs Applicable to Miscellaneous Equipment*

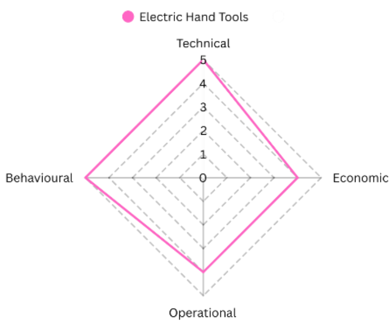
Program Name	Jurisdiction	Type	Eligibility	Incentive
Clean Technology Investment Tax Credit (CT ITC)	Federal	Tax Credit	Clean technology property including non-road fully electric vehicles & equipment	Up to 30% of the capital cost
Accelerated CCA for Zero-Emission Off-Road Equipment (Class 56)	Federal	Tax Deduction	Self-propelled off-road zero-emission vehicles and equipment	100% first-year deduction
Low Carbon Economy Fund – Challenge Stream	Federal	Grant	Projects that reduce on-site GHG emissions in industry – includes electrification of construction/mining equipment	Up to 40% of project costs
CleanBC Go Electric Specialty-Use Vehicle Incentives (SUVI)	British Columbia	Rebate	Specialty zero-emission vehicles for commercial/fleet use not covered under light-duty EV program.	33% of purchase cost

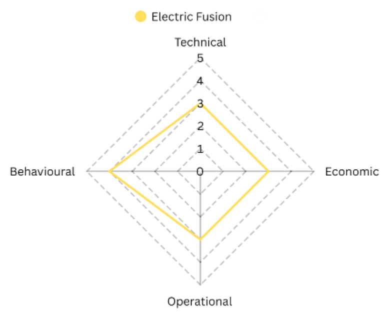
** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

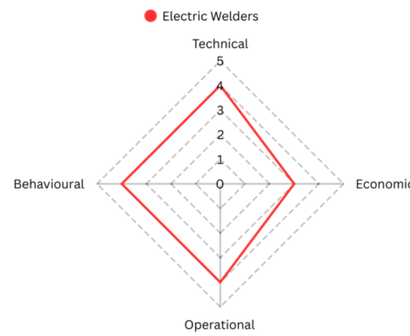
136 https://www.gardnerdenver.com/content/published/api/v1.1/assets/CONT40FC5F21FEEB4574AFA86ED3DBB08221/native/pd-cb-he-retrofit_5th_9-17.pdf?channelToken=e9993619ab2548ba8fa9fc1166ee3776
137 https://swamatics.com/super-helical-hybrid-blower/

C.5 Small Tools

		Emissions	Technology	Economic	Operational	Behavioural
C5. Small Tools	**Electric Hand Tools**	100% direct emissions	5	4	4	5
			Widely available	Cost competitive	Simple charging	
	Electric Welders	100% direct emissions	4	3	4	4
			Good options available	Moderate cost	Standard power	
	Electric Fusion	100% direct emissions	3	3	3	4







Technical

Electric small construction tools have been commercially available for several years, with options for handheld tools like concrete hammers, saws, and leaf blowers. For example, Milwaukee's MX FUEL battery-powered concrete breaker provides similar impact energy to pneumatic and gas equivalents, capable of typical medium-duty tasks on a single battery charge. Makita's 80V XGT electric cut-off saw matches traditional gas-powered saws in cutting speed and performance. Commercial-grade electric leaf blowers, such as Stihl's BGA 200, deliver airflow comparable to gasoline backpack blowers. Electric welders, including Fronius AccuPocket 150, provide reliable welding with battery-driven operation sufficient for intermittent tasks. Battery-powered fusion machines, such as Highland's Supercell, effectively handle electrofusion for HDPE pipe up to 12" diameter. Electric plate compactors (Wacker Neuson AP1850e) and jumping rammers (AS60e) match gas-powered compaction force and achieve typical daily operational goals.

Economic

Pricing for small electric construction tools generally presents a minimal upfront premium compared to fossil fuel-powered models. Some examples below:

Tool Type	Gasoline Cost	Electric Cost
Cut-off Saw	$1,000 - $1,500	$1,500 - $2,000

Welder	$4,000 - $8,000	$3,250 - $4,400
Plate Compactor	$1,300 - $2,000	$3,500+

Small electric tools significantly reduce operating costs, primarily due to reduced energy and maintenance expenses. Long-term cost savings often offset initial price differences, making electric options economically viable, particularly under frequent-use scenarios.

Operational

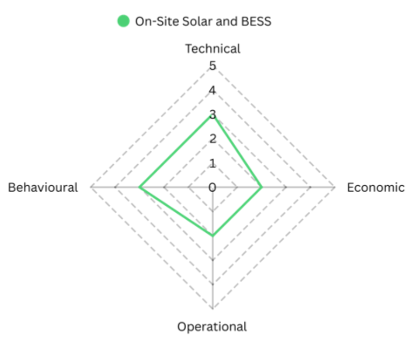
Electric small tools require basic infrastructure considerations primarily related to battery management and charging. Contractors must plan for either on-site grid electricity or portable charging solutions, and schedule battery swapping or charging periods into daily workflows. Electric small tools typically provide adequate runtime for intermittent use common in their respective tasks, with additional batteries or quick-charging capabilities ensuring sustained productivity. Minimal to no training is required for electric small tools, mainly focusing on battery management practices, proper storage, and routine maintenance checks.

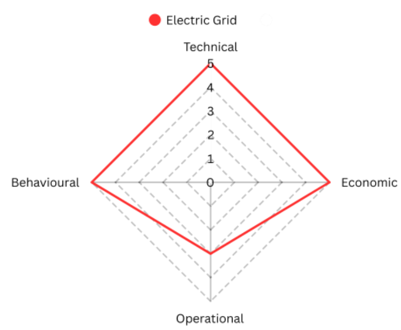
Behavioural

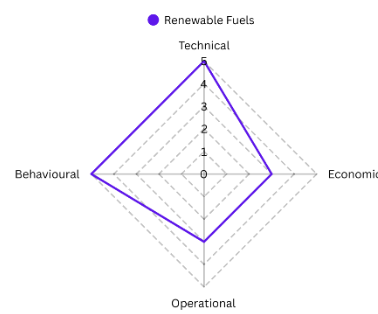
Electric handheld tools, leaf blowers, plate compactors, and welders have achieved high acceptance among construction crews due to ease of use, quiet operation, and elimination of exhaust fumes.

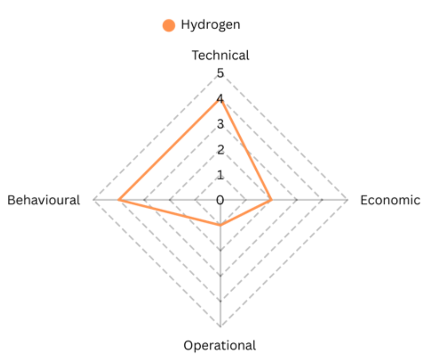
D.1 Propane and Diesel Generators and Grid Access

		Emissions	Technology	Economic	Operational	Behavioural
D1/D2 Generators and Electricity	**Access to Electric Grid**	Varies with grid mix, up to 90-100%	5	5	3	5
			Technically viable	Cost lower than diesel	Limited access for certain projects	
	Hydrogen Fuel Cells	Up to 100% (depends on upstream emissions)	4	2	1	4
			Commercially available	High cost	Limited availability and retraining	
	Renewable Fuels	50-80% lifecycle emissions	5	3	3	5
			Drop-in replacement	10-50% fuel premium	Limited availability	
	On-site solar and BESS	100% of direct emissions	3	2	2	3
			Integration of techs	high costs	Retraining on storage and generation	









Electrification

Technical

Battery electric generators deliver silent, zero-emission power for many on-site uses. For example, a 5-kW portable battery unit can run for one hour and recharge in two to five hours. Battery-based generators are commercially available with manufacturers, such as JCB E-TECH powerpack[138], Portable Electric VOLTstack[139]. Hybrid generators pair a diesel or propane engine with battery energy storage systems (BESSs) to handle peak loads or recharge the batteries. By using stored energy to handle routine loads and only running the engine when needed, hybrid generators significantly

138 https://www.jcb.com/en-gb/products/generators/powerpack
139 https://portable-electric.com/

cut fuel use and CO_2 emissions. A case study found a 230 kVA diesel paired with a 250 kW/575 kWh battery achieved a 4:1 run ratio, saving over 150 gallons (or 570 L) of diesel per month[140]. Further, technology to integrate battery-electric generators with solar BESS systems is also commercially available with Ver-Mac's solar-powered battery trailer[141]. There is a wide variety of commercially available hybrid generators, which EllisDon is currently piloting. The Hybrid Power Solutions E-Generators[142] and Powr2 Hybrid Generator are two examples available in Canada.

