CORVINUS UNIVERSITY OF BUDAPEST

EMBRACING THE ROLE OF SOCIETAL FACTORS IN THE LOW-CARBON TRANSITION

Ph.D. THESIS

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Budapest, 2014

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Embracing the role of societal factors in the low-carbon transition

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Andrea Tabi

Budapest, 15. October 2014

Dedicated

to my Mom

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I. Introductory chapter

1. Research objectives and significance

Due to the energy- and resource-intensive lifestyle pursued in developed countries during the last century, humankind has to face serious environmental issues in the future. To avoid the threatening consequences of climate change triggered by the rising CO_2 emission worldwide, policy makers come up with ambitious CO_2 emission abatements targeting reductions in production and consumption. Besides the promise of technological solutions we need to turn the searchlight on societal factors that play a prominent role in engaging in environmental actions.

The central topic of this thesis is the transition to a low-carbon economy and society. Various definitions of a low-carbon economy exist from international organisations and practitioners. Lately, it stands in the centre of sustainability research as a more focused interpretation of the sustainable development concept, introduced by the Brundtland Commission (WCED, 1987)[1]. According to the definition of the UK's National Strategy for Climate and Energy, low-carbon economy '***ensures that energy supplies remain secure, new economic opportunities are maximised, costs are minimised and the most vulnerable are protected'*** (HM Government, 2009, p. 6.). Low-carbon societies aim at reducing their greenhouse gas (GHG) emissions without significantly affecting their economic growth, i.e. minimal use of intensive energy while shifting towards resource-efficiency including renewable energy concepts and also societal changes in consumer behaviour such as transport, heating activities or electricity use, etc. (Ali et al., 2013). Since energy conversion is the main source of GHG emissions, we need to elaborate on more efficient energy strategies including the reconsideration of the current energy systems with low-carbon and renewable

[1] Sustainable development refers to "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

energy technologies and adoption of new consumption patterns (e.g. Nakata et al., 2011). Skea and Nishioka (2008) suggested the following framework which could provide a basis for research and action: '*A low carbon society should: (1) take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met; (2) make an equitable contribution towards the global effort to stabilize the atmospheric concentration of CO_2 and other greenhouse gases at a level that will avoid dangerous climate change, through deep cuts in global emissions; (3) demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies; (4) adopt patterns of consumption and behaviour that are consistent with low levels of greenhouse gas emissions*' (Skea and Nishioka, 2008, p. S6). In order to achieve the transition towards low-carbon economy the steps described below regarding low-carbon society need to be accomplished. This constitutes the theoretical basis of the present thesis that covers all aspects and features of low-carbon transition.

The scientific significance of this thesis is to present a comprehensive scrutiny and a summary of the most important societal barriers that could risk the implementation of curbing CO_2 emission. It aims at providing conclusions and implications to both scientific research and praxis. Building on the theoretical background and previous research experiences, this research broadens the scientific discussion on low-carbon transition. The thesis is built upon three research studies that revolve around possible decarbonisation pathways. Findings of each study make a contribution to designing more efficient environmental and climate policies. In the next part of this chapter the main research goals are presented, which reflect the previous findings and shortcomings emerging from the related literature.

In the first study, consumer preferences for green electricity products are analysed and linked to socio-demographic, psychographic and behavioural characteristics. The aim of this study is to study consumer acceptance towards renewable energies The emergence of green power, where residents get the opportunity to switch to renewable energy without being involved in the physical generation (Wüstenhagen et al., 2007), is an unexploited field in the literature. The research takes into account various factors that help to explain to what extent subscribers of green electricity tariff differ from potential adopters. The findings of this study provide targeted messaging improving the adoption of green electricity and valuable information for policy makers and practitioners.

In the second study, the focus is on low-carbon behavioral patterns. Even though we can measure high environmental concerns and preferences, yet we can observe inertia among consumers to adopt low-carbon lifestyle elements. Therefore, it seems that in order to reach actual carbon reduction, we need to change our consumption patterns drastically. To do so, we need to have a closer look upon the impacts of our current consumption behavior (Csutora, 2012). The goal of this research is to explore the effect of pro-environmental behaviour on CO_2 emissions with respect to residential energy consumption. Changing such behaviour has considerable potential for conserving energy resources and is an important target of climate policies.

