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The process of industrialization from the perspective of energetic metabolism Socioeconomic energy flows in Austria 1830–1995

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Abstract

This paper empirically analyzes the socioeconomic energy metabolism of Austria in the period 1830–1995. During this period Austria underwent a transition from being a largely agricultural society to being an industrial society. We describe the changes associated with this transition in terms of the 'physical economy,' or more precisely, in terms of changes in the throughput of energy, assessed in physical units (J per year). In accordance with currently used methods of material flow accounting (MFA), we define the indicators 'direct input' and 'domestic consumption' with respect to socioeconomic energy flows. Using these indicators, we analyze the transition from 1830, at which time biomass provided more than 99% of Austria's domestic energy consumption (DEC), to 1995, when biomass accounted for 30% and fossil energy for 60% of DEC. Total DEC in Austria increased by a factor of 6 in this period. The paper discusses the relevance of these changes for processes of interaction between society and its natural environment, focusing on the interrelations between energy metabolism and changes in land use.

Keywords: Socioeconomic metabolism; Energy flow accounting (EFA); Land use and land cover change; Human appropriation of net primary production (HANPP); Biophysical indicators

1. Introduction

Conceptualizing the economy as a physical process is a central aim of the emerging interdisciplinary field of ecological economics. For example, in his seminal book *Ecological Economics* Joan Martinéz-Alier heavily criticized the 'chrematistic' orientation of the current economic mainstream and pleaded for an approach that takes the material and energetic aspects of economic processes into account (Martinez-Alier, 1987). A predominant approach to analyzing the physical economy is the concept of 'socioeconomic metabolism' (more narrowly termed 'industrial metabolism'; Ayres and Simonis, 1994). The basic idea of socioeconomic metabolism can be traced back to Marx; today, the metabolism concept is a cornerstone of research into the 'human

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dimensions' of environmental change (for reviews, see Fischer-Kowalski, 1998; Fischer-Kowalski and Hüttler, 1998). Prominent economists, including Kenneth Boulding and Robert Ayres, re-invented the concept in the late 1960s and early 1970s and elaborated the first empirical analyses of the material flows of a national economy (Ayres and Kneese, 1969; Boulding, 1973). Today, international standards for national material flow accounting (MFA) are being developed (e.g. Adriaanse et al., 1997; Bringezu et al., 1997; Matthews et al., 2000, Eurostat, 2001).

Analyses of socioeconomic energy flows figure prominently in the work leading up to today's metabolism research (Martinez-Alier, 1987). In contrast, material flows build the focus of current metabolism studies. This may be due to the fact that socioeconomic energy flows are commonly reported in energy statistics, so that the need for research has seemed less urgent in this field. However, the energy statistics published by national statistical offices (e.g. Bittermann, 1999) or international bodies (IEA, 1992, 1995; UN, 1997) cover only the energy used in 'technical' energy conversions—that is, the production of heat, power and light in technical processes (e.g. internal combustion machines, furnaces, electric devices). Neither the uptake of nutritional energy by humans and domesticated animals, nor the production of energy by their muscular activity are accounted for in energy statistics (Haberl, 1997a). In other words, biomass is accounted for in energy statistics only if it is used as fuel for heat or electricity production.

The shortcomings of such an approach become evident in analyses of agricultural societies, which rely strongly on muscular energy for the provision of mechanical energy, with the noteworthy exceptions of the use of windmills, water-mills and sailboats (Smil, 1992, 1994). Human ecologists, ecological anthropologists and the economists whom Martinez-Alier (1987) describes as the forerunners of modern ecological-economical thought have been using such a broader notion of socioeconomic energy flows for a long time (e.g. Boyden, 1992; Giampietro and Pimentel, 1991; Giampietro et al., 1992; Giampietro and Pimentel, 1990; Kemp, 1971; Odum, 1971; Pimentel et al., 1973). In analyzing the energy system's transition in the course of industrialization, it must then be seen as insufficient to restrict the analysis to heat and power production (e.g. Fouquet and Pearson, 1998). However well researched such analyses may be, their narrow focus covers up rather than clarifies the relevant transition processes at hand.

Therefore, we will first propose a method to account for the energetic metabolism of societies, and in a second step we will use this method for an appraisal of energy flows in the Austrian economy during the last 170 years. This empirical analysis will form the basis for a discussion of shifts in sustainability problems during the transition from a largely agricultural economy to the still quickly industrializing Austrian economy of today.

In this discussion, we are guided by the following questions: how did socioeconomic energy metabolism and the significance of biomass in the socioeconomic energy system change during this transition process? What can we learn from the historical process for future development? We address these questions based upon empirical evidence and an analysis of important aspects of the development of the socioeconomic energy metabolism. We will present a quantitative analysis of the socioeconomic energy metabolism of Austria (in its current boundaries) in a time series from 1830 to 1998, and relate these results to figures for the development of domestic energy consumption (DEC) in Austria. In addition, we will use these figures to discuss the significance of the changes in Austria's energy metabolism for society-environment interrelations—especially with respect to land use—during industrialization.

2. Concepts and methods

2.1. The concept of socioeconomic metabolism

In analogy to the biological notion of metabolism, the concept of socioeconomic metabolism describes physical exchange processes (i.e. material and energy flows) between human societies and their natural environment as well as