# Available energy and turbulence in magnetised plasmas

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**Abstract.** In this talk, I shall present work on a concept closely related to the thermodynamic notion of free energy, and discuss how it can shed light on turbulence. Any plasma possesses some "available" energy, an upper bound on the amount of thermal energy that may be converted into flows or electrostatic fluctuations. Gardner [1] investigated this energy for a Vlasov plasma already in 1963, and concluded that monotonically decreasing distribution functions of particle energy are stable. The concept becomes more interesting and useful for magnetised plasmas if the constancy of *adiabtic invariants* is taken into account [2]. For example, invoking the constancy of the magnetic moment and the parallel invariant results in a non-trivial expression for the available energy of trapped electrons, which can be used to estimate turbulence levels for trapped-electron-mode-driven turbulence in magnetic-confinement fusion devices. This allows one to assess how the magnetic geometry, e.g. the triangularity of a tokamak or the shape of a stellarator, affects the turbulence. I will furthermore show that choosing another set of invariants makes available energy relevant for ion-temperature-gradient driven turbulence. Finally, I will discuss the relation between available energy and the Helmholtz free energy, which is often considered in plasma turbulence research and plays an important role in classical thermodynamics.

## References

[1] C. S. Gardner, "Bound on the Energy Available from a Plasma," *The Physics of Fluids*, vol. 6, pp. 839–840, June 1963. Publisher: American Institute of Physics.

[2] P. Helander, "Available energy and ground states of collisionless plasmas," *Journal of Plasma Physics*, vol. 83, Aug. 2017. Publisher: Cambridge University Press.