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Environmental impact of personal consumption from life cycle perspective – A Czech Republic case study

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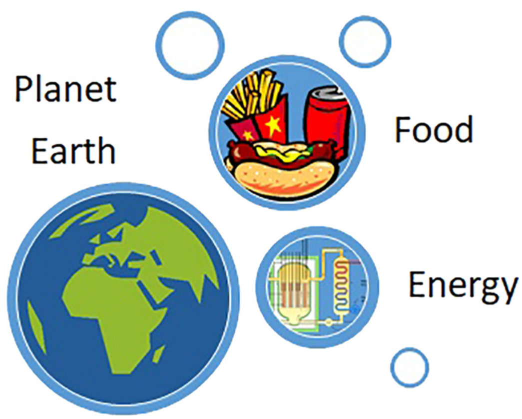
HIGHLIGHTS

- The ecological crisis is linked to growing population and consumption.
- Effective change of personal consumption patterns is necessary for sustainability.
- Proposal of LCA as a tool for calculation of personal environmental impact
- Energy consumption and food consumption show the biggest environmental impact.
- Diet change shows highest potential for the environmental impact reduction.

GRAPHICAL ABSTRACT



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ABSTRACT

The impact of human civilization on the environment is now obvious. With the rapidly growing human population, the problem of human consumption becomes more and more urgent. It is therefore necessary to try to change the patterns of human life and find a more sustainable way of living. To achieve the goal of sustainable society efficiently, it is crucial to identify hot spots for possible impact reduction. Even though several tools now exist, such as footprint calculators, they usually have a narrow perspective, calculating impact only on a single environmental problem. In this study, the Life Cycle Assessment (LCA) method was employed, to measure the environmental impact of human consumption across the entire life-cycle as well as a wide range of impact categories. The use of LCA to identify the major problems of personal consumption is presented in a case study of an average inhabitant of the Czech Republic. Data of average personal consumption were collected and an LCA model was created in GaBi 8 software. Characterization results, obtained using ReCiPe 2016 (E) methodology, show the environmentally dominant segments of consumption which are: household energy consumption – where the dominant process is heating; and food consumption – where the dominant processes are meat and dairy production. This study provides a thorough impact analysis and identifies the hots spots, where actions should be taken. The results provide the necessary basic data for policy-makers, so that steps to reduce individual personal environmental impact can be taken.

1. Introduction

Our planet is now facing tremendous environmental pressures. The impact of human civilization is apparent all over the globe, observable

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over all marine and continental ecosystems (Pachauri and Meyer, 2015). Climate change and ecosystem biodiversity loss are among the greatest problems humanity is currently facing. The events of habitat degradation and species extinction are taking place within an unprecedentedly short timescale (Novacek and Cleland, 2001). Personal consumption is among the greatest contributors affecting global environment. With the rapidly growing human population – from less than one billion humans 200 years ago (Max Roser, 2018), at over 7,6 billion people now (Worldometers.info, 2018), to the predicted 9 billion in 2050 (Valdivia et al., 2013) – this impact is expected to become even larger. Since the population growth is taking place predominantly in developing countries, the demand for basic human needs such as food water and shelter will have to be met (Valdivia et al., 2013). But unfortunately, the capacity of our planet to meet these requirements is not unlimited (Goldstein et al., 2013). Meeting these needs, while preserving a healthy environment, is probably the biggest challenge for today's society. Due to the complexity of human consumption scenarios, people usually do not realize the diameter of the environmental impact they are causing (Kalbar et al., 2016). It is therefore necessary to survey the composition of human consumption, especially in the industrialized countries, considering that the consumption level there is much greater (Valdivia et al., 2013).

Even though the consumption in industrialized countries is unsustainably large, in the European countries, household consumption is still growing, accounting for almost 55% of GDP in 2016 (eurostat, 2018). Household consumption, in terms of volumes, in the EU states showed an increase of 10.4% during the period 2005–2016 (eurostat, 2018). This is caused, among other factors, by the paradigm of economic growth dominating politics and policies (Schneider et al., 2010). But a complete change of the economic model is rather implausible; therefore, a gradual transformation of consumer behavior seems more likely to achieve an environmentally sustainable society. To conclusively accomplish sustainable development, a thorough appraisal of the environmental burden caused by human consumption is necessary.

