Outsmarting Cabin-Battery Thermal Compromises for EVs

Makers of electric vehicles have had to carefully balance the thermal comfort requirements of passengers with the drain thermal management systems place on the batteries. Every little bit of energy consumption matters when one of the most basic metrics of success is battery range. As such, researchers are exploring every avenue – from advanced climate control solutions and energy harvesting strategies – to achieve increased vehicle range, efficiency and safety.

Targeted, Decentralized Heating and Cooling Technologies

According to one estimate, up to 25% of an EV's range is degraded as a result of the energy required for HVAC systems.[i] In general a vehicle's cabin is heated or cooled by a forced air system. For heating, this means using waste heat from the engine, but since electric vehicles produce little to how waste heat, this is no longer a feasible solution for cabin comfort. Some use a resistance heater and fans to push the warm air throughout the cabin, but this can be costly in terms of battery life.

As a result, manufacturers are exploring a wide variety of solutions for cabin heating that won't tax the vehicle's battery life. Perhaps one of the least obvious but simplest idea is for EVs and hybrids to be pre-heated or pre-cooled while still connected to the grid. This provides a pre-set interior temperature without taxing the battery range.

But once you're on the road, you need to continue to provide a comfortable interior, and for that manufacturers are working on methods that will reduce the overall energy required for maintaining passenger comfort by zeroing in on temperature controls for individual occupants. Rather than aiming for a uniform temperature throughout the vehicle regardless of how many people are traveling, decentralized intelligent heating and cooling systems have the potential to ensure customizable comfort levels for each passenger while using less energy than conventional systems.

BMW is also exploring direct heating solutions to solve this problem, but for they've turned to infrared heating. This technology uses electromagnetic radiation to transfer heat energy directly to the passengers through the surfaces of the vehicle. That means it's only transferred when the electromagnetic wave hits an object,

making it much more efficient than forced air heating, and even more efficient than convective or conductive heating.

BMW Intelligent Thermal Management with Infrared Heating

This solution is said to cut energy consumption needed for passenger heating and increase vehicle range quite a bit – up to 30% by their current estimates. It works by silently delivering heat to passengers through panels in the foot wells, doors, and other panels.

And since heat is provided only for occupants riding in the vehicle and not in zones that remain unoccupied, this further increases the efficiency of such a system. The vehicle would be equipped with smart systems that could sense which seats were occupied, plying heat only to those who needed it. With individual controls, this could be further optimized to provide only as much heat as each passenger wanted.

Not only is this experienced as a very natural form of heat, it is also one that can be switched on and enjoyed within a very short moment – it takes only about 60 seconds for the heat to be sensed according to BMW. This makes infrared heating extremely attractive especially in very cold regions. Additional benefits of infrared heating is that it is silent and produces no drafts or moving air, which together further increases passenger comfort.

The downside to using infrared technology for interior heating is that it cannot be reversed. In other words, the same tech can't be applied to provide cooling during hot weather. As a result, any vehicle that used infrared heating would also be equipped with a conventional NVAC cooling system.

BMW's energy efficiency measures rely on what they call Intelligent Energy Management, which includes the infrared heating solutions as well as several others. The Intelligent Energy Management concept centers around the idea that

every possible kilowatt of energy needs to be stored and then saved to be used somewhere else in the vehicle, thereby increasing the overall range.

Along a totally different track is the US Department of Energy's partnership with GM which has been conducting tests for the effectiveness of thermoelectric materials for achieving comfort through the use of customized temperature regulation. Their early results seem to indicate that equivalent comfort can be obtained by using thermoelectric materials in this way. Further, when measuring energy consumption of this type of system compared to conventional cooling and heating techniques, the researchers found that there was a 36.5% savings in power. Their next step is to commercialize the design for the LaCrosse for further real world testing.[ii]

Advanced Waste Heat Recovery and Reuse Technologies and Concepts

Aside from heating passenger bodies directly, many manufacturers are turning to heat pumps as a more efficient way to provide thermal comfort with less energy. Heat pumps are an innovative solution for reusing waste heat generated from systems such as electric auxiliaries, the battery, and human passengers as well.

The 2013 Nissan Leaf is already using this technology, thanks to technology developed by Renault's Zoe. Through a partnership with Renault, Zoe's heat pump, which could improve the Leaf's cold-weather range by up to 25 miles, will be installed in the 2013 Leaf. The heat pump is capable of producing 2 killowatts of cooling or 3 kilowatts of heating from 1 kilowatt of electricity, making it an ultra-efficient way to provide passenger comfort in a vehicle that doesn't otherwise generate its own waste heat.[iii]

Visteon's Heat Pump for Electric and Plug-in Hybrid Vehicles

Visteon Corporation is also working on their own heat pump system which transfers energy from ambient air to cool and heat the interior of the vehicle. They claim that their system uses 50% less energy from the battery, which helps extend battery life by 30% between charges.

Though BMW, as we've noted, it already paying a lot of attention to their infrared technological advances for passenger comfort, they believe

there is a lot of potential in heat pump systems, and as such are investing a fair bit in this technology as well. They believe that heat pumps are to be the likely next stepping stone in the evolution of vehicle passenger comfort. They also estimate that an efficient heat pump system can improve a vehicle's range by as much as 30% compared to air-heated electric vehicles.[iv]

Their system relies on an air conditioning compressor with refrigerant that is compressed and elevated to a higher temperature level. This allows them to use their system for heating, cooling, and dehumidification as needed.

When heat is needed, their system collects and stores ambient heat from the air outside and from within the vehicle. Their intelligent thermal management system monitors the entire vehicle so that it can move heat around the vehicle with precision.

As with their other vehicles, this heat pump system will allow passengers to have individual control over the temperature in their own zone so that each reaches the comfort level they seek. In all, BMW estimates that heat pumps will save about 50% in energy compared to conventional heating systems.[v]

One of the offshoots of this waste heat research being conducted by BMW is the use of a new semiconductor material known as telluride, which is an environmentally stable material that can convert between 15% and 20% of waste heat to electricity. The material, which is being tested at Northwestern University and Michigan State University, exhibits a thermoelectric figure of merit (ZT) of 2.2, which is purportedly the highest recorded in the world. That means it's extremely good at converting heat to electricity. BMW is working on the technology for their exhaust systems as well as combustion engines, though perhaps may find applications in the EV/HV market as well.[vi]

Ohio State University researchers are working on an EcoCARE which is a prototype PHEV in order to test whether an Organic Rankine cycle (ORC) waste heat recovery system (evaporator, condenser, pump, expander) could recover waste heat from the engine. In the end, they were able to determine that the ORC system could recover about 1.7% of the fuel energy in the NEDC cycle, making this an effective solution for increasing fuel economy at highway conditions for hybrid and plug-in hybrid electric vehicles.[vii]

Is Zero Energy Cabin Thermal Comfort on the Horizon?

As demands for more energy efficient vehicles increases, researchers are turning to a variety of technologies for vastly reducing the energy required to keep a vehicle cabin comfortable, including new materials, waste heat recycling, and so forth. The question of whether all of these advancements will result in a zero emissions heating and cooling system for modern vehicles remains to be answered, but the potential does seem to be there.

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