The last study challenges the theory of service economy that has been highly promoted because of its putative environmentally-friendliness. Servitization of economy is assumed to bring along less energy- and resource-intensity. By means of a structural decomposition analysis of the environmentally extended input-output framework, the actual environmental load of services can be revealed (Alcántara and Padilla, 2009). Evidence shows how the traditional concept of services that is still rather vague and ill–defined, leads to serious underestimation of carbon impact in developed economies. The goal of this study is to draw attention to the real carbon impacts of services and to provide environmental policy implications.

2. Theoretical background

2.1. The CO_2 problem

The rising concentration of greenhouse gases[2] in the atmosphere is the main trigger of climate change causing environmental damages and endangering our current lifestyle. Although all these gases may have numerous natural sources, yet '*it is extremely likely that human activities caused more than half of the observed increase in global average surface temperature from 1951 to 2010*' "(Stocker et al., 2013, p. 60.). CO_2 emissions from fuel combustion and cement manufacture are responsible for more than 75% of the increase in atmospheric CO_2 concentration since pre-industrial times (Denman et al., 2007). In the first part of this section, the current policy measures and their efficiency to mitigate carbon emissions are discussed. In the second part, possible explanations to the CO_2 problem are presented.

The Council of the European Union adopted a target of a maximum 2°C rise in global average temperature above pre-industrial level in 1996. Later on, in 2009 at the 15th session of the Conference of Parties (COP 15) a new target was suggested that the increase in global temperature should stay below 2°C (UNFCCC, 2009b). CO_2 emission on global level has increased in the last decades, recently showed a little decline due to the financial crisis in Western countries, but CO_2 emission continued to rise by 4.6% in 2010 (IEA, 2012). On the other hand, according to the latest report by the European Commission (2013) on the progress towards achieving Kyoto targets, in 2011 the GHG emission (excluding emissions due to land use, land use change and forestry, and from international aviation) was 18.3 % lower compared to 1990 levels reaching the lowest level ever since. The EU-15 countries agreed on reducing their overall emission to 8% below the level of the base year in 1997, when they ratified the Protocol. The first period's target (2008-2012) seems to be overachieved; in 2011 the EU-15 emissions accounted for 14.9% below the base year (EU

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[2] Six GHGs are covered by the UNFCCC and its Kyoto Protocol: Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), HFCs (Hydrofluorocarbons), PFCs (Perfluorocarbons), and Sulphur hexafluoride (SF_6) (UNFCCC, 2009a).

progress report, 2013). In Hungary, the CO_2 emission from domestic production has declined in the last years mainly due to the economic downturn. Hungary has also signed the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol with the target of 6% below the annual average of 1985-1987 for the first period (EEA, 2013).

Despite the remarkable CO_2 reduction achievements in the Western countries, the CO_2 concentration does not seem to stop rising. Figure 1 depicts the measured CO_2 concentration levels in two observatory stations; the first one is the oldest CO_2 monitoring station in Mauna Loa, Hawaii and other one is in Cape Grim (operating from 1976), Tasmania. CO_2 is released into the atmosphere mostly by burning fossil fuels and cement production, land use change and other human activities. Human activities especially from the industrial revolution in the 19th century, when the global average concetration is estimated around 280 ppm (with fluctuations between 180 and 280 ppm during ice ages and interglacial periods) started to increase sharply with the more intense fossil fuel combustion (NOAA, 2013). According to the NOAA's report (National Oceanic and Atmospheric Administration), the atmospheric CO_2 concentration level exceeded 400 ppm in May 2013 for the first time. The current target to reach is 350 ppm that is regarded as a threshold of the planet's capacity for preserving and maintaining life in the long run (Hansen et al., 2008). The measured CO_2 ppm at observatory stations show that 350 ppm level was already surpassed around 1988.

