Title: designing an energy scarce world – call for transition engineering

The history of society and the economy is strongly influenced by the energy supply available for a certain generation. Originally, development and progress was constrained by the availability and conversion of sunlight by photosynthesis. With the extraction of fossil fuels, sunlight concentrated over millions of years in natural processes became available in much shorter time scales. Finally, the invention of heat and combustion engines and their steadily improving efficiencies propelled the industrialisation and enabled the tremendous increase in economic activity seen until today (Kander et al. 2014). Though mostly neglected in economic theory, energy is the production factor mainly responsible for the economic growth of the last decades (Kümmel 2011).

Energy use is nowadays strongly coupled with the extraction of natural ressources and emissions of pollutant particles and heat. The emissions are unavoidable on condition that basic laws of thermodynamics apply and have strong negative impact on ecosystems and climate (Kümmel 2011). This way, we already passed the "planetary boundaries" and left the "safe operating space for humanity" (Rockström 2009). The Earth Overshoot Day on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year was claimed to be on August 20 in 2013. We risk to lose the ability for regeneration of our ecosystems, which caused many well-developed societies to collapse (Diamond 2005). Engineered systems such as oil-rigs and power stations are responsible for the greatest risks to the environment.

From the ressource perspective, the imminent "Peak Oil" has been replaced by "Peak Everything" (Heinberg 2007), indicating the vulnerability of our societies to material and energy supply. Our agriculture needs an energy input of 10 joule in terms of fertilizers, pesticide and fuel for an outcome of 1 joule nutrition (Pimentel/ Henry 1994). The energy return on energy invested (EROI) for fossil fuels is much better, but declining: The expenditure of extracting the materials eat up a growing portion of the extracted yield causing net energy available for other economic activity to drop (Dale et al. 2011, 2012).

While we have benefitted from economic growth in the last decades and mostly still expect further growth, we in reality are facing a big crisis. Society has to face the question how to reduce demand while ensuring prosperity. Green technology and energy efficiency are important, but will on no account allow for continuing growth of economic activity while saving the planet. Engineers should therefore focus on the sustainability of the whole concepts instead of optimizing the energetic efficiency of bad habits: electric cars will not allow us to continue the ongoing process of urban sprawl and land use change.

A transition roadmap for engineers starts with observation the of past trends and the current state. Scenarios can be used to project possible future developments and necessary technological developments for each setting. This shrinks the phase space for feasible sustainability and may lead to a realistic vision. In the fifth step, core differences between vision and current system and has to be identified including barriers, opportunities and benefits of different change routes. It follows the detection of decision points and triggers for change that will finally start the process of transition. (Krumdieck 2013)

Transition Engineering aims to re-focus the inventive and the facilitative intent of the professional engineers in every field to the problem of re-designing and re-developing all fossil fuel consuming systems to use less fuel. The goal is to "make things work" on long timescales and to offer feasible alternatives and a strong impetus towards change.

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