Economic

When considering generators, electric and hybrid systems typically come with a price premium compared to traditional diesel and propane generators. These higher upfront costs often reflect advanced technology integrations, such as BESSs and power management. However, despite these initial cost differences, electric and hybrid options frequently deliver significant long-term savings through reduced fuel consumption, lower maintenance requirements, and enhanced operational efficiency.

Generator Type	Price Range
Diesel	$14,000 to $22,000+
Propane	$4500 to $10,000+
Hybrid + BESS (solar)	Varies based on BESS system
Electric	$17,000+

There are also incentives and credits that improve the economics: for example, Canada's federal Clean Technology investment tax credit offers a 30% credit for stationary battery storage projects, and some provinces provide grants for low-emission construction equipment.

Table 15: Financial Incentive Programs Applicable to Generators*

Program Name	Jurisdiction	Type	Eligibility	Incentive
Clean Technology Investment Tax Credit (ITC)	Federal	Tax Credit	Solar PV, wind, hydro, geothermal, *stationary energy storage (batteries)*, etc.	30% of capital cost
Clean Electricity Investment Tax Credit	Federal	Tax Credit	Non-emitting electricity generation systems	15% of capital cost
Accelerated Capital Cost Allowance for Clean Energy (Class 43.1/43.2)	Federal	Tax Deduction	Specified clean energy generation and energy conservation equipment	Up to 100% first-year depreciation
Green Transition Fund	Nfld	Grant	Renewable energy and clean tech projects to reduce GHGs in commercial operations	Varies by project

** Programs are subject to change. Incentive level may be tied to equipment size, purchase price, class, etc.*

140 https://www.bicmagazine.com/industry/powergen/case-study-greener-power-jobsite-efficiency/
141 https://www.ver-mac.com/en/products/solar-powered-platforms/
142 https://hybridps.ca/

Operational

Switching to battery-electric or hybrid generators requires adjustments in daily site management, particularly around charging schedules and power planning. Battery generators would require planned charging sessions via grid connections or backup generators during downtime or overnight. Hybrid setups use diesel or propane to recharge batteries when needed. Further, there must be compliance with electrical safety standards, appropriate training for managing charge and utilization schedules.

Behavioural

Introducing battery-electric or hybrid generators on-site can face skepticism from those accustomed to traditional diesel or propane systems. Workers often rely on the familiar sound of engines running and may be concerned about the silent operation of batteries and their capacity to handle power demands. Demonstrations and training sessions will allow for overcoming those reliability concerns.

Hydrogen

Technical

Fuel cell generators are more efficient at converting fuel into electricity than diesel engines. For example, a hydrogen fuel cell operates at about 40 to 60 percent efficiency, whereas a diesel engine converts only about 25 to 40 percent[143] of the fuel's energy into energy, with the rest as heat. However, commercial availability for hydrogen generators is extremely limited with only a handful of options from manufacturers including Generac's EODev GEH2[144], H2 Portable[145], Hitachi's HyFlexTM[146], and H2Genset[147], with other manufacturers such as Sommers in the testing phase.

Economic

Hydrogen fuel cell generators currently have higher upfront costs than conventional diesel or propane units. Construction-scale hydrogen generators (10 to 50+ kW) can range from $100,000 to $300,000+ per unit, in contrast to tens of thousands for diesel or propane gensets of similar power output. Given these high capital costs for hydrogen equipment, government funding and incentives can help justify the investment. In Canada, the several programs listed earlier assist in reducing upfront costs.

Operational

Using hydrogen fuel on-site brings many operational considerations compared to diesel or propane. Ensuring a reliable hydrogen supply requires detailed planning for secure storage, handling protocols, and careful scheduling. Hydrogen delivery and storage involve high-pressure cylinders or trailers, which require safety procedures due to hydrogen's flammability and difficulty in leak detection.

Staff must be specifically trained in hydrogen handling and emergency response, as this differs significantly from diesel or propane operations. Further, local regulations may mandate special permits and compliance with fire codes, adding complexity to project planning. While hydrogen supply logistics are improving in urban areas, rural and remote sites can face challenges due to limited suppliers and transportation difficulties.

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143 https://www.mdpi.com/2071-1050/14/14/8285

144 https://www.generac.com/industrial-products/hydrogen-fuel-cells/100kva-hydrogen-fuel-cell-power-generator-eodev-geh2/

145 https://cice.ca/projects/portable-hydrogen-generators/

146 https://publisher.hitachienergy.com/preview?DocumentId=8DAN000030&languageCode=en&Preview=true

147 https://www.h2-genset.com/en/

Appendix 2 - Methods

1. Context: Terminology and Emission Factors

1.1 Categories

As defined through this report categories are the groupings of equipment. Each category has a letter assigned to it and subcategories of these letters have a number. The categories consist of:

- A. On-Road Equipment and Vehicles
    - A.1. Light duty vehicles
    - A.2. Medium and heavy-duty vehicles
- B. Off Road Mobile Machinery
    - B.1. Excavation and Earthworks
    - B.2. Concrete and Asphalt
    - B.3. Misc. Land
    - B.4. Misc. Marine
- C. Stationary Equipment and Machinery
    - C.1. Lighting
    - C.2. Heating
    - C.3. Cranes and Lifts
    - C.4. Misc. Equipment
    - C.5. Small Tools
- D. Electrical Generation/Connection
    - D.1. Generators
    - D.2. Electrical Connection to the Grid

1.2 Constants, Emission Factors, and Accepted values

Parameter	Value	Unit	Source
Renewable diesel Energy Density	34.94	MJ/L	[148]
Biodiesel Energy Density	34.94	MJ/L	“”
Diesel Energy Density	36.4	MJ/L	[149]
Gasoline Energy Density	35	MJ/L	“”
Electricity Energy Density	3.6	MJ/kWh	Accepted Value
Propane Energy Density	25.53	MJ/L	[150]
Heavy oil Energy Density	41.73	MJ/L	“”

[148] https://afdc.energy.gov/fuels/properties
[149] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/canadas-energy-transition/canadas-energy-transition-historical-future-changes-energy-systems-update-energy-market-assessment-global-energy.html?=undefined&wbdisable=true
[150] https://apps.cer-rec.gc.ca/Conversion/conversion-tables.aspx

Light oil Energy Density	37.2	MJ/L	“”
Ethanol Energy Density	23.6	MJ/L	“”
Acetylene Energy Density	0.0548	MJ/L	[151]
British Columbia Electricity EF	15	gCO2e/kWh	[152]
Alberta Electricity EF	540	gCO2e/kWh	“”
Saskatchewan Electricity EF	730	gCO2e/kWh	“”
Manitoba Electricity EF	2	gCO2e/kWh	“”
Ontario Electricity EF	30	gCO2e/kWh	“”
Quebec Electricity EF	1.7	gCO2e/kWh	“”
New Brunswick Electricity EF	300	gCO2e/kWh	“”
Nova Scotia Electricity EF	690	gCO2e/kWh	“”
Prince Edward Island Electricity EF	300	gCO2e/kWh	“”
Newfoundland and Labrador Electricity EF	17	gCO2e/kWh	“”
Yukon Electricity EF	80	gCO2e/kWh	“”
Northwest Territories Electricity EF	170	gCO2e/kWh	“”
Nunavut Electricity EF	840	gCO2e/kWh	“”
British Columbia NG EF	1976.31	gCO2e/m3	[153]
Alberta NG EF	1972.31	gCO2e/m3	“”
Saskatchewan NG EF	1930.31	gCO2e/m3	“”
Manitoba NG EF	1925.31	gCO2e/m3	“”
Ontario NG EF	1931.31	gCO2e/m3	“”
Quebec NG EF	1936.31	gCO2e/m3	“”
New Brunswick NG EF	1929.31	gCO2e/m3	“”
Nova Scotia NG EF	1929.31	gCO2e/m3	“”

[151] https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2011-pso-methodology.pdf
[152] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html#fn19
[153] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html#toc6

Prince Edward Island NG EF	1929.31	gCO2e/m3	“”
Newfoundland and Labrador NG EF	1929.31	gCO2e/m3	“”
Yukon NG EF	1976.31	gCO2e/m3	“”
Northwest Territories NG EF	1976.31	gCO2e/m3	“”
Nunavut NG EF	1976.31	gCO2e/m3	“”
Light Oil EF	2761.94	g CO2e/L	“”
Heavy Oil EF	3174.56	g CO2e/L	“”
Kerosene EF	2568.94	g CO2e/L	“”
Gasoline EF[154]	2311.96	g CO2e/L	“"
Propane EF	1544.29	g CO2e/L	[155]
Biodiesel EF	2512.51	g CO2e/L	“”
Diesel EF	2720.81	g CO2e/L	“”
Acetylene EF	3719	g CO2e/L	[156]
Renewable Diesel EF	2697.49	g CO2e/L	[157]
Diesel Generator Efficiency	35%	-	[158]
Propane Generator Efficiency	27%	-	“”
Diesel Heater Efficiency	80%	-	[159]
Biodiesel Lifecycle EF	30	g CO2e/MJ	[160]
Off-site Diesel EF	0.617	kg CO2e/L	[161]
Off-site Gasoline EF	0.47	kgCO2/L	“”
Off-site Natural Gas	0.39	kgCO2/m3	[162]