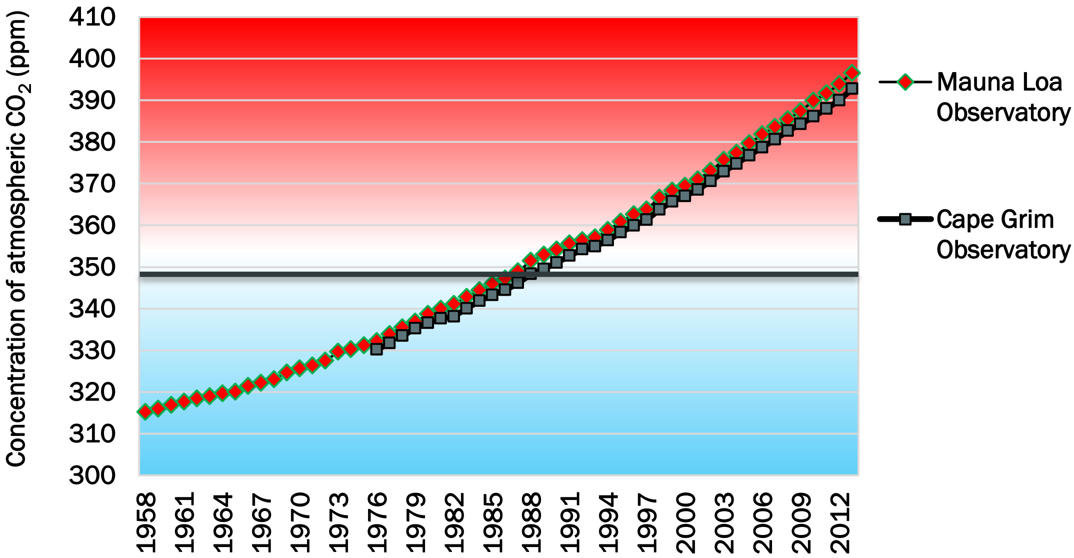

Figure 1: Atmospheric CO_2 concentration (ppm) (Data source from Mauna Loa and Cape Grim Observatory stations' webpage)

Despite all the efforts, there is an unstoppable global CO_2 rise putting the eco-system and current economies at risk. So long as there is no global climate policy and global emission targets defined that applies to all nations, the CO_2 abatement measures can be undermined through several ways, which can suggest misleading policy achievements.

CO_2 reduction in Europe can be attributed to the partial decoupling of the GHG emissions from the GDP growth, which can be mainly ascribed to the international outsourcing of different economic activities leading to virtual success (Schaltegger and Csutora, 2012). There are three main outsourcing waves during the 20th century identified in the literature. The first wave dates back in the late 1970s when mainly manufacturing processes were outsourced for cost-cutting reasons within countries' borders. In the second wave the motivation was not only the cost efficiency, but also the intention of firms to focus on core competencies and the idea was to outsource everything else that did not belong to the area of the expertise. This is called the era of strategic outsourcing (Hätönen and Eriksson, 2009). This happened in the 1990s, when IT outsourcing started to boom (Gonzales et al., 2001). This phenomenon led the world to the outsourcing of waste and pollution mainly to Asian countries. The third wave, from the 2000 onwards, outsourcing has become a norm rather than a competitive edge.

As a consequence of unilateral climate regulations, carbon costs triggered another type of outsourcing during the last decade that causes two interrelated issues: carbon leakages and competitiveness losses (Böhringer et al., 2012; Branger and Quirion, 2014). Carbon leakage affects primarily the EITE (Energy-intensive and trade-exposed) sectors such as ferrous metals (e.g. iron and steel), non-metallic mineral products (e.g. cement), non-ferrous metals (e.g. aluminium), pulp and paper, chemicals, rubber and plastics. Carbon leakage is defined as the increase in emissions outside a region as a direct result of the policy to cap emission in this region (IAE, 2008, p. 8.). Carbon leakage can be generated through two main mechanisms: energy and non-energy markets. The leakage related to energy markets occurs, when in a large country group have an unilateral carbon abatement, which triggers a decreasing demand in fossil fuels that pushes down the international prices. This can induce larger demand and consumption in non-abating countries (Arroyo-Curras et al., 2013). The carbon leakage via non-energy markets occurs because of the increased production costs imposed by CO_2 abatement policies affecting the international competitiveness of energy-intensive industries. So, these industries delocate their production processes to countries with weaker environmental regulations (Burniaux et al., 2000). Nonetheless, other sectors at the end of the supply chain (downstream sectors), which purchase intermediate goods with high carbon content, could be more affected by embedded carbon costs accumulated along the supply chain than upstream suppliers (Csutora and Dobos, 2012) preventing technological innovations.

