Title: Sustainability potential evaluation and modeling of energy matrices using life cycle approach

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Abstract

The thesis first introduces world energy use and environmental situation. The role of energy usage, its contribution to mankind's welfare is also discussed. Most important existing tools for energy use modeling and planning policies are summarized, evaluating their contribution to a future sustainable energy matrix. A literature review on the sustainability issue and its quantification is conducted. Various general sustainability definitions are discussed as well as their derivations for energy sustainability quantification. Basic principles for energy sustainability are established and a diagram depicting energy sub-sphere role on general sustainability is proposed.

The thesis introduces an exergy life cycle indicator for evaluating sustainability potential of energy routes and energy matrixes. All elements integrating the indicator are discussed and their foreseeable implications are evaluated. The indicator is tested in a case study where energy routes leading to different final products are evaluated.

Suitability of using the indirect life cycle exergy cost (k_T) as a potential for economic development is assessed. The relation between traditional energy sources and its high Exergetic Return of Investment (ERO) and short periods of exergy payback, both depending of k_T is demonstrated. In order to calculate the EROI using the Ecoinvent database. The EROI concept is adapted to the Life Cycle Analysis (LCA) framework. The suitability of using non-renewable life cycle exergy cost (k_{nr}) as environmental indicator is assessed also. The relation between k_{nr} and all three weighting variants of Ecoindicator99 is evaluated. On this regard it is found that whenever k_{nr} decreases, so does the EI99 egalitarian weighting variant in all cases.

Finally a life cycle modeling approach is introduced to depict actual demand of energy or energy intensive products delivered within a system (electricity, heat, etc.), and to optimize the energy mix, according to any of the available life cycle impact assessments (LCIA). Future scenarios are obtained for the Belgian electricity mix and partial mix of heat with and without nuclear energy phase out, considering the possibility of using of natural gas, biomass for cogeneration, wind power and solar photovoltaic energy.

From the thesis results it is concluded that the proposed indicator leads to energy alternatives with the potential of reducing environmental impact at the lowest indirect life cycle exergy cost, i.e. with the highest exergy surplus. Besides, it was found that nuclear energy, biomass energy, and wind energy would play an important role in the GWP reduction effort. However, issues like rising of human toxicity impact via air and land, as well as climbing of land occupation for energy use, should be addressed.