[154] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-15-v1.pdf
[155] National Inventory Report 2025 – Annex 6
[156] https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2011-pso-methodology.pdf
[157] https://theclimateregistry.org/wp-content/uploads/2023/06/2023-Default-Emission-Factors-Final-1.pdf
[158] https://www.sustainablemaintainance.com/2025/02/how-does-generator-efficiency-vary.html
[159] https://planarheaters.com/understanding-diesel-heaters-efficiency/
[160] https://pubs.acs.org/doi/10.1021/acs.est.2c00289
[161] https://sustainable.stanford.edu/sites/g/files/sbiybj26701/files/media/file/scope-3-emissions-from-fuel-and-energy-activities-march-2023.pdf
[162] Readme-Pre-publication-Updated-carbon-intensity-of-natural-gas-and-propane.pdf

Off-Site Propane	0.23	kgCO2/L	“”
Off-Site Light Oil	0.32	kgCO2/L	[163]
Off-Site Heavy Oil	0.39	kgCO2/L	“”
Energy Consumption ICE Truck	3.74	MJ/km	[164]
Energy Consumption BEV Truck	1.21	MJ/km	“”
Energy Consumption Gasoline Light	2.52	L/hr	[165]
Energy Consumption Electric Light	16.17	kW/hr	[166]
Energy Consumption Gasoline Skid Steer	9.31	L/hr	[167]
Energy Consumption Electric Skid Steer	6.05	kW/hr	[168]
Energy Consumption Gasoline Forklift	4.00	L/hr	[169]
Energy Consumption Electric Forklift	25.2	kW/hr	[170]
Energy Consumption Gasoline Blower	1.29	L/hr	[171]
Energy Consumption Electric Blower	1.56	kW/hr	[172]
Energy Consumption Diesel Mini Excavator	3.86	L/hr	[173]
Energy Consumption Electric Mini Excavator	4.00	kWh/hr	[174]

***EF =** Emissions Factor*
***NG =** Natural gas*
***RD** = Renewable Diesel*
ICE = Internal Combustion Engine
BEV = Battery Electric Vehicle

[163] https://sustainable.stanford.edu/sites/g/files/sbiybj26701/files/media/file/scope-3-emissions-from-fuel-and-energy-activities-march-2023.pdf
[164] https://transitionaccelerator.ca/wp-content/uploads/2024/11/EC_Household_Energy_Affordability_Technical_Report.pdf
[165] https://www.ipsigenerators.com/wp-content/uploads/2019/07/10000022008_MLT4060KV_SPEC.pdf_ext.pdf
[166] https://www.atlascopco.com/en-gr/construction-equipment/pfl-landings/templates/battery-light-tower-campaign
[167] https://wheelercat.com/wp-content/uploads/2023/01/Cat-Performance-Handbook-from-VST-fuel-consumption-2022-12-09T21-20-09.pdf
[168] https://www.bobcat.com/na/en/equipment/future-products/t7x-s7x-all-electric-compact-loaders
[169] https://www.bobcat.com/mea/en/equipment/diesel-forklifts/2-5-to-3-5-tons-nxs-series
[170] https://www.bobcat.com/na/en/equipment/forklifts/electric-counterbalance-forklifts/small-capacity-4-wheel-cushion-tire
[171] https://www.stihlusa.com/tools-calculators/backpack-blower-fuel-savings-calculator/
[172] https://www.stihlusa.com/products/blowers-and-shredder-vacs/battery-blowers/bga86/
[173] https://wheelercat.com/wp-content/uploads/2023/01/Cat-Performance-Handbook-from-VST-fuel-consumption-2022-12-09T21-20-09.pdf
[174] https://www.jcb.com/en-us/products/compact-excavators/19c-1e

2. Methodology, Analysis and Assumptions with the Data

2.1 Dataset Description

Standard quantitative and qualitative data included project name, province, city, low emissions tag, main project material, area, cost, number of months emissions were reported for, project length, emissions or fuel use data by fuel type.

Some companies provided additional qualitative remarks or quantitative data which helped to further subdivide emissions into activity categories. Data of this kind was limited.

To summarize there are two levels of data: project level and equipment level.

2.2 Key Data Set Issues

- **Electrical and Natural gas may be underestimated.** Most companies have projects missing electrical or natural gas because the client paid.
- **Diesel and gasoline are underestimated.** Many companies are missing a portion of diesel and gasoline associated with subcontracted work.
- **Sub-contractor related emissions vary.** The amount of self-performed work is unknown in most cases and if known it does not directly relate to emissions.
- **Reported emissions most often don't represent an entire project.** Many projects do not have emissions data for the span of the projects, only a fraction.
- **Equipment level data is sparse.** Unavailability of granular data for most projects meant that at the equipment level emission allocation was assumed off of a small dataset.

2.3 Procedure

For each company data was combined and analyzed using the same procedure. First files and information were separated by relevance to the project level or equipment level. Data was then standardized for each company. Standardization involved cleaning and parsing data, combining relevant files, calculating emissions, and filling data gaps through estimation. The final step was the completion of the analysis and statistics.

3. Project Level Data: Detailed Methodology

3.1 Data Description

- Valid project level data for 617 projects.
- Fuel use quantities or emissions by fuel type for all projects.
- Key identifiers included: project archetype, province/territory, city/town, project timeline, emission file timeline, and project cost.

3.2 Summary of Assumptions

- **Assumption 1:** Any project that did not have a cost value or timeline was eliminated from the dataset.
- **Assumption 2:** Emission factors were recalculated using standardized emission factors, applied based on the type of fuel and, where relevant, the provincial or territorial location.
- **Assumption 3:** Projects identified as missing natural gas and/or electricity were assigned values for these fuels if they met specific parameters.

- **Assumption 4:** Assigned electricity and natural gas values were based on cost-weighted medians from projects with known values.
- **Assumption 5:** All projects were assumed to use diesel and gasoline unless flagged otherwise.
- **Assumption 6:** For projects with zero values for gasoline or diesel, a cost-weighted median value from projects with full reporting was applied.
- **Assumption 7:** For projects that reported diesel and gasoline but were assumed to have partial values (missing subcontractor fuel), diesel amounts were scaled using company-specific ratios.

3.3 Standardization

3.3.1 Project elimination

Assumption: Any project that did not have a cost value or timeline was eliminated from the dataset. This left 617 projects for analysis.

Originally there were more projects, and some were eliminated on other parameters such as absence of a breakdown of emissions by fuel type or valid emission file timelines.

3.3.2 Data set merging and emission factor application.

All company datasets were organized and cleaned so that they had the same columns which included the identifiers mentioned as well as fuel emission and quantities.

Emission factors were all recalculated so that standardized emission factors were used. Emission factors were applied based on the type of fuel, and if necessary, the provincial/territorial location.

3.3.3 Accounting for unreported natural gas and electricity.

Some companies reported that they did not have information on whether natural gas and electricity was left out of the data set because it was absent on a project or because it was paid for by the client. This meant that many projects in heavily populated locations did not have electrical or natural gas values. To account for this, natural gas and electricity were assigned to projects that were missing these fuels if those projects met specific conditions. Projects were not included in this step if it was confirmed that they did or did not have natural gas and electricity.

Assumption: Projects that were identified to be missing natural gas and or electricity were assigned values for these fuels if the projects met specific parameters.

The electricity and natural gas values assigned were the median cost weighted values of a subset of projects that had existing values for both electricity and NG. The median value for electricity was 0.0088 kWh/$ and for NG it was 0.000098 GJ/$. These values were then applied by multiplying by the dollar value and adjusting for the project timeline. Values were assigned to any project that met all the parameters below.

The parameters that projects had to meet to be assigned an electrical and or NG value were either of the following:

- Population greater than 30,000. All cities and towns in Canada have grid electricity connection available with populations above this size.[175] Projects were manually checked for proximity to major NG pipelines. Majority of projects were located close to major urban centres or near pipelines, so a 30,000-population baseline was also used for natural gas.

[175] https://natural-resources.canada.ca/sites/nrcan/files/canmetenergy/files/pubs/2013-118_en.pdf

- Project cost was greater than $3 million for electrical connection and greater than $11 million for natural gas connection. All projects were assessed to see if the population criteria left any gaps. It was observed that some projects under the 30,000-population baseline did have electrical and natural gas connections. For these projects the minimum reported project cost for natural gas and separately for electricity was used as a baseline for an additional selection criterion.

Specific to NG, projects in New Brunswick or any of the territories were not assigned NG because none of these locations have widely available commercial NG sales.

Total energy with the median values added in did not exceed a cap of 4.8 MJ/$. The cap was based on the highest reported project energy value for a project with natural gas and electricity. If a project exceeded this value with the input of NG and electricity, then it was assumed that this project was never connected to the grid or pipeline and it was reassigned its zero values for natural gas and electricity.