Another well-studied phenomenon in energy research that contributes to rising emission is the rebound effect. It describes a mechanism, whereby efficiency improvements in energy services that make effective costs lower, trigger an increase in consumption of those services, which partly or fully offsets the positive effects of technological achievements. This is the so-called direct rebound effect, which is elaborated by many studies in several fields such as electricity systems and residential electricity consumption, heating activities and transport (Jin, 2007; Howells et al., 2010; Hens et al., 2010; Matiaske et al., 2012). This issue was first noted by William Stanley Jevons in the 18th century in his paper 'The coal question'. He observed that the coal consumption in England had risen more sharply, after the introduction of James Watt's new coal-fired steam engine with improved energy efficiency. Now, it is known as the rebound effect derived from Jevons paradox (Kerekes, 2012). The literature identifies an indirect rebound effect as well, which occurs when the decrease in price of a good or service rebounds not to itself but to the demand of another good or service (Harangozo, 2009; Freire-González, 2010). Greening et al. (2000) indicated a great variation in the magnitude of the effect because of identification and measurement issues. According to numerous studies reviewed the extent of rebound effect e.g. in space heating or in automotive industry generated by household consumption account for in both cases around 10-30% (Greening et al., 2000).

2.2. Tackling the CO_2 problem

According to the Brundtland report, sustainable development should ensure '*... that it meets the needs of the present without compromising the ability of future generations to meet their own needs*'. Although there are limits of resources and nature's resilience and its ability to absorb the effects of human activities, '*technology and social organization can be both managed and improved to make way for a new era of economic growth'* (WCED, 1987, p. 16.). At the UNCED conference held in Rio de Janeiro in 1992, the leading economies expressed the need for changing consumption and production patterns (Lorek and Spangenberg, 2014). The main document issued during the conference, the Agenda 21, stresses the difference in lifestyles of the industrialized and developing countries, namely the global problem caused by the overconsumption in developed countries is not compatible with sustainable development. This statement also appears in the document issued by the European Union entitled 'Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan' (2008) referring that our current practices need to be changed radically.

As agreed in the UNFCCC Conference of the Parties (COP 16) in Cancun, Mexico, developed countries should and developing countries are encouraged to improve low-carbon development strategies or plans (LCDPs) to significantly reduce greenhouse gas emissions over a specific period of time (UNFCCC, 2010). Some nations and international and intergovernmental organizations have already elaborated their own low-carbon actions plans during the last years that provide a detailed blueprint of planned reduction steps.

The implementation plan of low-carbon economy in the European Union is established in the document entitled 'A Roadmap for moving to a competitive low-carbon economy in 2050' (2011). This contains possible actions needed to be adopted to achieve targets of reducing GHG emission. CO_2 reduction in domestic emissions by 80% compared to the level in 1990 is set by the EU until 2050 in terms of real internal reduction without any compensation in the carbon market. Table 1 shows the reduction targets presented in the document, which need to be accomplished by 2050. Regarding the current GHG emission, the agreed reduction targets by 2020 seems to be met, but the 20% target set in the Energy Efficiency Plan (European Commission, 2011) might not be fulfilled under current conditions. The major goal is to reduce carbon emission from electricity generation that could also contribute to lower emissions in transport and heating sectors by replacing current feedstock with electric power.

Table 1: Sectorial reduction targets set by EU Roadmap 2050

GHG reductions compared to 1990	2005	2030	2050
Total	**-7%**	**-40 to -44%**	**-79 to -82%**
Sectors			
Power (CO_2)	-7%	-54 to -68%	-93 to -99%
Industry (CO_2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO_2 aviation, excl. maritime)	+30%	+20 to -9%	-54 to -67%
Residential and services (CO_2)	-12%	-37 to -53%	-88 to-91%
Agriculture (non-CO_2)	-20%	-36 to -37%	-42 to -49%
Other non-CO_2 emissions	-30%	-72 to -73%	-70 to -78%

Source: A Roadmap for moving to a competitive low-carbon economy in 2050 (2011)

Some nations have already prepared low-carbon development plans tailored to their own countries (e.g. Bangladesh, Brazil, China, Costa Rica, Guyana, India, Indonesia, Japan, Mexico, South Africa, South Korea and the UK). The planned level of reduction varies across countries since no target value has been agreed upon for LCDPs (WWF, 2011).

Though, Hungary has no focused low-carbon development plan yet, national strategies are developed that address climate change and energy security. According to the National Climate Change Strategy (2008-2025) (hereafter NCCS), Hungary is threathened by changes in temperature and percipitation resulting in more extreme wheather phenomena such as prolonged drought periods, floods and inland inundations. It places emphasis on GHG reduction ' ... *achieved by reducing the overall energy use in a manner that enables a shift in production and consumption towards lower material and energy needs*' (NCCS, 2008, p. 3.). Hungary's NCCS is based on the scientific findings of VAHAVA Report (Farago et al., 2010) that summarizes the results of the project titled "Global climate change, Hungarian impacts and responses" launched in 2003.

