Teasing Energy from Zero-Point Fluctuations

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For generations people have devised schemes to extract energy from random fluctuations. With the advent of thermodynamics, its second law dictated that energy could not be extracted if the fluctuations were in equilibrium with their surroundings. This did not stop Maxwell from trying to do so in 1871. He famously devised a demon who used his intelligence to admit fluctuations passing in one direction but block those going in the other, so as to provide a net energy flow. After some analysis the poor demon was shown to be a fraud, but that did not stop generations of physicists from devising new demons, none of whom has done even a thimbleful of useful work using ambient thermal energy.[1] Ratchets do not work in systems in equilibrium.

Nearly 100 years ago Planck[2] and others showed that ambient fluctuations were not only thermal in origin, but also had a non-thermal component. This non-thermal zero-point energy (ZPE) became a central part of quantum mechanics. As with thermal energy, ZPE exists in space itself – in the form of electromagnetic energy – as well as in matter. In 1948 Casimir predicted that this ZPE could produce measurable forces between two closely spaced plates forming cavities. As ZPE entered the vernacular, schemes to harvest these fluctuations were developed. These included using the attractive force between the plates of Casimir cavities,[3, 4] applying resonators to down-convert ZPE to usable frequencies,[5] and employing diodes to rectify the ambient ZPE.[6]

All of these harvesting schemes are variations on Maxwell's demon. They attempt to ratchet ambient energy. In 1917 Einstein showed by a detailed balance argument that no asymmetry can exist in the rates of energy flowing between two points in a system in

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[1] There are certainly claims to the contrary, such as the Moray valve, but they have not been reproduced successfully, to my knowledge.

[2] See, for example, M. A. B. Whitaker, "Planck's first and second theories and the correspondence principle," Eur. J. Phys. 6, 266-270 (1985).

[3] R. Forward, "Extracting electrical energy from the vacuum by cohesion of charged foliated conductors," Phys. Rev. B, 30, 1700, 1984,

[4] F. Pinto, "Engine cycle of an optically controlled vacuum energy transducer," Phys. Rev. B **60** 14,740-14,755 (1999).

[5] F. B. Mead, "System for converting electromagnetic radiation energy to electrical energy," U.S. Patent No. 5,590,031, issued 1996.

[6] T.F. Valone, "Proposed Use of Zero Bias Diode Arrays as Thermal Electric Noise Rectifiers and Non-Thermal Energy Harvesters," Proc. Space, Propulsion and Energy Sciences International Forum (SPESIF), Workshop on Future Energy Sources, AIP, Huntsville, AL, Feb. 24, 2009, pp. 1-19.

equilibrium.[7] This detailed balance argument applies as heartlessly to these ZPE harvesting methods as to Einstein's radiation emitted and absorbed by atoms.

One hope lies in the fact that ZPE is not a constant in the universe, but as Puthoff wrote in 1990,[8] changes with boundary conditions. One can reduce the ZPE density in a Casimir cavity, and make use of that region of lower ZPE density to tease energy from the ambient ZPE. That concept lies behind a recently proposed method to extract ZPE from gas flowing through a Casimir cavity.[9]

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[7] See, for example, L. Couture and R. Zitoun, *Statistical thermodynamics and properties of matter*, translated by E. Geissler (Overseas Publishers, Amsterdam, 2000), p. 229.
[8] H.E. Puthoff, "The energetic vacuum: implications for energy research," Speculations in Sci. and Tech, 13, 247-257 (1990).
[9] "Quantum vacuum energy extraction ," Bernard Haisch and Garret Moddel, U.S. Patent No. 7,379,286, issued 2008.