3.3.4 Accounting for unreported diesel and gasoline

Many projects did not include fuel amounts associated with subcontractors. Diesel and gasoline make up large portions of fuel use and associated emissions and are seen on almost every project. The only projects that would not use diesel or gasoline would be projects that are simply finishing, such as drywalling, or projects which were cancelled. Since neither of these types of projects were flagged in the data set and these would typically be low-cost projects anyways, all projects were assumed to have diesel and gasoline.

Assumption: All projects have diesel and gasoline.

To account for zero diesel and gasoline values due to unreported subcontractor values cost weighted median values from projects that reported all fuel accounted for were applied to the dataset.

Assumption: For projects that had zero values for gasoline or diesel a cost weighted median value from projects that had all diesel and gasoline accounted for was applied.

The median values were sub divided into two categories, building and not-building, and are as follows:

- Diesel building: 0.031 MJ/$
- Diesel not-building: 0.054 MJ/$
- Gasoline building: 0.027 MJ/$
- Gasoline not-building: 0.020 MJ/$

For some projects where diesel and gasoline were reported it was assumed a portion was missing – associated with the subcontractor. Each company provided information about the level of self-performance on types of projects or activities. Diesel was scaled by a ratio for each company separately as the types of projects the ratio applied to differed by company. The ratio was found by comparing a company's cost weighted median value for diesel to the cost weighted median diesel value from projects that accounted for all fuel use. All relevant projects were then scaled by their company specific ratios.

Gasoline was not applied in a similar fashion because there were too few projects that had confirmed complete gasoline volumes.

3.35 Cumulative additional fuel and spot checking

A table was output that contained all the additional fuel that was added into the dataset by project. Overall, the additional fuel corresponds to 170,109 tCO_2e or 37% of the total emissions after the adjustment explained above.

4. Equipment Level Data: Detailed Methodology

4.1 Data Description

- Equipment fuel use details for ~15 projects.
- Equipment fuel use details by mobile and stationary tags for some companies.
- Qualitative information about fuel use for each unique company.

4.2 Summary of Assumptions

- **Assumption 1:** If equipment descriptors span multiple categories and no data is available to split fuel use, fuel is equally divided among those categories.
- **Assumption 2:** Small emission equipment categories (e.g., small tools, lighting) can be assigned zero fuel if they are included among multiple equipment types.
- **Assumption 3:** Gasoline is predominantly used in light-duty vehicles (LDVs) and, when assignment information is missing, gasoline is assigned entirely to category A1.
- **Assumption 4:** All electricity is assigned to category D2.
- **Assumption 5:** All light and heavy oil is assigned to category C2, assuming predominant use in heating, especially in areas like the Maritimes.
- **Assumption 6:** If a project uses natural gas and grid electricity, natural gas is assumed to be for heating (C2).
- **Assumption 7:** If natural gas is absent but propane is present (and electricity exists), propane is assumed for heating (C2).
- **Assumption 8:** If no natural gas or propane is present but electricity is, diesel is assumed for heating.
- **Assumption 9:** If no grid electricity but diesel, or natural gas or propane are available, these are used for electrical generation (D1) depending on the project location.
- **Assumption 10:** If no NG, propane, or electricity is available, diesel is assumed to be used for both heating and electrical.
- **Assumption 11:** When project-specific diesel usage data is missing, average category use from other projects is applied:
    - A2 (Medium/Heavy Duty Vehicles): 28.8%
    - B (Large Equipment): 57.6%
    - C (Other Equipment – Excl. Heating): 13.6%
    - These represent 100% of uncategorized diesel, as heating and electrical diesel use is accounted for separately.

4.3 Standardization

4.3.1 Equipment level information sorting

With projects that had equipment level information fuel was designated to categories based on the type of equipment used. For values that had multiple equipment descriptors which spanned multiple categories fuel was assigned to the categories by dividing the total by the number of categories. If one of the categories within the list of multiples was assumed to be a small emission category like small tools or lighting, then this was assigned a value of zero.

Assumption: If equipment descriptors span multiple categories, and there is no further information available to quantify how this fuel can be split up, fuel is assigned to all the categories listed and divided by the total number of categories listed.

Assumption: A value of zero can be assigned for small emission categories when equipment descriptors span multiple categories.

Example Calculation – Equipment descriptors fall under multiple categories:

Fuel Type: Diesel

Fuel Total: 5,000 L

Equipment Descriptor: Excavator, Telehandler, and Plate Tamper

Step 1 – Identify if there is information available to split this fuel up further:

- Interview company: answer is no, fuel use by specific equipment in list unknown, hours of operation for specific equipment unknown.

Step 2 – Categorize equipment into categories:

- Excavator: B1
- Telehandler: B3
- Plate Tamper: C5

Step 3 – Eliminate small emissions category equipment:

- C5 not considered

Step 4 – Assign fuel by number of categories:

- 2 categories B1 and B3 each get 2,500 L

4.3.2 Differentiation by mobile and stationary tags

For some companies, data was separated into mobile and stationary equipment. This typically meant that fuel consumed in “mobile” equipment was purchased at a gas station. This fuel was either consumed in a mobile vehicle or it was toted to site for use in various pieces of equipment and machinery.

Through qualitative interviews and the stationary vs mobile tag it can be determined that gasoline is predominantly used in light duty vehicles (category A1).

Assumption: Gasoline is used predominantly in LDVs and in place of missing category designations can be assigned solely to category A1.

4.3.3 Qualitative information provided to designate fuels to heating and electrical

All companies could identify what types of fuel are used for heating and electrical. For companies that provided detailed equipment information the assumptions below did not apply. Additionally, projects were not “inflated” at this step with any additional fuel.

From this electrical, light oil, and heavy oil were assigned completely to respectively to D2, C2, and C2 categories. Light and heavy oil may be used in some equipment or machinery but for this purpose the majority was assumed to be used for heating as projects that had oils were in the Maritimes where natural gas can be less accessible.

Assumption: All electricity can be assigned to category D2.

Assumption: All light and heavy oil can be assigned to category C2.

Depending on location and company portions of natural gas, propane, and diesel were all assigned to heating (C2) and electrical generation (D1).

Assumption: If projects had natural gas and grid electrical, natural gas was assigned to C2.

Assumption: If projects had no natural gas but had propane and grid electrical, propane was assigned to C2.

Assumption: For projects that had no natural gas or propane but had grid electrical diesel was assumed to be the heating source.

A portion of diesel was assigned to projects based on the known median heating value for projects with natural gas. The median heating value for projects using natural gas was adjusted for the efficiency of diesel heaters so that a proportional amount of diesel was assigned to heating – diesel heaters are less efficient than natural gas or propane heating.

58% of diesel was assigned to C2 for this type of project.

Assumption: For projects that had natural gas or propane, and no grid electrical diesel was assumed to be the electrical generation source. For some companies and locations this was untrue and, in this case, natural gas and then propane (with the unavailability of natural gas) was assumed to be the source of electrical generation.

A portion of diesel (natural gas or propane for indicated projects) was assigned to projects based on the known median electrical value for projects using grid electricity. The median electrical value for projects using grid electricity was adjusted for the efficiency of diesel generators (natural gas or propane for indicated projects) so that a proportional amount of diesel was assigned to electrical generation – generators are substantially less efficient than a grid connection.

- 37% of diesel was assigned to D1 for this type of project if fuel was applicable
- 43% of propane was assigned to D1 for this type of project if fuel was applicable

Assumption: For projects that had no natural gas, no propane, and no grid electricity diesel was assumed to be both the heating and electrical source.

A portion of diesel was assigned to projects based on the known median heating value for projects with natural gas and the known median electrical value for project with grid electricity. These values were adjusted for the efficiencies of diesel heaters and generators so that a proportional amount of diesel was assigned to D1 and C2.

- 33% of diesel was assigned to D1
- 45% of diesel was assigned to C2

Example Calculation – Determining median heating and electrical values and equivalent heating values from diesel for electrical generation:

Step 1 – Determining median heating and electrical values

- The median NG, electricity, and energy per dollar values adjusted for project timeline were found for projects that had both natural gas and electricity:
    - Electricity: 0.0330 MJ/$
    - NG: 0.1067 MJ/$
    - All Energy: 0.1869 MJ/$

Step 2 – Recalculating heating and electrical values adjusted for the efficiencies of equipment.

- Diesel generator efficiency: 35%
- Diesel required to generate equivalent electricity: 0.0330/35% = 0.0903 MJ/$
- Percentage of electricity from diesel: 0.0903/(0.1869 - 0.0330 + 0.0903) = 37%

Step 3 – Applying this to the dataset

- Projects that had a heating value already (from NG or propane) but were missing electricity had 37% of diesel assigned to category D1

4.3.3 Diesel designation

Division of diesel into categories for projects that did not have information available to assign diesel.

