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FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

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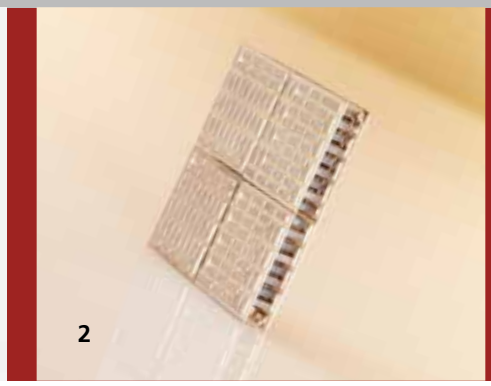
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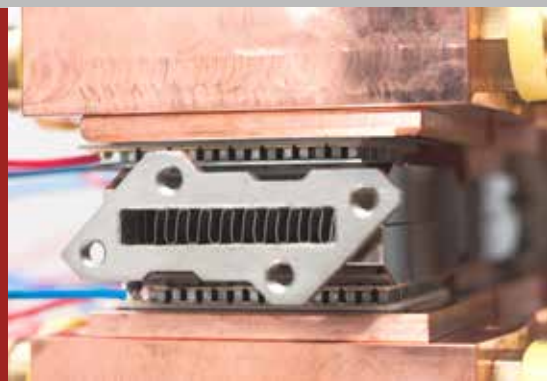


1 *Energy efficient: thermoelectric modules produce valuable energy from waste heat.*
2 *Thermoelectric module.*
3 *Thermoelectric generator.*

THERMOELECTRICS
WASTE HEAT RECOVERY

Waste heat is generated in all areas of daily life – in industrial processes, private households, and in traffic. According to the Institut für ZukunftsEnergieSysteme (IZES / Institute for Future Energy Systems), the potential waste heat available in Germany is 300 TWh per year – an energy resource that has been largely untapped up to now. Thermoelectric technology lends itself to the utilization of waste heat: converting heat directly into electrical energy will make an important contribution to the energy transition in Germany. Fraunhofer IPM has developed innovative thermoelectric generators for this purpose, which are suitable for hot gas temperature ranges from 600 – 900 °C.

What is thermoelectricity?

Thermoelectric materials convert heat flows into electric currents. This mechanism of action is based on the »Seebeck effect« discovered by Thomas Johann Seebeck in 1822. For decades, the technology has been used for the supply of electric power in space probes. Thermoelectric generators (TEG) can already produce electricity from small temperature differences. They do not produce emissions, are noise- and vibration-free, and require no maintenance. In addition, TEG are scalable and easy to retrofit. State-of-the-art TEG can be used for a broad spectrum of applications in the context of waste heat utilization – ranging from recovering energy in automobiles, power plants and industrial processes up to central heating in residential buildings.

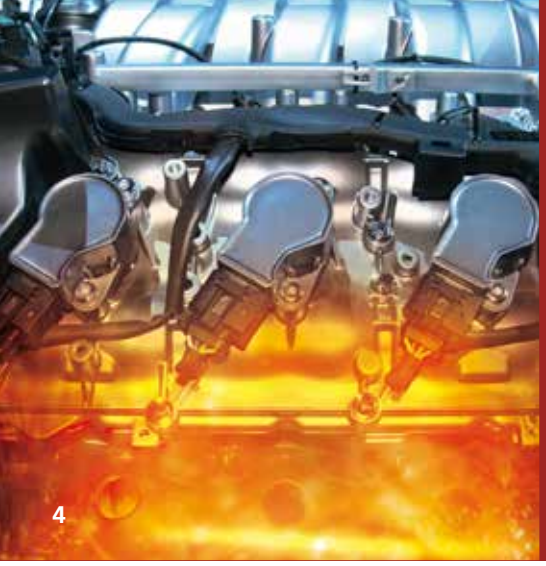
Applications

While it was previously only possible to thermoelectrically generate energy up to just a few watts (e.g. for self-powered sensors), systems in the kilowatt range are already feasible today. In the future, thermoelectric generators will achieve even higher outputs and will be even more

Fraunhofer Institute for Physical Measurement Techniques IPM
Georges-Köhler-Allee 301
79110 Freiburg, Germany

Contact
Dr Jan D. König
Thermoelectrics
Phone +49 761 8857-329
jan.koenig@ipm.fraunhofer.de

www.ipm.fraunhofer.de/en



cost-efficient due to improved production processes.

In the context of the energy transition in Germany, the waste heat market needs to be efficiently utilized through the use of thermoelectrics, along with new solar and wind energy sources. The innovative high-temperature generators from Fraunhofer IPM, which are already being used by industry partners, generate power densities of more than 1 W/cm². Moreover, new thermoelectric materials and processing methods are providing additional impetus to this research field. The three application scenarios presented below illustrate the substantial advantages that thermoelectrics can offer for combined heat and power plants or private households, for example.

4 *Thermoelectric generators are already being tested in the automotive industry.*
5 *Thermoelectrics can increase the electrical output of a combined heat and power plant by up to 3%.*
6 *Private households can generate 600 kWh yearly by using thermoelectric modules. At present, that equals savings of about 140 euros.*

Fuel savings with thermoelectrics in the car

In the »HeatReCar« project funded by the European Union, it has succeeded in producing 500 watts of electrical energy from the exhaust gas of a small transport van. In the »New European Driving Cycle« (NEDC), the thermoelectric generator achieved a fuel saving of 2.2%, which is equivalent to a saving in CO_2 emissions of 6.7 g/km. In the globally standardized cycle »Worldwide Harmonized Light Duty Test Procedure« (WLTP) fuel savings amounted to as much as 3.9% and the reduction in CO_2 emissions achieved was 9.6 g/km.

The developments of Fraunhofer IPM and partners from industry and research are a significant contribution for industrial applications with thermoelectric systems and the associated improvement of energy efficiency.

Thermoelectrically optimized combined heat and power plants

Combined heat and power plants (CHPP) are an essential component of the energy transition in Germany. They can reduce primary energy use by 40% and in modern electrical networks, they are a valuable operating reserve for balancing the volatility of renewable energies.The use of TEG at the waste gas heat exchanger can increase the electrical output of a CHPP by up to 3 % (at the expense of the heat generation). At a typical combined heat and power plant with 50 kW_{el}, a gas consumption of 145 kW and an overall efficiency rate of 90%, this would yield an additional electrical output of up to 1.5 kW. With a presumed operating time of 90 % per year, that corresponds to about 9000 kWh/a and reduces annual electricity costs by € 2600 (at 28,7 eurocents/kWh, www.bdew.de).

Central heating with thermoelectric generators

Almost all single family houses have a central heating system. Depending on the size of the house, about 20,000 kWh/a of primary energy is converted into heat in these homes.

If thermoelectric modules are used at the boiler of the heating system to convert 3% of the accumulated heat into electricity, an additional 600 kWh/a of electrical output would be available for the household – especially in the cold seasons, which is the peak load time for the electrical grid. At an assumed electricity price of 28,7 eurocents/kWh (less 6 eurocents/kWh for the primary energy), that corresponds to a reduction of energy costs of around € 140 per household.