Study finds effects of car preheating on vehicle fuel consumption and emissions are minimal

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Published in *Applied Energy*, a new study by the University of Eastern Finland and Tampere University found that the benefits of car preheating for both fuel economy and emissions are minimal. The researchers focused on vehicle fuel consumption and emissions under cold winter conditions. Of particular interest were cold start emissions and their relation to preheating.

The results show that cold starts are challenging, especially for diesel-powered vehicles under cold winter conditions. During the measurement campaign conducted in Finland, outdoor temperatures dropped as low as -28°C, and this was reflected in vehicle emissions. The route driven in the measurement campaign aimed to replicate typical commuting scenarios, including both urban and highway driving, as well as stops at intersections and traffic lights.

Vehicles were driven on the same route under three conditions: after a cold start, preheated, and with the engine already warmed up by driving. After a cold start, the engine coolant needed nearly the entire drive (13.8 km, about 19 minutes) to reach its optimal operating temperature (>60°C). The studied vehicles were equipped with either electric or fuel-powered preheaters.

"Efficient preheaters (at least 1 kW) helped in warming the engine coolant before starting, but they didn't significantly speed up reaching the optimal operating temperature. Higher starting temperatures primarily improved vehicle comfort by providing a warmer cabin and preventing window frost. Additionally, according to car manufacturers, preheating can reduce engine wear during cold starts," Postdoctoral Researcher Ville Leinonen of the University of Eastern Finland says.

The study found slightly lower overall fuel consumption (10%–20%) when the vehicle was driven after being warmed up compared to after a cold start. Only 2 out of the 6 vehicles studied, both equipped with fuel-powered auxiliary heaters, showed small fuel savings due to preheating. Even in these vehicles, preheating before starting only helped reduce fuel consumption by less than 4% compared to cold starts.

"The calculated fuel savings did not account for the fuel or electricity consumption of the auxiliary heaters during preheating. When considering the fuel consumption during preheating, the post-preheating drive resulted in 26%–37% higher overall fuel consumption than after a cold start. Preheating also had an impact on overall emissions," Research Director Santtu Mikkonen of the University of Eastern Finland points out.

These findings reinforce the notion that the use of fuel-powered auxiliary heaters cannot be justified by better fuel economy or reduced emissions in actual cold temperature driving. Nevertheless, when considering the entire lifespan of a vehicle, the benefits of preheating may become apparent through extended engine oil life and longer engine durability, although these factors were not examined in this study.

No evidence on positive effect of preheating on particulate emissions

Assistant Professor Panu Karjalainen of Tampere University points out that, as a natural consequence of the observations on total fuel consumption, preheating did not significantly affect particulate emissions either. The number concentration of particles exceeded regulatory limits for new vehicles by up to a hundredfold. This may be partly explained by the fact that regulations only take into account solid particles larger than 23 nanometers in size and apply to emissions measured under warm conditions. The measurements conducted under cold winter conditions showed high concentrations of smaller particles, some of which could be liquid.

Even though diesel particulate filters are supposed to capture nearly all particles from emissions, significant particulate emissions were observed during driving in diesel vehicles equipped with fuel-powered auxiliary heaters. This can be attributed to the emissions produced by these heaters during operation, as they automatically provide additional heat to the engine or cabin while driving. The effect of auxiliary heaters on in-use emissions is more pronounced because there is no emissions aftertreatment for heaters as there is for engine emissions.

In contrast to particle number emissions, there were differences in emissions of particle mass, black carbon and nitrogen oxides in different driving situations. Particle mass and black carbon emissions were lower when driving with a warm engine compared to cold starts, especially in gasoline-powered vehicles. The largest reductions in particle mass were observed to be 85% over the entire route and 99% during the initial idle and early route sections.

Nitrogen oxide emissions were up to 90% lower when driving with a warm engine compared to after a cold start, depending on the vehicle. However, the benefits of preheating for reducing particle mass emissions were only observed in one gasoline vehicle, where these emissions decreased by 72%, and in one diesel vehicle, where the reduction was 24%. For black carbon emissions, preheating showed only minimal benefits. Regarding nitrogen oxide emissions, significant benefits from preheating were observed in only one gasoline vehicle, where the reduction was 41%.

It is noteworthy that, when considering the emissions from auxiliary heaters as well, the reduction in nitrogen oxide emissions is only 15%. Importantly, electric preheaters were not found to provide significant benefits in terms of fuel consumption or emissions reduction.

For diesel vehicles, the role of auxiliary heaters in total nitrogen oxide emissions was not as significant as in gasoline vehicles, as diesel vehicles had significantly higher in-use nitrogen oxide emissions. Although all studied vehicles exceeded nitrogen oxide emission limits, the largest exceedances were observed in diesel vehicles, even up to 21 times the limit. It's worth noting that nitrogen oxide emissions from one diesel vehicle exceeded the regulatory limit by a factor of 12, despite being equipped with a selective catalytic reduction (SCR) system. This suggests that the SCR system did not function properly in cold temperatures.

All benefits and downsides of preheating are not known

In summary, using preheating solely for the purpose of improving fuel economy and reducing emissions does not find support in actual cold-temperature driving conditions. However, in different driving scenarios and considering the entire lifespan of vehicles, emissions reduction might lead to somewhat different conclusions. The studied emissions, including particulate and nitrogen oxide emissions, indicated some reductions for vehicles with fuel-powered auxiliary heaters. Nevertheless, these benefits diminish significantly or even become negated when accounting for the fuel consumption and emissions of the auxiliary heater during the preheating cycle.

Furthermore, it's important to note that preheating may have benefits regarding emissions that were not measured in this study, such as emissions of specific hydrocarbons. In addition, emissions from fuel -operated auxiliary heaters may be higher due to limited aftertreatment, potentially offsetting any advantages in terms of these emissions as well.

More information: Miska Olin et al, Engine preheating under real-world subfreezing conditions provides less than expected benefits to vehicle fuel economy and emission reduction for light-duty vehicles,

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