From the projects that did have granular values for the categories (beyond heating and electrical generation) averages were generated. For the categories A2, B, and C - excluding heating percentages were assigned. It was assumed:

- A2 had an average value of 17% of the diesel usage
- B had an average value of 34% of the diesel usage
- C – excluding heating had an average value of 8% of the diesel usage

These percentages represent the average of the portion of diesel used within the designated categories for projects that had values. Heating and electrical generation from diesel are not assigned to other projects because these values are already known therefore A2, B, and C – excluding heating represent 100% of the remaining uncategorized diesel usage on the projects that did not have granular values. Therefore, these percentages are adjusted to represent a portion of 100%.

- A2 was assigned 28.8% of the remaining diesel
- B was assigned 57.6% of the remaining diesel
- C – excluding heating was assigned 13.6% of the remaining diesel

5. Learning From Project Data: Detailed Methodology

Most of the charts and values in part two of the report were just generated through direct correlations from the data relevant to sections 3 and 4 of the appendix.

5.1 Variance in Project Emissions

Additional observations from the data set are included here. It was observed that emissions vary widely between projects and that they only correlated well with cost. Project area and duration did not correlate well to emissions. The strongest relationship was with project cost, with the entire data set having a 68% correlation. When data was subdivided into archetypes, this correlation increased to 80%-100 % for most archetypes. As a result, cost was used as the primary adjustment factor in the analysis that follows to account for differences in project scale.

Two key risks in using cost are a lack of standardization of scope between companies and a lack of standardization of cost over time. This means that there could be inconsistencies and elements left out when cross-comparing data between companies. Examples of this include companies including or excluding land, fleet operation, overhead, design, or permitting costs. Additionally, inflation or other price increases were not accounted for. There is most likely variation in what was reported but overall, there was a strong correlation between cost and emissions.

Error! Reference source not found., displays 80% complete project emissions plotted against project cost. M ost projects are clustered near the lower end of the emissions-per-dollar spectrum, indicating a strong left-skewed distribution. However, a few outlier projects with exceptionally high emissions per dollar significantly raise the overall average. Even when we observe Figure 4, which displays the entire data sets emissions adjusted for the percent of the project that has occurred (e.g. if 70% of the project occurred, emissions are increased to estimate 100% of project emissions), we see the same trends with even more left skew. Overall, about 12% of the dataset is outliers above the upper bound. Since these outliers distort the average, results are reported using median values, which better reflect typical project performance.

These outliers may be due to several factors:

- Lack of utility connections: Remote projects that were not connected to the electrical or natural gas grid relied heavily on diesel, leading to inflated emissions. For instance, diesel represented 47% of all connected project emissions whereas for remote projects it represented 84% of the emissions.
- Early-stage projects: In cases where very little of the project has been completed, or where the project was very short, overall diesel usage may appear disproportionately high if utility connections were established for only a short portion of the occurred project.
- Data inaccuracies: A small number of data points may reflect errors in reporting project timelines, completion percentages, or cost figures. For instance, 20 projects did not report the project timeline correctly and the months' emissions were reported for exceed the number of months reported for project length.

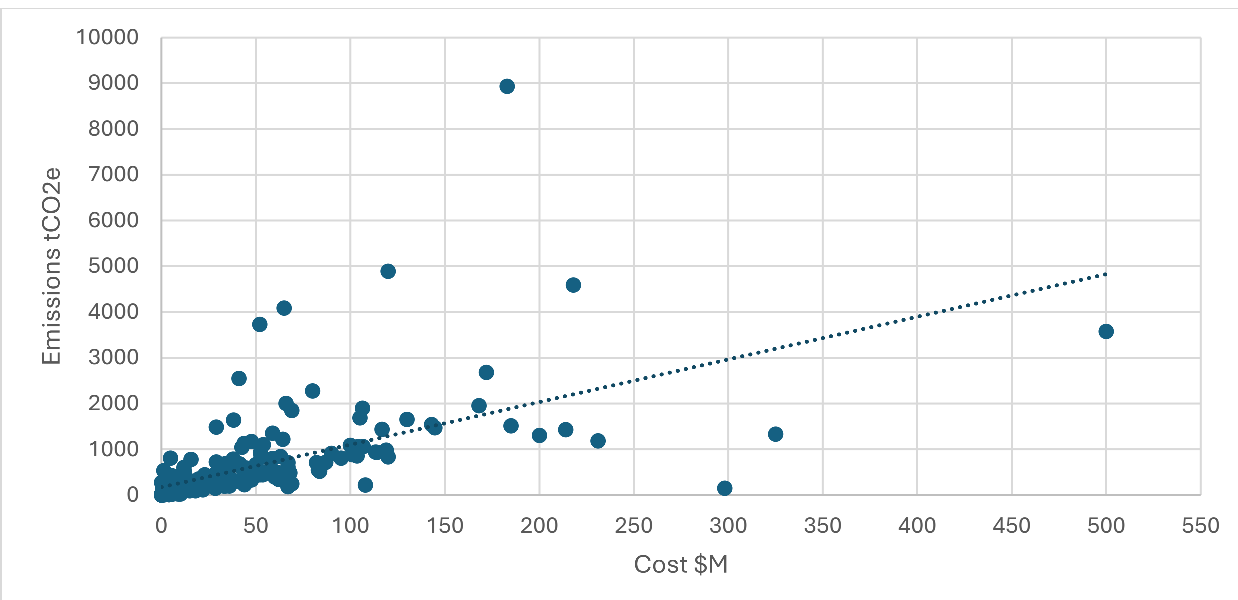


Figure 3: On-site Emissions tCO2e plotted against project cost in $M for projects 80% or more complete

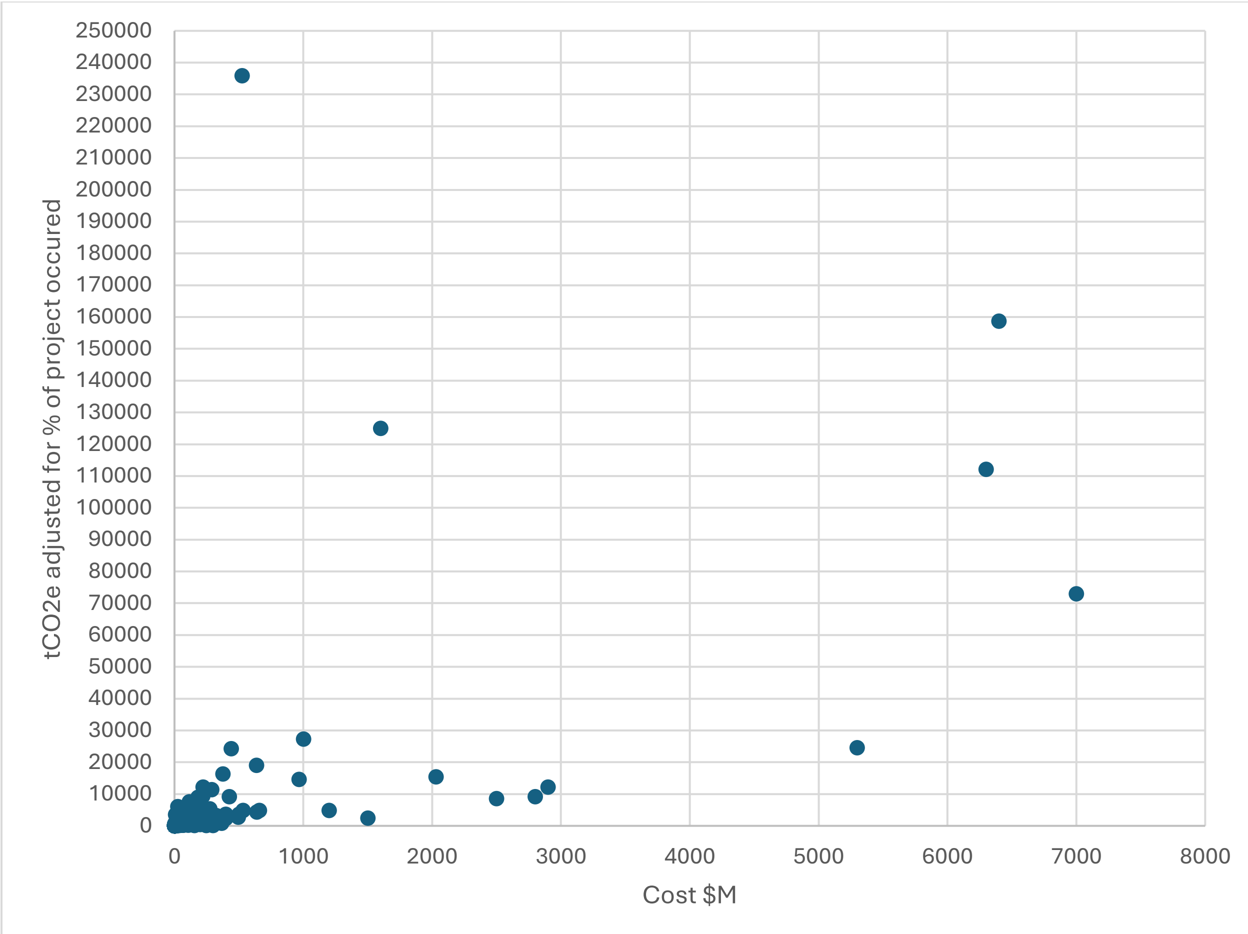


Figure 4: On-site Emissions tCO2e adjusted for % of project occurred plotted against project cost in $M for all projects

An important takeaway from the discussion about cost and emissions is that cost does not cause emissions to go up. The key trend that was observed was that emissions were higher for remote projects that did not have access to grid energy (natural gas and electricity). Median emissions were also greater for projects that used a lot of concrete (nodes and hubs: airports, ports, parkades, public recreation sites and water management infrastructure: dams, flood mitigation or retaining, stormwater, wastewater, and water treatment).

