From Primary to Useful Energy: energy transitions in Denmark 1870-2013

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Overview

Energy efficiency is a key concern for policy-makers. In the last decades, it has been considered the main offsetting factor of rising global energy consumption and CO_2 emissions. But its importance has let itself been felt since the beginning of industrialization (Henriques and Borowiecki, 2017). Although the effects of energy efficiency have been remarkable throughout modern history, there is disagreement on how to account for energy technological change.

Economic measures of efficiency, such as primary energy per value added (energy intensity) are normally used as a proxy of efficiency, but this has been criticized by some for not capturing adequately how productively energy is used within the economy. Certain resource economists (e.g. Ayres and Warr 2009) have turned to the concept of 'useful exergy', which addresses this shortcoming by focusing on what energy is used for, i.e. energy services (e.g. the heat actually provided to a room, or light, or motion) rather than where it comes from, i.e. energy carriers, enabling accounting for the engineering efficiency of different energy uses. Warr et al (2010) applied 'useful exergy' methodology to the study of long-run energy transitions in four countries (Japan, Austria, US and UK) and found that aggregated primary energy to 'useful exergy' efficiencies increased significantly in the last century, but stabilized after the first oil crisis. Moroever, they found that while long-run primary energy intensities exhibited a secular decline, 'useful exergy' intensities increased in all economies until the oil crisis, and declined thereafter. Additionally in a series of modeling exercises (e.g. Ayres and Warr 2009) the authors have also demonstrated that, by incorporating useful exergy as a primary factor of production, it is possible to explain growth without resorting to an exogenous multiplier, such as the Solow residual. This project aims to investigate energy transitions in Denmark throught the construction of a long-run database on long-run energy uses which captures the energy efficiency gains along the energy system for Denmark in the period 1870-2013. Aditionaly, we will investigate the role of long-run exergy efficiency as a driver of CO_2 emissions in Denmark vis a vis other factors.

Methods

´Useful exergy' accounting comprises four steps (Ayres et al. 2003; Serrenho et al. 2016): 1) Collecting primary and final energy at the aggregate and sectoral level; 2) Allocation of the final energy consumption in each economic sector to useful work categories (heat, light, mechanical work and muscle work and other electric uses); 3) Gathering historical efficiencies for each final to useful transformation and 4) calculation of overall 'useful exergy' index.

Results

A first analysis of the data obtained shows that results are sensitive to methodological choices, such as the use of different proxies for high-temperature heat energy efficiencies, application (or not) of 2nd law efficiency for electrical uses and differences in how to account for exergy efficiency of muscle work. A more complete analysis will allow us to gain important insights on past energy transitions in Denmark. Of special interest is the analysis of the long-run evolution of useful exergy intensity in comparison with the primary energy intensity figures (Henriques and Borowiecki, 2017). How efficient did Denmark become during her historical transition from an agrarian to a service society? Can a peak in the evolution of long-run efficiency (Useful Exergy/ Primary Exergy) and a downward trend in useful work intensity (Useful Exergy/GDP) be observed as for the four countries studied by Warr et al. (2010)?

Conclusions

In the case that the results for Denmark confirm the trend for the 4 countries the hypothesis conclusion in Kander et al (2013) that energy services are less important as driver of economic growth in advanced countries after 1970, will be strengthened. If this is the case the shift to a low and renewable energy society woud be compatible with further economic growth.