The Hungarian National Renewable Energy Action Plan (2010) (hereafter NREAP) set the achievement of 14.65% in energy consumption by 2020 (Table 2), which exceeds the obligatory minimum target, but it is still among the lowest within the EU member states. As for electricity consumption, the national target is 10.9% by 2020. The current share of renewable energy sources in electricity consumption accounted for 6.86% in 2012, which grew to 7.5% in 2013 (see Table 2).

Table 2: National Renewable Energy Source (RES) targets by 2020

RES	2013	2014	2015	2016	2017	2018	2019	2020
in heating and cooling	8,50%	9,10%	9,80%	11,80%	13,70%	15,70%	17,40%	18,90%
in electricity	7,50%	8,60%	8,10%	7,10%	8,60%	10,20%	10,70%	10,90%
in transport	5%	5,20%	5,40%	5,80%	6,40%	7,30%	8%	10%
Overall share of RES	7,50%	8%	8,30%	9,30%	10,70%	12,30%	13,40%	14,65%

Source: NREAP, 2010

Nuclear power and imported natural gas have crucial role in electricity generation, latter causes a significant energy dependency for the country. Thus, the most important strategic goals of the Hungarian energy policy, among the reduction of emissions, are the optimization of economic development and energy security. Besides the import-dependent natural gas supply, Hungary imports a significant amount of electricity (around 10% of total consumption) as well (MAVIR, 2012). Therefore, the expansion of energy supply from domestic sources is highly preferred in long-term considerations of the Hungarian energy policy. Currently, more than 80% of natural gas consumption stems from imports primarily from Russia and former CIS countries (NREAP, 2010). The National Energy Strategy 2030 (hereafter NES) clearly promotes low CO_2-intensive electricity generation primarily by extending nuclear power and only secondly by renewable energy sources (NES, 2011). These policy efforts are not in line with the future path of Western European countries, where currently nuclear phaseout has been targeted. In the NES 2030 the energy efficiency is regarded as one of the most important measures to decrease GHG emission. To achieve this, renovations of the current building stock is highlighted (NES, 2011). Energy use in buildings is an important part of global energy challenges, because they have a significant share of GHG and other climate forcing agent emissions (Urge-Vorsatz et al., 2013). Building energetics is responsible for around 40% in Hungarian energy consumption (Szlávik and Csete, 2011).

2.3. Climate policy instruments

In the course of time, the palette of environmental and climate policy instruments have been broadened (see Table 3) that can be classified into three major groups; Direct or Command-and-control (CAC) regulations, Indirect regulations or Market-based mechanisms and Decentralized regulations (Kerekes and Szlavik, 2001).

Table 3: Environmental policy instruments (Kerekes and Szlavik, 2001)

Direct or Command-and-control regulations	Indirect regulations or Market-based mechanisms	Decentralized regulations
• norms • limits • licensing • liability • fine • ban • standard	• taxes, charges, levies, duties, effluent charges • incentives • fiscal and budgetary subsidies (tax credits, exemptions and allowances, direct transfers, low-interest loans and grants, R&D) • tradeable permits	• unilateral firm statements • voluntary agreements • environmental marketing • environmental certifications (ISO, EMAS, etc.) • eco-labelling • ecoaudit • enforcement incentives • environmental liability insurance • information-based measures • BAT (Best Available Technology,), BATNEC (Best Available Technology Not Entailing Excessive Cost)

Historically, the first regulations aiming at reducing environmental damages have come to life during the 1970s and 1980s. These were mostly CAC measures that were exposed to constant criticisms for its costliness and inflexibility among economists. As of the late 1980s, market-based instruments have emerged and become widespread. Decentralized regulations such as voluntary agreements or eco-labels have turned up firstly in the 1990s. They refer to commintments made by firms regarding improvements of their environmental performance that surpasses the required level (Lyon and Maxwell, 1999).