5.2 Quantifying Upstream Emissions

This section describes how off-site emissions, or upstream energy emissions, were incorporated into the analysis. Since some of the solutions in part 4 involve lifecycle emissions, lifecycle emissions were calculated for all types of energy to maintain clarity. Lifecycle emissions also better describe the true benefit of eliminating or reducing certain fuels.

For all charts, the off-site emissions were calculated using the emission factors in section 1.2. The off-site emissions were calculated by fuel type using the energy associated with the fuel and multiplying it by the emission factor to find the off-site emissions related to energy generation and transportation.

For clarity in the calculations, the following was considered off-site:

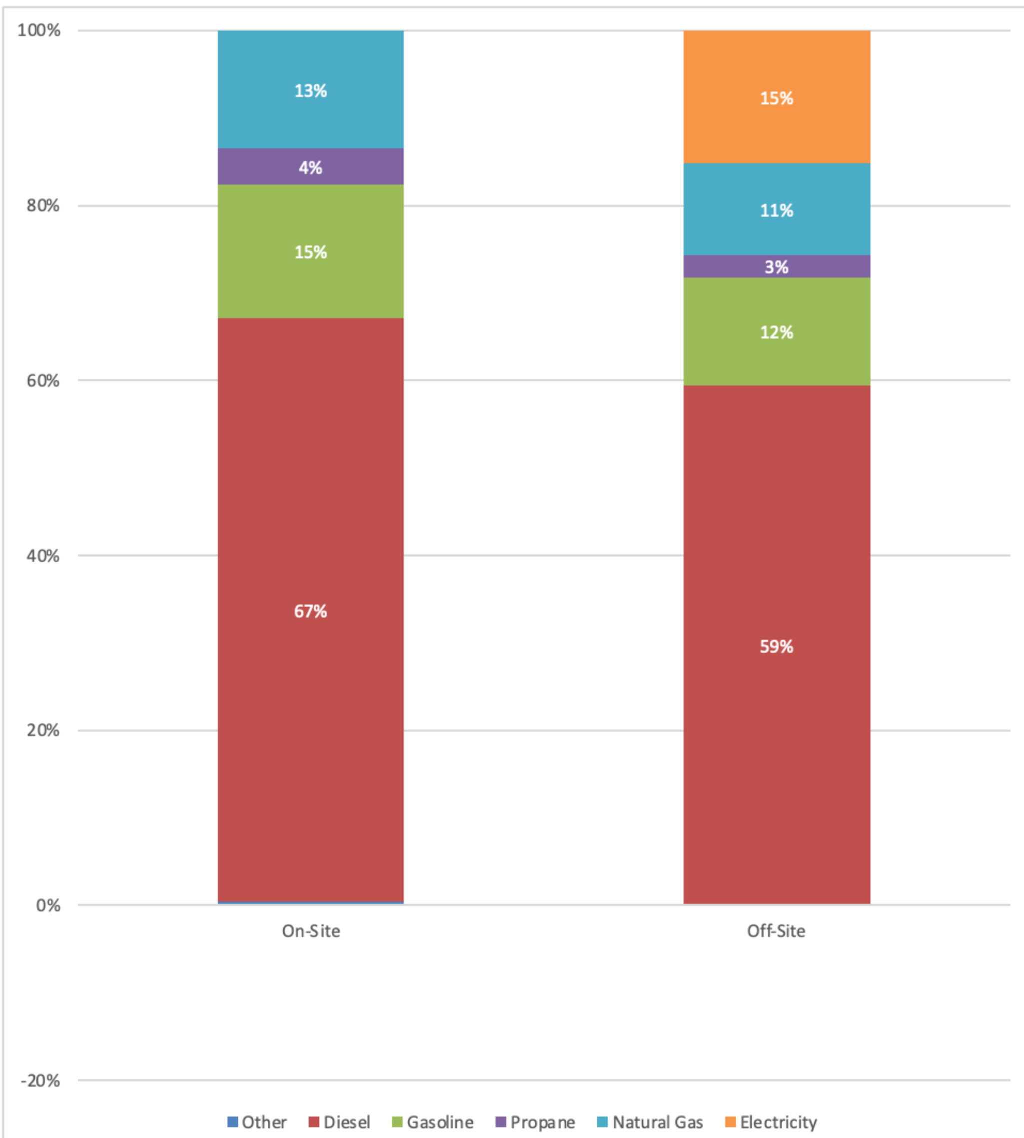
- Generation or production of energy products, including electricity, natural gas, propane, diesel, renewable diesel, biodiesel, gasoline, light oil, and heavy oil.
- Transportation of the same fuels and electricity.

On-site emissions were only considered as:

- Combustion of fuels on-site.

Figure provides more detail on the overall share of each fuel type splitting these into on and off-site emissions. All fuels are labelled, and the portion called "other" refers to fuels with low representation in the dataset (small volumes and emissions), including renewable diesel, biodiesel, acetylene, heavy oil, and light oil.

Figure 5: Proportion of lifecycle emissions attributable to each fuel type



6. Making it Happen: Detailed Methodology

This section describes how emissions decreases for *Part 4: Making it Happen – The High Impact Actions* were calculated. These emission decreases relied on assuming the implementation of solutions and calculating their associated emission reductions within the scope of the data sets median project.

For the median project of the data set Table 16 contains the breakdown by fuel. For the remainder of this section the median project will be referred to as the baseline. Each action in section 4 affected different fuels and sometimes only a portion of the fuel. This section of the methodology is broken up by the actions in section 4 with the last sub-section addressing the cumulative effect of all the actions. Table 16 contains the baseline on-site and off-site emissions for each fuel.

Table 16: Median project fuel breakdown

Fuel	Baseline (tCO2e/$M) On-Site	Baseline (tCO2e/$M) Off-Site
Electricity	0.0	0.5
Natural Gas	1.7	0.3
Propane	0.5	0.1
Gasoline	2.0	0.4
Diesel	8.6	1.9
Other	0.1	0.0
Total	**12.9**	**3.2**

Some assumptions and logic apply to all actions that concern electrification. To calculate the emission associated with the increased electricity the MJ associated with the fuel being replaced were found using emission factors and energy densities. These were then converted back to electricity by converting to kWh and then using the average emission intensity for low-carbon intensity grids. Low carbon (BC, MB, ON, QC, and NL) grids were chosen because it is realistic to expect grid emissions will decrease in the other provinces and territories and including all provincial and territorial emission factors overinflates electrical emissions.

The average grid carbon intensity used was 13.1 gCO2e/kWh.

KEY ASSUMPTION: The electrical grid carbon intensity of high carbon grids will decrease over time.

6.1 Action 1: Accelerate Electrification of LDVs, Lighting, and Misc. Small Equipment – Methods

Action 1 is associated with total gasoline use. LDVs, lighting, and misc. small equipment, which is not already electrified, can be assumed to be using gasoline.

KEY ASSUMPTION: LDVs, lighting and misc. equipment use ~100% of the gasoline in the dataset.

Therefore if 100% implementation is assumed across the baseline project then the reduction corresponds to 100% elimination of gasoline in the project. In this case the 2.0 $tCO2_e$/$M associated with on-site gasoline and the 0.4 $tCO2_e$/$M associated with off-site emissions go to zero. This gasoline is then replaced with electricity.

The amount of electricity required to replace gasoline consumption depends on the efficiency of the equipment. For simplification, it was assumed that 90% of the gasoline is consumed by light-duty vehicles (LDVs), while the remaining 10% is used by lights, small tools, and small equipment.

For each of the four equipment types considered, the energy consumption per unit of use (per hour or per kilometer) was identified for both gasoline and electric versions. A ratio was then calculated between the two energy values to determine the energy savings for each equipment type.

Example Calculation – Determining energy and emissions savings associated with electrifying LDVs.

Step 1 – Determine the ratio of energy consumption for internal combustion engines and electric trucks.

