Thermoelectric Generators are on the Way

Within three years it's likely you'll look under the bonnet of a new 4x4 and discover there's no alternator. The electric power to run the vehicle's ancillary systems will come from the exhaust system – or, rather, from a thermoelectric generator (TEG) that's part of it.

A TEG consists of two dissimilar metals or metal alloys and, as the German physicist, Thomas Seebeck, discovered in 1821, an electric current flows when there's a temperature difference between the sides. A few years later a French physicist, Jean Peltier, found that applying an electric current to the metals produced a temperature difference on each side.

This Peltier-Seebeck effect is employed in temperature-measuring thermocouples and solid-state food coolers and heaters. At the milliamp level the difference between skin and ambient temperature is being used to provide the energy for low-powered electronics in 'smart' garments
TEGs consists of pairs of p-type and n-type semiconductor materials that are sandwiched between thin ceramic wafers. These thermocouples are connected electrically in series and thermally in parallel, forming an array.

TEGs have been used as power sources in deep-space probes for about 30 years. The heat source in these units is decaying radioactive material, providing a long-term heat source. Automotive TEGs currently under development use exhaust system heat to produce electricity.
In even the most efficient internal combustion engine, only about a third of the total energy from combustion actually gets to the wheels, while the other two-thirds is lost in driveline friction, in alternator load, in cooling the engine and in exhaust heat.

To reduce cooling system losses, some engine makers experimented with so-called 'hot' engines, without cooling systems, during the 1980s and 1990s, but these engines were high polluters and some of the ceramic parts had a propensity to return to their parent material – sand.

Attention then focussed on reducing exhaust heat losses or employing exhaust heat to do work. Several major vehicle makers – notably BMW, Ford and General Motors – are investing heavily in TEG R&D, with the aim of having production systems in place within three years.
BMW recently picked up an award for its efforts in TEG R&D. The Ökoglobe Award is presented by the DEVK insurance group, the Automobil-Club Verkehr and the Center Automotive Research, Gelsenkirchen University of Applied Sciences.

General Motors' researcher Jihui Yang said that a TEG fitted to a Chevrolet Suburban, eliminating the alternator, should reduce fuel consumption by at least five percent, but the target reduction in fuel consumption is 10 percent. While it's not clear how much the device would add to the price of a vehicle, the whole point of the research is to make it cost-effective, Yang said.

BSST, a subsidiary of thermo-electrics supplier Amerigon Inc, is working with Ford to develop climate control systems based on thermo-electrics.
Ford wants a system that would target a person's extremities when it's cold or the back of the neck in summer heat, rather than blow out a lot of air to change the temperature of the entire vehicle.

TEG Future

The development of TEG materials is progressing at a frantic pace.
Thermoelectric efficiency (ZT) is proportional to electrical conductivity, temperature and thermoelectric power, which is the voltage produced in a material per degree. ZT is inversely proportional to thermal conductivity.

Engineers in the United States and Japan have found a new technique to improve the efficiency of a thermoelectric energy converter. Instead of decreasing the thermal conductivity, which is normally how efficiency is improved, they increased electrical conductivity by doping the material with the toxin thallium. The scientists involved in the research, from Ohio State University, Caltech and Osaka University admit that the major problem with this route is that the materials used are toxic: lead telluride, the standard compound for high-temperature thermo-electrics, doped with the famously poisonous thallium. So researchers are working on applying the same technique, using less-toxic materials.

Aside from the toxicity factor, thermoelectric efficiency has to be increased even further for it to be a viable ancillary power source in a vehicle. Until recently, ZT figures below 1 were typical. The most efficient material used commercially in thermoelectric power generators is an alloy called sodium-doped lead telluride, which has a ZT rating of 0.71. The new material, thallium-doped lead telluride, has a rating of 1.5, but other experimental materials are approaching a ZT greater than 2.
The most likely applications of thermo-electrics in vehicles will be air conditioners and co-generators, in power ranges of 100 watts to 5kW, with ZT ratings of 1 to 3. They should be commercially available from 2010-2015.

The futuristic generation of thermo-electrics, with ZT ratings above 3, may be significant boosters of efficiency for vehicles and, with ZTs predicted up to 20, may even become replacements for internal combustion engines. These higher-ZT TEGs are expected to be commercially available from 2015.