The following policy tools related to emission reduction are highlighted by the IPCC report on mitigation of climate change (IPCC, 2007, 750. p.):

- Regulatory measures and standards (these specify the abatement technologies (technology standard) or minimum requirements for pollution output (performance standard) that are necessary for reducing emissions)
- Taxes and charges (a levy imposed on each unit of undesirable activity by a source)
- Tradeable permits (these are also known as marketable permits or cap-and-trade systems. This instrument establishes a limit on aggregate emissions by specified sources, requires each source to hold permits equal to its actual emissions and allows permits to be traded among sources)
- Voluntary agreements (an agreement between a government authority and one or more private parties with the aim of achieving environmental objectives or improving environmental performance beyond compliance to regulated obligations. Not all Voluntary agreements are truly voluntary; some include rewards and/or penalties associated with participating in the agreement or achieving the commitments)
- Subsidies and incentives (direct payments, tax reductions, price supports or the equivalent thereof from a government to an entity for implementing a practice or performing a specified action)
- Information instruments (required public disclosure of environmentally related information, generally by industry to consumers including labelling programmes and rating and certification systems)
- R&D (activities that involve direct government funding and investment aimed at generating innovative approaches to mitigation and/or the physical and social infrastructure to reduce emissions. Examples of these are prizes and incentives for technological advances)

- Non-Climate Policies (other policies not specifically directed at emissions reduction which may have nevertheless significant climate-related effects).

In the next part of this section the most well-known policy intruments targeting low-carbon transition are briefly analyzed, without attempting to be comprehensive.

CO_2 pollution as an externality of industrial and transport activities is deeply rooted in economic theories. To handle external damages caused by an activity, market-based instruments can be derived from two basic economic theories; the Pigouvian tax and the Coase theorem. Pigou (1920/1938) introduced the economic analysis of pollution starting with making a distinction between private and social costs. Pigou argued that levying tax on a polluting activity internalizes the external costs of the environmental damage and in doing so, limits the pollution as well. The Pigouvian tax has gained attention and found disciples among several economists and manifested in numerous environmental policies such as the Polluter Pays Principle fostered by the OECD (Cerin, 2006). Eco-taxes are applied in many countries around the world, e.g. the Environmental Tax Reform (ETR) movement during the early 1990s has positive impacts on the economy, environment and society (EEA, 2011).

As an alternative approach to incorporate externalities, Ronald Coase introduced his idea in his seminal essay entitled “The Problem of Social Cost” (1960), which has become widespread as the Coase theorem in the literature. It states that if property rights are well-defined, transaction costs are minimal or zero and trade in an externality is possible, then bargaining might lead to an efficient outcome regardless of the initial allocation of property. Building on the Coase theorem, the European Union launched the Emissions Trading Scheme (EU ETS) in 2005 as the first cap-and-trade system for GHG emissions (followed by the cap-and-trade initiatives in the US, Australia, Japan, New Zealand). Cap-and-trade approach means that the system limits the overall GHG emission, but within this limit, companies can buy and sell emission allowances, so companies can cut their emissions in the most cost-effective way. The EU ETS covers more than 11,000 power stations and manufacturing plants in the 28 EU member states as well as Iceland, Liechtenstein and Norway. Aviation operators flying within and between most of these countries are also covered. In total, around 45% of total EU emissions are limited by the EU ETS (European Union, 2013). Recent studies report on the shortcomings of the emissions trading system including carbon leakage and competitiveness loss (Monjon and Quirion, 2011; Meunier, 2014; Martin et al., 2014a). To alleviate these concerns, EU ETS gives free allowances to firms in energy-intensive and trade-exposed industries (Martin et al., 2014b). In the thid period of EU ETS, from 2013 onward, a much higher number of free allowances are issued for electricity sector and industries exposed to carbon leakage (Monjon and Quirion, 2011). As a consequence of the ill-constructed operation, the ETS system collapsed in 2013; the price of allowances fell from almost 30€/tCO_2 in mid-2008 to less than 5€/tCO_2 (Koch et al., 2014; Stram, 2014). The deepest point of allowance prices has been reached in the first half of 2013 (see Figure 2).