- Values from literature:
    - Internal combustion engine truck: 3.74 MJ/km
    - Electric truck: 1.21 MJ/km
- ratio of energy savings = 1.21/3.74 = 0.3236

Step 2 – Calculate the amount of electricity associated with LDVs that replaces gasoline

- $LDV\ Electricty = \frac{Gasoline\left(\frac{tCo2e}{\$M}\right)*1{,}000{,}000}{EF\ Gasoline} * Gasoline_{Energy\ density}\left(\frac{MJ}{L}\right) * \frac{ratio_{energy\ savings}}{3.6\left(\frac{MJ}{kWh}\right)} * \frac{Grid\ carbon\ intensity}{1{,}000{,}000}\ x\ 90\%$
- $LDV\ Electricty = 0.49\left(\frac{tCo2e}{\$M}\right) + \frac{1.96\left(\frac{tCo2e}{\$M}\right)*1{,}000{,}000\ (\frac{g}{t})}{2311.96\ (\frac{gCO2e}{L})} * 35\left(\frac{MJ}{L}\right) * \frac{0.3236}{3.6\left(\frac{MJ}{kWh}\right)} * \frac{13.1\left(\frac{gCO2e}{kWh}\right)}{1{,}000{,}000\left(\frac{g}{t}\right)}\ x\ 90\%$
- LDV Electricity = 0.0315 tCO_2e/$M

Step 3 – Add to total electricity

- The electricity calculated for LDVs was added to the baseline electricity consumption. The remaining 10% of gasoline consumption (for lights, tools, and small equipment) was converted similarly, using the average energy savings ratio for those equipment types.

Once the electricity replacement is found the net reductions for on and off site can be calculated. For this action the reductions in $tCO2_e$/$M are:

- Gasoline: 1.96 on-site, 0.40 off-site
- Electricity: -0.04 off-site
- Net Reductions: 2.32

The percentage reduction is then calculated as:

Net Reduction/Total Baseline = 2.32/16.10 = 14.5%

6.2 Action 2: Electrify and Optimize Temporary Heating – Methods

Action 2 is associated with total natural gas use as essentially all natural gas used in the data set was used for heating. It is most feasible to replace natural gas heating with electricity. It is less feasible to replace propane or diesel heating with electricity as when propane or diesel are used for heating it is typically because a project is in early stages and is not connected to the natural gas grid or cannot be connected to the natural gas grid at all because of its location. It can reasonably be assumed that grid electricity is typically available where natural gas is available, as electricity is available in more locations in Canada than natural gas. It is understood that electrical capacity may be an issue in some locations but for this scenario simplification can be used, and all natural gas can be assumed to be replaced with electricity.

KEY ASSUMPTION: Natural gas is ~100% consumed by heating.

Therefore if 100% implementation is assumed across the baseline project then the reduction corresponds to 100% elimination of NG in the project. In this case the 1.73 $tCO2_e$/\$M associated with on-site NG use and the 0.3 associated with off-site go to zero. This NG is then replaced with electricity.

The electricity consumed by the electric heater was calculated using the same methods as the LDV sample calculation. Appropriate heater efficiencies were chosen from literature.

Therefore, for this action the reductions in $tCO2_e$/\$M are:

- Natural Gas: 1.73 on-site, 0.34 off-site
- Electricity: -0.10 off-site
- Net Reductions: 1.97

The percentage reduction is then calculated as:

Net Reduction/Total Baseline = 1.97/16.10 = 12.2%

6.3 Action 3: Incorporate Hybrid and Electric Solutions for Excavation & Earthworks – Methods

Action 3 is about a specific portion of the diesel. Approximately 28% of diesel fuel usage is associated with category B. Since data availability limited the split of category B into subcategories B1, which is excavation and earthworks, was never assigned a value. In category B. The other fuel categories are B2 concrete and asphalt, B3 misc. land, B4 misc. marine. This dataset had few marine projects so a value of zero can be assumed for B4 within a median project. There is no way to accurately split up the fuel amongst the other B sub-categories so for the purpose of this scenario 50% of the diesel associated with category B was assigned to B1. To summarize the portion of diesel this action applies to is 50% of 28% of the total diesel where 28% of the total diesel is category B and 50% of this portion is the assumed B1 diesel.

This action was also split into two, and emission reduction were calculated separately for 100% implementation of electric equipment and hybrid equipment. Action 3.1 refers to hybrids and Action 3.2 refers to electric.

5.3.1 Action 3.1: Hybrid Excavation and Earthworks Equipment Methods

Hybrid equipment was assumed to have average emission reductions of 20%.[176]

Therefore if 100% implementation is assumed across the baseline project then the reduction corresponds to 0.24 $tCO2_e$/$M of on-site diesel emissions and 0.05 $tCO2_e$/$M of off-site diesel emissions eliminated. This diesel is then replaced with electricity. Hybrid equipment is difficult to measure the efficiency or emissions savings of because it typically depends on operations so a 1:1 energy ratio was used for diesel and electricity in this case.

Therefore, for this action the reductions in $tCO2_e$/$M are:

- Diesel: 0.24 on-site, 0.05 off-site
- Electricity: -0.12 off-site
- Net Reductions: 0.18

The percentage reduction is then calculated as:

Net Reduction/Total Baseline = 0.18/16.10 = 1.1%

6.3.2 Action 3.2: Electric Excavation and Earthworks Equipment Methods

100% of the targeted diesel was assumed to be replaced with electricity. Therefore, if 100% implementation is assumed across the baseline project then the reduction corresponds to 1.2 $tCO2_e$/$M of onsite and 0.27 $tCO2_e$/$M of off-site diesel emissions eliminated.

The electricity consumed by the fully electric earthworks and excavation equipment was calculated using the same methods as the LDV sample calculation. Appropriate energy consumption factors were chosen from literature.

Therefore, for this section the reductions in $tCO2_e$/$M are:

- Diesel: 1.20 on-site, 0.27 off-site
- Electricity: -0.21off-site
- Net Reductions: 1.33

The percentage reduction is then calculated as:

Net Reduction/Total Baseline = 1.33/16.10 = 7.8%

6.4 Action 4: Deploy Grid-Connected and Hybrid Power Solutions for Temporary Energy Needs – Methods

Action 4 is about a different portion of the diesel. Approximately 21% of diesel fuel usage is associated with temporary power or category D1.

This action was also split into two, and emission reduction were calculated separately for 100% implementation of electric equipment and hybrid equipment. Action 4.1 refers to hybrids and Action 4.2

[176] https://transweb.sjsu.edu/sites/default/files/1533-analyzing-the-potential-of-hybrid-and-electric-off-road-equipment-in-reducing-carbon-emissions-from-construction-industries-research-brief.pdf

refers to electric. For both subsections, electricity emissions were not calculated as in this case the generator would be for temporary power and not grid-connected. Therefore, this power is a straight reduction as the generator is producing its own electricity (solar, diesel solar hybrid, etc.).

6.4.1 Action 4.1: Hybrid Temporary Power Methods

Hybrid equipment was assumed to have average emission reductions of 50%.[177,178,179] Therefore, if 100% implementation is assumed across the baseline project then the reduction corresponds to 0.90 $tCO2_e$/$M of on-site and 0.20 of off-site diesel emissions eliminated. This diesel is then replaced with electricity.

Therefore, for this section the reductions in $tCO2_e$/$M are:

- Diesel: 0.90 on-site, 0.20 off-site
- Net Reductions: 1.10

The percentage reduction is then calculated as:

$$Net\ Reduction/Total\ Baseline = 1.1/16.10 = 6.9\%$$

5.4.2 Action 4.2: Electric Temporary Power Methods

100% of the targeted diesel was assumed to be replaced with electricity. Therefore, if 100% implementation is assumed across the baseline project then the reduction corresponds to 1.81 $tCO2_e$/$M of on-site and 0.40 $tCO2_e$/$M of off-site diesel emissions eliminated.

Therefore, for this section, the reductions in $tCO2_e$/$M are:

- Diesel: 1.81 on-site, 0.40 off-site
- Net Reductions: 2.21

The percentage reduction is then calculated as:

$$Net\ Reduction/Total\ Baseline = 2.21/16.10 = 13.7\%$$

6.5 Action 5: Transition to Renewable Diesel as a Bridge – Methods

Action 5 addresses the reduction of diesel lifecycle emissions by transitioning to biodiesel or renewable diesel. This change can result in emission reductions ranging from 40% to 80%.[180,181].

In the case where diesel is fully replaced with biodiesel or renewable diesel, the emissions reductions are calculated using the following parameters:

- On-site emissions for both diesel and biodiesel or renewable diesel are approximately equal, as the on-site emission factors for these fuels are nearly identical.

