# Social energy: a useful concept for analyzing complex social systems?

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This text collects some ideas for an exploratory workshop to further the development of the social energy concept. It shall serve as a basis for proposing a Satellite Meeting at the European Conference of Complex Systems 2011 (see http://eccs2011.eu/). Comments are welcome to sarah.wolf@pik-potsdam.de or on the blog.

Energy, as used in physics, is a concept that specifies a capacity to do some work. It appears in various forms (internal energy, free energy etc.), describing characteristics of a system. Mathematical representations of energy occur in formal models which provide precise descriptions of the system under consideration. Given that in mathematical language operations can be performed with the symbols used in these descriptions, the mathematical model at the same time is a tool for analysing the system's behaviour over time – its dynamics. Energy is thus a measurable characteristic of a physical system that helps understand system behaviour.

In everyday language, the concept energy is used in a related but much broader sense: electricity and heating are forms of energy that are closer to the physics interpretation of the term, but also people may have energy. They can for example feel "full of energy" or be "bursting with energy". Here, the concept expresses a drive, which includes not only a capacity but also a willingness to do something.

The idea of "social energy" comprises elements from both fields just described. On the one hand, in analogy to the term energy in physics, "social energy" is intended to foster a better understanding of the behaviour of the systems under consideration. On the other hand, since the concept refers to social systems, one needs a broader interpretation of the term energy than in physics. Social energy sets a broader frame in which to develop models that facilitate thinking about SESs and their dynamics.

Socio-ecological systems are complex systems in the sense that a single description from one point of view is generally not sufficient. Several descriptions from different perspectives may be necessary to capture their essential features, and some of these descriptions may seem contradictory in the sense that they cannot be usefully summarized into a common domain of discourse. This is due to the fact that, depending on the perspective chosen and the domain of discourse adopted for speaking from that perspective, different interactions between (different) parts of a system may be relevant. For example, a community may be described as a group of individuals, related to each other in a network of personal acquaintances, or as a set of institutions related by certain power structures. The relations at the different levels need not be consistent with each other.

To analyze the dynamics of a socio-ecological system, first of all, a representation of that system is needed. Two prominent representation tools are narratives and agent-based models.

Narratives play a fundamental role in representing essential features of SESs. For the past evolution of a given social system, the historical sciences probably give the best accounts, and, for example, many typical situations in human emotional interaction are probably modelled much better by Shakespeare's works than by statistics. However, narratives and other system descriptions from a social science perspective are mostly given in natural language, that is, using ordinary language possibly interleaved with technical terms. In contrast to mathematical language, this does not provide the opportunity to analyse a system's dynamics by solving an equation or iterating a dynamical system etc.

Iteration is possible in agent-based (or multi-agent) modelling, a computational approach to investigating the dynamics of complex systems. Here, the representation of the system is restricted to a micro-level. In a computer, the individual parts constituting the system are represented as agents and equipped with rules for interaction. The macro-level can then be observed by running simulations, that is, repeatedly iterating interactions between the agents. Each run shows a specific instance of possible dynamics of the system. While agent-based models are valuable tools for generating ideas, they generally contain far too many variables for the human mind to keep track off, so that a thorough understanding of what happens in the model is hard to obtain. The dynamical system represented by the implementation of the model remains implicit; practically, assembling the system's state out of many agents' state variables and its transition function out of their interactions is rarely feasible.

In economics, agent-based models are used to overcome specific shortcomings of standard neoclassical models: these compute a single "equilibrium" (out of several theoretically possible ones) under narrow assumptions, and they are static, that is, they do not provide information about the dynamics of the system. Regime shifts, for example from a growing economy into a crisis, can thus not be represented in the standard models – whereas they could be interpreted as transitions from one equilibrium to another one in the underlying theory.

Both narratives and agent-based models describe system dynamics by linking the micro- and macro-level. In addition to this, the concept "social energy" aims at further combining the focus on gaining a thorough understanding about the system as a whole (from narratives) with the formal approach (from agent-based models). By paving ways for drawing on mathematics similar to some models used in physics, social energy sets a frame for identifying parameters to be used in models that help analyze SESs. Regime shifts in SESs (not only economic systems) and the energy needed to induce them or gained from having made such a transition are a topic of special interest where the analogy with physical systems seems promising.

Some examples of mathematical models that can be located into the social energy frame can be found in an economics context. In fact, the research area of econophysics shows some overlap with the proposed ideas.

- Wyart and Bouchaud [2007] model self-referential stock prices using a system with several meta-stable states. Their model explains regime shifts in correlations (positive or negative) between some information index and stock prices observed in data. The actions of chartist agents who base their decisions about buying or selling stocks on alleged correlations actually create these correlations. Feedback in the system thus triggers transitions; the "social energy" for making such a transition originates from the collective, without the single agents aiming at the transitions.

- Grauwin et al. [2009, 2010] compare individual dynamics as usually considered in economics with collective dynamics, standard in physics. They link the two types of dynamics by introducing a function that can be interpreted as a potential function, expressing a capacity of the system, which could be interpreted as "social energy". The link function paves the way towards analytical investigation of economic models from game theory, that can be seen as agent-based models.

- Wolf [2010] propose to model win-win options in climate policy – such as green growth, assessed from a practical perspective by Jaeger et al. [2010] – as regime shifts in a potential landscape.

- Ruiz de Elvira [2010] proposes to model wealth creation as determined by energy flows, considering how energy is embodied and stored.

- A global social energy landscape can be interpreted as a distribution of capital and labour around the planet.

Each of these examples adds some aspects to the social energy concept. However, the focus of this concept is broader: not only economic, but more generally social-ecological systems are of interest. Areas where a social energy concept can be quite naturally applied are, for example, risk management and climate change adaptation. In these fields, the notions of capacity and resilience play important roles. Analyzing these before the background of analogies with concepts from physics may be very helpful.

Also, social energy is not restricted to the methodology of finding social context interpretations for equations used in physics models. The ideas encapsulated in the physics concepts can in themselves be useful sources of inspiration for modelling social systems. To mention just one example, the concept of Helmholtz free energy includes an entropic term. Information – be it how much information agents in a system have, or how information structures in a society are set up and may change – is certainly an interesting variable for understanding the energy available in the society to make some transition.

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