Achieving optimal efficiencies for nanoengines

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(PhysOrg.com) -- "There's a lot of recent interest in understanding the functioning and optimal performance of small systems," Katja Lindenberg tells *PhysOrg.com*. Lindenberg is a scientist in the Department of Chemistry and Biochemistry and the Institute for Nonlinear Science at the University of California, San Diego, in La Jolla. Along with Massimiliano Esposito, also at the Institute, and Christian Van den Broeck at Hasselt University in Diepenbeek, Belgium, Lindenberg has been studying the efficiency of very small thermochemical engines.

"Thermodynamics applied to small systems is different from what we are used to," Lindenberg continues. “It’s a relatively new field, and we are trying to understand optimal performance criteria.” The results of an investigation by Lindenberg, Esposito and Van den Broeck into power generation by small thermochemical engines is presented in Physical Review Letters: “Universality of Efficiency at Maximum Power.”

Lindenberg explains that “maximum efficiency is achieved only near equilibrium, where the power output is very small. Instead of focusing on maximum efficiency alone, we are studying how to achieve maximum possible efficiency at maximum power.”

Esposito says that in order to explore the general rules that govern performance at maximum power, a general single framework is needed - one that can encompass many systems that on the surface appear very different from one another. “The systems of interest all produce a workflow, or power, fueled by a heat flow through the system generated by a temperature gradient," he says. "Optimal efficiency at maximum power is obtained when the heat and work fluxes are strongly coupled. For instance, if the workflow is a flow of particles against a chemical potential gradient, strong coupling occurs when the only carriers of heat are the same particles."

"This strong coupling between the work and heat flows is a natural feature of small systems — nanosystems," Esposito continues, "but would be difficult or impossible to achieve in a macroscopic system." The team has illustrated this concept in a paper appearing in *Europhysics Letters*, in which they consider electrons flowing through a quantum dot.

Both Lindenberg and Esposito emphasize that, so far, their work is purely theoretical and only illustrated in model systems. "It might be difficult to build a device that satisfies the conditions we have set out," Lindenberg admits, "but on a fundamental level it gives a conceptual basis for what is possible. It provides an idea of what the ultimate goal would be when it comes time to design a device."

What sort of devices might be possible? Like many theorists, Esposito and Lindenberg hesitate to prognosticate. However, Esposito mentions at least one idea regarding the use of thermochemical engines: "Perhaps a device could be created to recover the energy from heat loss in a car's engine."

For now, though, work moves forward in trying to understand small systems and their properties. "With continued interest in the smallest of systems," Esposito points out, "it is increasingly important to learn how one can use extremely small systems to achieve optimal efficiencies at maximum power."

More information:

Esposito, Lindenberg and Van den Broeck, "Universality of Efficiency at Maximum Power." *Physical Review Letter*s (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.130602 .

Esposito, Lindenberg and Van den Broeck, "Thermoelectric efficiency at maximum power in a quantum dot." *Europhysics Letters* (2009). Available online: www.iop.org/EJ/abstract/0295-5075/85/6/60010/ .