177 https://www.sciencedirect.com/science/article/pii/S2590174524002587
178 https://powr2.com/emission-free-power
179 https://www.precisiondrilling.com/wp-content/uploads/2023/02/EverGreenEnergy-Battery-Energy-Storage-System-Reduces-Fuel-Consumption-and-GHG-Emissions-for-the-Operator.pdf
180 https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2021.690725/full
181 https://pubmed.ncbi.nlm.nih.gov/35576244/

- Off-site diesel emissions are eliminated, as it is assumed that diesel is no longer utilized.
- Off-site emissions associated with biodiesel or renewable diesel are negative and are calculated as follows:
- The off-site emission factor for biodiesel or renewable diesel is determined by subtracting the on-site combustion emission factor from the lifecycle emission factor:
  Off-site emission factor = lifecycle emission factor – on-site combustion emission factor = 30 gCO_2e/MJ – 75 gCO_2e/MJ = -45 gCO_2e/MJ
- The quantity of MJs required from biodiesel is approximately equivalent to that required from diesel. Thus, diesel is first converted into MJ, and the off-site emission factor for biodiesel or renewable diesel is applied to calculate the associated emission reductions.

Therefore, for this section, the reduction in tCO_2e/$M are:

- Diesel: 8.60 on-site ,1.92 off-site
- Biodiesel or Renewable Diesel: -8.58 on-site, 5.13 off-site
- Net Reductions: 7.07

The percentage reduction in lifecycle diesel emissions is then calculated as:

Emissions Reduction/Total Baseline = 7.07 / 16.10 = 43.8%

6.6 Total Impact of Implementation – Methods

This section is purely dedicated to calculating the total emissions reductions. First the actions had to applied, 1-4 were applied normally and then action 5 was applied on the remaining diesel after the implementation of Action 3.2 and Action 4.2. The diesel action 5 was applied to 5.59 tCO2e/$M on-site and 1.25 tCO2e/$M off-site. This approach was adopted to prevent double-counting, ensuring that Action 5 only applies to the remaining diesel after the preceding actions have been implemented. The net reduction of action 5 was then recalculated using the smaller amount of diesel to be -4.6 tCO2e/$M (0 tCO2e/$M on-site and -4.6 tCO2e/$M off-site).

All lifecycle emission reductions were added up and compared to the baseline emissions. Remaining emissions were calculated as follows:

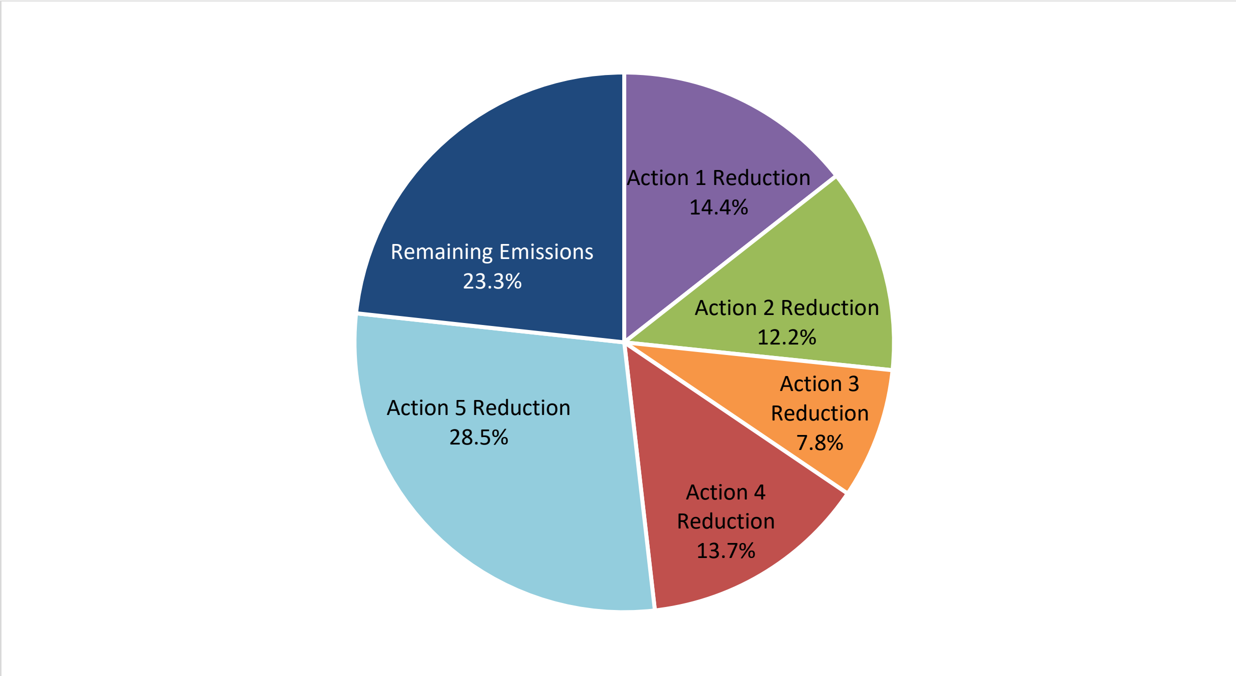
Remaining emissions = (baseline off-site emissions + off-site reductions) + (baseline on-site emissions + on-site reductions)

$$= (3.2 + (-0.4 -0.2 -0.1 -0.4 -4.6)) + (12.9 + (-2.0 -1.7 -1.2 -1.8 +0)) = 3.7$$

$$3.7/16.1 = 23\%$$

Figure 6 shows the emissions reductions in percentages by each action for the baseline project.

Figure 6: Contribution of the five high-impact actions to reduced project emissions



For simplification of calculations for the total implementation timeline it was assumed that ¼ of the emissions remained at 100% implementation or that 100% implementation of all 5 activities reduced emissions by 75%.

7. Costs and Return on Investment Calculations

This section describes the methods and assumptions used to calculate and estimate the annual cost of fuel, electricity costs, annual fuel savings, and return on investment (ROI) analyses for various categories of construction equipment.

7.1 Equipment and Energy Consumption Data

For each class of equipment – Light-Duty Vehicles (A.1), Excavation and Earthworks (B.1), Concrete and Asphalt (B.2), and Heating (C.2) - diesel or gasoline-powered equipment was selected as a baseline comparison. Manufacturer-provided specifications on fuel consumption rates and energy consumption were collected. If manufacturer data on electric equivalents was available, these values were directly utilized. In cases where electric equipment data was unavailable, a 1:1 energy consumption equivalency assumption was applied, using the fuel energy consumption rate from the diesel or gasoline counterpart as a proxy for electric consumption.

Example Calculation – Determining fuel and energy costs to identify number of years for ROI (British Columbia)

Step 1 – Determine the hourly cost of fuel for diesel equipment and cost of energy for electric equipment

For cost of fuel or energy per hour:

$$Fuel\ consumption\ rate\ \left(\frac{L}{hr}\right)\ \cdot\ Cost\ of\ fuel\ in\ province\ \left(\frac{CAD}{L}\right) = Cost\ per\ hour\ \left(\frac{CAD}{hr}\right) Energy\ consumption\ rate\ \left(\frac{kWh}{hr}\right) \cdot\ Cost\ of\ energy\ in\ province\ \left(\frac{CAD}{kWh}\right) = Cost\ per\ hour\ \left(\frac{CAD}{hr}\right)$$

If actual consumption data was unavailable, as with the Leeboy 8520C electric paver, the 1:1 equivalency was calculated as:

$$Fuel\ consumption\ rate\ \left(\frac{L}{hr}\right)\ \cdot\ Energy\ per\ litre\ of\ diesel\ (kWh) = Energy\ consumption\ rate\ \left(\frac{kWh}{hr}\right)$$

$$9.51\ \frac{L}{hr}\ \cdot\ 10.7\ \frac{kWh}{L}\ =\ 101.757\ \frac{kWh}{hr}$$

$$\text{Energy Cost} = 101.757\ \frac{kWh}{hr}\ \cdot\ 0.1398\ \frac{CAD}{kWh}\ =\ 14.23\ \frac{CAD}{hr}$$

$$\text{Fuel Cost} = 9.51\ \frac{L}{hr}\ \cdot\ 1.83\ \frac{CAD}{L}\ =\ 17.41\ \frac{CAD}{hr}$$

Step 2 – Determine the fuel cost savings of transitioning to electric by province

$$Fuel\ Cost\ per\ hour\ -\ Energy\ Cost\ per\ hour\ =\ Cost\ savings$$

$$\text{BC cost savings} = 17.41\ \frac{CAD}{hr}\ -\ 14.23\ \frac{CAD}{hr}\ =\ 3.19\ \frac{CAD}{hr}$$

Step 3 – Determine annual cost savings by province

$$Annual\ operating\ hours\ \cdot\ Cost\ savings\ =\ Annual\ Cost\ savings$$

$$=\ 1768\ hours\ \cdot\ 3.19\ \frac{CAD}{hr}\ =\ 5{,}634.94\ \frac{CAD}{yr}$$

Step 4 – Determine number of years for ROI based on annual cost savings and upfront cost difference

$$\frac{Change\ in\ Cost}{Annual\ Cost\ Savings}\ =\ ROI\ years$$

$$\frac{130{,}000}{5634.94}\ =\ 23.1\ years$$