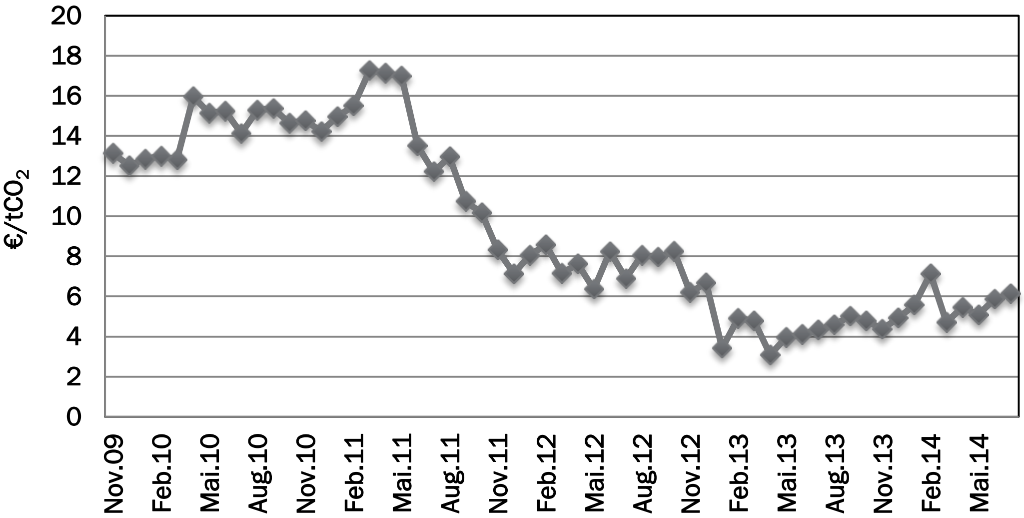

Figure 2: Carbon prices EU ETS from 2009 Nov- 2014 July (Source: www.investing.com)

To find a policy instrument that could handle the negative consequences of unilateral policy targets, several potential measures are analyzed including international sectorial agreements, cost containment measures, free or output-based allocation of allowances, and border carbon adjustments (Grubb and Neuhoff, 2006). Border Carbon Adjustments (BCAs) have been strongly analyzed in the literature (Kuik and Hofkes, 2010; Schinko et al., 2014). BCAs can be implemented as import tariffs, export rebates, or the obligation for importers to surrender carbon allowances for the amount of CO_2 that is emitted as a consequence of the goods' production (Kuik and Hofkes, 2010). According to the findings of a recent review study based on a meta-analysis of numerous studies, the typical range of carbon leakage is estimated from 5% to 25% without policy interventions and -5% to 15% with BCAs (Branger and Quirion, 2014). Stram (2014) suggest that implementing a small carbon tax would substantially contribute to greenhouse gas inventories, which would have negligible economic consequences for firms.

Policy instruments targeting a change in consumer behavior and lifestyle such as eco-labeling or awareness raising programmes are of particular importance in the field of energy conservation. With regard to low-carbon transition, energy and carbon labeling are to be highlighted. Energy efficiency labels play a significant role in reducing the energy consumption of appliances worldwide. Energy labels may be categorized as endorsement (e.g. the Energy Star issued by the US EPA) and comparison labels (e.g. the European Union Energy Label). Endorsement labels are given to the most energy-efficient products in a product category. Comparative labels have a rating system related to the rate of the energy efficiency of a product (Heinzle and Wüstenhagen, 2012). Heinzle and Wüstenhagen (2012) show that the extension of the classification of applianes and devices in the European Union (seven-point A–G rating scale) by adding new classes (A+, A++, etc.) result in a lower perceived importance of energy efficiency in consumer decision-making, which might not help to overcome information asymmetries. Eco-labeling is also used among electricity providers to differentiate their products along environmental characteristics (Truffer et al., 2001). Carbon labeling informs consumers about the carbon footprint associated with a certain good (the embedded CO_2 or CO_2-equivalent content). This way of spreading information might raise awareness about climate change and ease customers to make their purchase decisions based on CO_2 intensity of a product (Upham et al., 2011). Although the calculation of a product-level carbon footprint is a very suitable approach for drawing attention to carbon footprint of a particular product, on the other hand, its implementation also arises several biases during calculation such as system boundary issues (different starting and ending point choices in life-cycle analysis), product complexity, supply chain variability, allocation issues, scaleability and costs (McKinnon, 2010). Currently, the European market is flooded by different eco-labels that undermine the transparency and credibility of labeling. Hartikainen et al. (2013) investigated the Finnish consumers' understanding about product carbon labeling and showed that the majority of consumers are not familiar with the meaning of product carbon footprint and only a low percentage of respondents attach product carbon footprint to greenhouse gas emissions associated with the product. There are only few studies posing the question how eco-labels influence consumer choices.

