Revolutionizing EV HVAC Energy Use with Heat Pumps

Air conditioning for automobiles is a big energy consumer. In fact in the US, automobiles burn 170 million barrels of oil annually – equivalent to 5.5% of the nation's oil consumption – just to cool the interior of their vehicles. And cooling isn't the only problem – heating a vehicle has the same fuel-guzzling results.

While electric vehicles (EVs) and hybrid electric vehicles (HEVs) don't consume gas or diesel, the energy impact of heating and cooling these vehicle cabins can have equally negative energy-related consequences. This is especially true given the impact high-power climate control heating, ventilation, and air conditioning (HVAC) systems have on the range of electric vehicles.

With the EV and HEV market set to grow significantly in the coming years, one of the major challenges OEMs are looking to overcome is the range anxiety EV drivers feel, especially as it relates to a vehicle's climate control system. After all, you never want a consumer to be faced with the choice between using the climate control system and being stranded, or getting home while shivering or perspiring excessively.

Range Anxiety and Other Challenges for EV Heating and Cooling

The numbers are in, and they tell us clearly that running either the heating or air conditioning system in an EV or HEV drains the life of the battery. In fact, running the air conditioning on full will reduce an electric vehicle's battery capacity by up to 36%,[i] significantly increasing a driver's range anxiety. This can create high risk aversion for both manufacturers and vehicle owners. What causes one of the most anxious reactions from consumers is seeing the predicted range on the dashboard display dramatically decreased when climate control systems are turned on. Without a solution, this problem will be a deterrent for potential EV buyers.

But there's more. Cost is a factor when considering how to provide cabin climate control without decreasing EV range. Given the already high price premium for EVs, increasing battery size to compensate for the range reduction with A/C usage becomes prohibitively expensive. Add an advanced climate control system (that requires more complex (read expensive) components) and you could further increase the price tag on an electric vehicle.

Another challenge is that the temperature of the climate control system can directly impact the life of a Li-ion battery. These batteries are highly sensitive to temperature changes (especially high heat), and can be negatively impacted if improperly designed. Depending on where the climate control system is located, the battery life can be either positively or negatively impacted by the climate control design of the vehicle.

For instance, if heat is transferred from a warm cabin to the battery during a thermal soak, it can lead to higher battery temperatures and damage. A well-designed system, on the other hand, as with the Prius, might ensure cool cabin air is used to lower battery temperature, having a beneficial impact on the system. Regardless, the battery life needs to be considered when designing an electric vehicle temperature control system.

While electric heaters offer a low-cost option for warming the vehicle cabin, they have a coefficient of performance (COP) equal to 1. Heat pumps, on the other hand, have higher COPs, which means they could use waste heat from advanced power electronics, energy storage systems, and electric motor cooling loops, making them a more efficient option for EV climate control. They also avoid the problem of taking valuable stored energy away from propulsion.[ii] It is to the heat pump that we now turn our attention as a highly energy-efficient solution for EVs and HEVs.

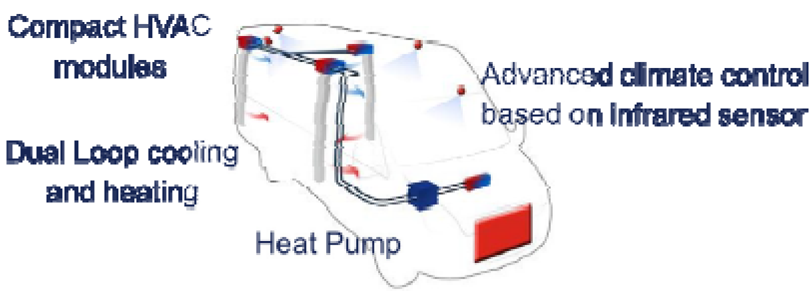
Heat Pump Systems for a New Approach to Electric Vehicle HVAC

By and large, today's vehicles harvest waste heat from within the vehicle to warm the interior of the cabin. Waste heat can come in the form of heat from ambient air or heat from the engine. This technology works well for conventional fuel vehicles that produce waste heat in significant quantities.

