< Equipped with a thermoelectric generator, heating stoves could in future deliver not just warmth, but also electric power, which can be used for control engineering or smart home applications.

GROUP **CALORICS AND THERMOELECTRICS**

Nano-CHPP: Power from the stove

In the future, thermoelectric elements will help to convert waste heat from tiled stoves and other heating stoves into electric power. It will thus be possible to equip them with electrical control engineering and integrate them into smart home systems. Targeted combustion control would also bring about dramatic reductions in emissions from small furnaces.

In the future, fireplaces and stoves could deliver more than just comforting warmth: namely, electric power. This will become possible thanks to thermoelectric generators (TEGs) that convert heat into electricity. To date, TEGs have gained a market foothold in several niche applications, but are only suitable for use at maximum operating temperatures between 250 and 300 °C. However, temperatures of over 500 °C and direct integration within combustion chambers are possible with the TEGs developed at Fraunhofer IPM. This will make it possible to turn small furnaces into small-scale power plants generating both heat and electricity – nano-CHPPs.

The high-temperature TEGs are made from half-Heusler alloys. Individual thermoelectric modules are connected to form larger assemblies. These achieve surface power densities of up to 1.5 watts per square centimeter, and their efficiency is five percent. It is consequently possible to utilize these TEGs in stoves with even low outputs of just four kilowatts; i.e. even when only the embers are glowing. Electricity yields are particularly high in tiled stoves that are connected to a heating circuit as a heating system support. Here, the TEGs can be installed between the hot combustion chamber and the cool water pipe in the outer shell of the stove. This results in a large temperature difference, which increases efficiency.

Self-powered, smartly connected and low in emissions

Power generated in this way can be used for many different purposes: To supply small electric appliances, or the measurement and control technology that regulates operation and optimizes combustion, as well as to integrate the stove into a smart home system. Even slight drops in temperature are sufficient to cover the energy needs of approximately 10 to 50 watts. If more electricity is produced, it can also be used to charge smartphones, for example, or power LED lighting. Surplus electricity can be stored temporarily in batteries to ensure a continuous power supply.

In areas where there is no nationwide electricity supply but wood is generally abundant, for example in parts of Canada or Scandinavia, small furnaces could therefore be fitted with electric control units in the future. And pellet boilers could also regulate pellet feeding independently without connection to a power source, or control their heating output via room thermostats. It will also be possible to integrate tiled stoves, which previously generated heat in a completely unregulated way, into smart home systems alongside lighting, heating and ventilation technology. Equipped with a TEG and a small control module, fireplaces will be able to signal the ideal time to add more logs as the room temperature drops, or shut down the heating system as soon as the temperature exceeds a pre-determined threshold.

Fitting small furnaces with TEG technology will also contribute to reducing emissions in coming years. The power generated can be used to optimize the combustion process with the help of measurement and control technology. The control module comprises all the sensors (e.g. temperature sensor, Lambda probe) and actuators required for this. Employing simple sensor technology, it is capable of recognizing different operating states and, based on this information, of adapting the system's airflow to match requirements via a fan or an automated damper.

Promising tests: TEGs in micro-CHPPs

Finally, operation of a TEG has been tested in a small combined heat and power plant in Braunschweig. This pilot experiment using a commercial bismuth telluride TEG yielded promising results. The modules proved to be stable and delivered up to 500 watts of power – enough to supply an entire building with electricity. There are plans to conduct a further trial with half-Heusler modules in a local CHPP. Here, the aim is for the modules to convert waste heat at temperatures of up to around 500 °C into electricity. In the future, the modules could then be used in furnaces for single-family homes, where they would generate power from heat.

HEUSLER ALLOYS are named after the German chemist and engineer Friedrich Heusler, who in 1903 was the first to describe the effect whereby mixing the three non-magnetic metals copper, manganese and aluminum gives an alloy that has ferromagnetic properties. Half-Heusler compounds are alloys derived from this mixture which, although not ferromagnetic, have semiconducting properties. Fraunhofer IPM's research has proven that these half-Heusler alloys are sufficiently robust for high-temperature applications.

Fitting small furnaces with a thermoelectric high-temperature generator will in future provide enough electric power for small regulators that signal the right time to add more logs or optimize air intake.

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