Magnetic materials for efficient energy conversion

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High performance hard and soft magnets are key components of energy-related technologies, such as direct drive wind turbines and e-mobility. They are also important in robotics and automatization, sensors, actuators, and information technology. The magnetocaloric effect (MCE) is the key for new and disruptive solid state-based refrigeration. Magnetic hysteresis – and its inherent energy product - characterises the performance of all magnetic materials. Despite considerable progress in the modelling, characterisation and synthesis of magnetic materials, hysteresis is a long-studied phenomenon that is still far from being completely understood. Discrepancies between intrinsic and extrinsic magnetic properties remain an open challenge, the so-called Brown´s paradox, and magnets do not operate yet at their physical limits. Basic material requirements, figure of merits, demand and supply, criticality of strategic elements are explained for both permanent magnets and magnetocalorics referring to the benchmark materials NdFeB and LaFeSi. New research avenues given by compositionally complex alloys (CCA), where the duality or unusual combinations of functional and mechanical properties can be explored, will be elucidated looking at soft magnetic materials. The search for perfect defects is driving the material design strategy.