But new electric and hybrid electric vehicles face a challenge – their engines produce far less heat. They can rely on electric elements for waste heat production, but this is a relatively big energy hog, which results in a substantially reduced electric drive range. And relying on the battery to produce heat can drain the driving range of an electric vehicle by as much as 40%.[iii]

One of the emerging technologies being used to solve cooling and heating problems for electric and hybrid-electric vehicles is the heat pump. This technology is not new in and of itself – it has been around for decades (if not centuries) – but heat pumps are just now coming into their own in the automobile industry.

They work as heat exchangers, transferring heat to and from a working fluid (a refrigerant in most cases) to the air. As such, heat pumps can be used to both heat and cool the cabin of a vehicle and are estimated to increase battery range substantially. Behr, for instance, estimates that their heat pump, which will be integrated in the refrigerant circuit to provide heating in electric vehicles, should increase the car's range by 40% to 50% compared to conventional systems.[iv]



EU's Magneto Caloric Heat Pump Concept

An EU program is also investing in heat pump technology for fully electric minibuses as part of their European Green Car Initiative. Using a Magneto Caloric heat pump technology that employs an advanced refrigeration concept, the aim of the research is to provide all of the heating and cooling requirements of the bus. The system will use wall temperature sensors and climate control based on thermal comfort estimation in a dual loop system.[v]

Delphi has also developed their own heat pump with promising results. The Delphi Unitary Heat Pump Air Conditioner (HPAC) integrates a refrigerant heat pump and a coolant distribution system to control cabin comfort. This system works in electric and hybrid vehicles by recovering the minimal waste heat energy produced the batteries, power electronics, and the electric motor. For very cold conditions, Delphi estimates that their thermal system would increase electric drive range by up to 10%, and a CO_2 emissions reduction in plug-in hybrids of 3.8 grams per mile.[vi]

Pacific Northwest National Laboratory (PNNL) scientists are working on another heat pump innovation they call the electrical metal-organic framework (EMOF) that would be used for more efficient heating and cooling systems for EVs and HEVs. Working as a molecular heat pump, the EMOF would circulate heat or cold as needed by controlling the EMOF's properties with electricity. The estimate that a 2-litre bottle-sized EMOF heat pump (about 5 pounds) could handle the heating and cooling requirements of a typical vehicle with far less impact on driving distance.[vii]

Finally, you'll see heat pump technology in the Renault ZOE, a new production electric vehicle which is set to go on sale in the autumn of 2012. This vehicle will operate like a reverse cycle air conditioning system. The heat pump will consume very little energy so that it will have minimal impact on drive range.

In fact, the heat pump will generate only 2 kW of cooling or 3 kW of heating using just 1 kW of electricity. ZOE, which relies on a 22 kWh Li-ion battery pack, is estimated to get a range of 201 km (130 miles), though this will likely fluctuate depending on the weather. In all, Renault estimates ZOE will produce total emissions between 12 g/km and 62 g/km of carbon dioxide equivalent depending on the energy generation mix of each country, which is a fair bit lower than the 89 g/km achieved by the Toyota Prius.[viii]

More Heat Pump Innovations on the Horizon

If the flurry of developments in EV and HEV heat pump technology and the projected increase in electric vehicle sales are any indication, researchers and vehicle manufacturers will continue to push the boundaries of heat pump technology to further reduce climate control energy requirements and extend battery life. Components will become more finely tuned and smaller, and the complexity of the systems will likely increase as innovations lead to even leaner HVAC designs.

And heat pump technology can also be applied to conventionally-powered vehicles. Gas or diesel-powered vehicles lose significant energy to heat waste. One researcher has pegged gas energy expended to waste heat at 50% to 75%, all of which spills out a vehicle's tailpipe.[ix] As such, there's tremendous potential to use heat pump technology on gas and diesel vehicles as well. Forthcoming developments should be interesting!

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