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# IMPACT OF COLD CLIMATE ON EMISSIONS AND FUEL CONSUMPTION OF VEHICLES: KNOWLEDGE GAP SYNTHESIS

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## ABSTRACT

Transportation and mobile equipment are the emission source of 48% of total emissions in Canada in 2019, according to NPRI. Out of 33 Canadian major cities, 11 cities experience at least one night of -30°C weather each winter. The cold climate affects vehicle emissions (criteria air contaminants, CACs) and energy consumption (greenhouse gas emissions, $CO_{2,eq}$). Low ambient temperatures significantly increase the emission of vehicle pollutants by affecting the thermal state of the internal combustion engine and aftertreatment systems. The cold climate also affects the energy consumption of vehicles, which increases $CO_{2,eq}$ emissions even in electric and hybrid electric vehicles (HEVs). Cold weather causes more use of personal cars, more idling, and more cabin heating. Further, the current vehicle emission standards do not regulate vehicular emissions under extremely low ambient temperatures (<-7°C).

In this study, we reviewed over 100 research articles including the recent literature on the effects of cold ambient temperature on vehicle emissions and energy consumption. The study focused on main types of vehicle powertrain technologies, including gasoline direct injection, advanced diesel engines, and HEVs. The impact of cold climate on vehicle emissions and energy consumption was found to be attributed primarily to thermal conditioning of the engine and exhaust aftretreatment system, poor fuel vaporization, condensation, more idling, and more cabin heating requirements. For instance, reducing the engine coolant temperature from 90°C to -30°C can double CAC emissions. Or in another investigation, at -19°C, the particle number (PN) emission was 3.8 times higher than that of 30°C for a plume-based fleet emission measurement in downtown Toronto, Canada. Results of another investigation showed at an ambient temperature of about -7°C, the increase in fuel consumption of light-duty gasoline vehicles due to cold start can be up to 40 to 80% of fuel consumption in a hot start mode; while this increase is 20% for the ambient temperature of 24°C.

Our review study identified the knowledge gaps and the need to understand advanced powertrain technologies' emission and energy consumption behaviour in cold climate cities. There is a general lack of studies at subzero temperatures, focusing on temperatures below -7°C. Electric vehicles (EVs) and plug-in HEVs are also prone to regional inhomogeneity in energy consumption and $CO_{2.eq}$ emissions mostly related to varying ambient temperatures. The increased energy consumption of EVs and PHEVs could become a crucial element for cold climate cities' decarbonization and electrification plans, considering electric power grid requirements in winter.