For the sustainability measurements, several methods have been proposed, such as ecological footprint calculators, an environmental sustainability index, and Life Cycle Assessment (Čuček et al., 2012). The concept of an ecological footprint was introduced by Rees (1992) and since then, many other footprints have been developed (Čuček et al., 2012). Since many online footprint calculators (Network, G.F, 2018; Fund, W.W, 2018; IslandWood, 2018) have been designed, it has made them an easily accessible public education tool. A group of indicators called the footprint family may be defined as a "set of indicators – characterized by consumption – based perspective – able to track human pressure on the surrounding environment" (Galli et al., 2012). The most commonly used indicators are: the ecological footprint – designed to track human demand on the biosphere's regenerative capacity (Galli et al., 2012), the carbon footprint – representing the amount of greenhouse gases (GHGs) that contribute to global warming or climate change (Čuček et al., 2012), and the water footprint representing the "total volume of direct and indirect fresh water used, consumed and/or polluted" (Čuček et al., 2012). As useful tools as the footprint calculators are, there are several problems such as differences in calculation methodology (Galli et al., 2016) and data scope transparency (Padgett et al., 2008). Furthermore, footprint calculators mostly focus on only one impact category such as climate change or water depletion. Such a narrow perspective may lead to inaccurate hot spot identification, affecting the efficiency of sustainable development policy.

In this study, the Life Cycle Assessment (LCA) method was used to estimate the environmental impact of human consumption, and to identify the environmentally important segments. LCA is a well established and standardized (ISO 14040 and ISO 14044) methodological framework for estimating environmental impact, attributable to the entire life cycle of a product or a process (Rebitzer et al., 2004). In contrast to footprint calculators, LCA is able to estimate the environmental impact across most of the impact categories, which makes missing a major environmental burden less probable.

In this study, an approach relatively similar to Personal Metabolism as proposed by Kalbar et al. (2016) was used. In contrast to Kalbar et al. (2016), in this study the average consumption data were used. The use of the average consumption data helps to avoid the variability of human consumption scenarios. To detect which processes are the major contributors, a model of the consumption style of an average inhabitant of the Czech Republic was made. In our opinion, the situation across Europe does not differ significantly, and the outcome of this study is thus applicable in other European countries, as well. Because lifestyle patterns of individuals vary greatly, average data, in our opinion, show wider consumption trends, making the results of this study more applicable for policymakers aiming towards the goal of more sustainable development.

2. Methodology

A model of average human consumption was designed using available data. The functional unit chosen for the model was the personal equivalent per year, representing the consumption of a single individual over the period of one year. Only principal segments, common for most consumption scenarios, were included within the system boundaries of the LCA. These segments are: food consumption, household energy consumption, personal travel, drinking water use and waste disposal. Other segments such as clothing, housing construction, vacations, etc. were avoided as being less substantial. Among selected segments, all processes were assessed for which data were available – either consumption data or models in LCA databases. Further methodological details are described in the following sub-sections.

2.1. Life Cycle Assessment method

The Life Cycle Assessment method, as defined in ISO 14040 and ISO 14044, was employed to evaluate the environmental impact of personal consumption throughout an entire life cycle, and across a wide range of impact categories. The model was designed using GaBi 8 LCA software (thinkstep, 2018), coupled with an internal database. Missing data, mostly food production models, were supplemented from the ecoinvent 3.3 database (ecoinvent, 2018). For the impact assessment, the ReCiPe 2016 method was employed, as this method provides characterization factors at the midpoint "assessing the environmental impact at a level in cause-effect chain from the release of substance or consumption of resources" (Dong and Ng, 2014) as well as at the endpoint level ("evaluating the environmental impact at the areas of protection level" (Dong and Ng, 2014)) (Huijbregts et al., 2017). ReCiPe 2016 enables us to choose out of three different value perspectives: individualistic, hierarchist and egalitarian (Huijbregts MAJ et al., 2016). Here, the egalitarian perspective was chosen, since it is "the most precautionary perspective, taking into account the longest time frame and all impact pathways for which data is available" (Huijbregts MAJ et al., 2016). The most significant categories were chosen based on normalized and weighted results, acquired using ReCiPe 1.08 methodology – the newest available normalization methodology. Endpoint equalitarian/average (E/A) normalization was performed and dominance analysis was executed. Complete normalization and weighting results are available in the supplementary information. The impact categories chosen, which will be described in further detail, are: climate change categories (34.7% of overall environmental impact), land use (14.2%), fossil depletion (17.8%), fine particulate matter formation (8.8%) and human toxicity (16.9%). Even though the impact category water use is not considered in the ReCiPe 1.08 methodology, acknowledging global water situation (Gudmundsson and Seneviratne, 2016; Dai, 2013), this category will be scrutinized as well. At the midpoint level Climate change represents "integrated infrared radiative forcing increase of a greenhouse gas (GHG), expressed in kg CO_2-eq." (Huijbregts et al., 2017). At the endpoint level this category aims to "quantify the link between time-integrated radiative forcing and time integrated temperature