Governmental subsidies and incentives are also widespread to change consumer behavior including industrial and residential users. In the European Union numerous tax incentives are currently used to promote green electricity including an exemption on the payments of excise duties for power plants, limited tax incentives in personal income tax, lower tax rates in VAT etc. (Cansino et al., 2010). Feed-in tariffs (FiT) are one of the most popular support systems for renewable energy sources from small household applications to large utility scale systems. For instance, feed-in tariffs accounted for nearly 72% of all solar PV installed worldwide until 2012 (IEA, 2013). FiTs are designed to foster both residential and industrial consumers to become "prosumers", or, simply put, people who are consumers and producers of energy at the same times. The "prosumer movement" dates back to the 1980s. Back then prosumer was defined as a person that creates goods, services or experiences for his own use or satisfaction (Toffler, 1980). The concept has been developed in the course of time and currently prosumers are characterized by a strong personal engagement in co-creating value (Izvercianu et al., 2014).

Information or awareness-raising campaign is also a widespread method to promote climate policy intention to the public. To mention one example, the Energy Efficiency Advice Centres (EEACs) offer consultancy to encourage households to understand, and then take action to reduce the negative environmental impact of their energy use (Lucas et al., 2008). In spite of such campaigns and incentives, consumers are still reluctant to adopt energy-efficient measures and low-carbon technologies such as solar PV installations (IPCC, 2013).

The choice of appropriate policy instruments is the key for mitigating the overall CO_2 emission and for stimulating technological innovations. Besides technological solutions, the role of societal factors in energy and climate research is essential. It has been realised that low-carbon transition forced by regulations and policies can only lead to partial success without appropriate social support.

3. Conceptual framework

3.1. The framework

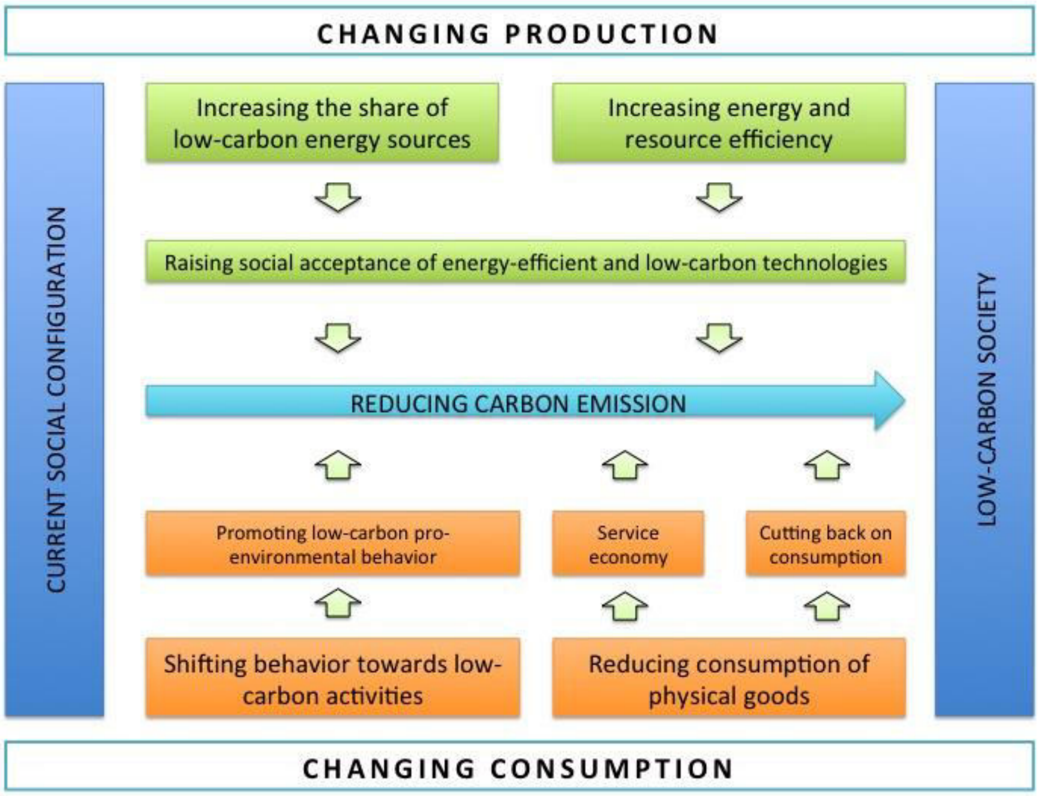

Figure 3: The conceptual framework of the thesis (Source: Own compilation)

The way we produce and consume goods and services cause a constant rise in CO_2 level that current climate policies, for the time being, cannot stabilize efficiently. To face the low-carbon challenge, current production and consumption practices have to be revised and radically changed. Both sides require the active social participation. Figure 3 depicts a simplified framework that shows the most important societal factors playing a role in low-carbon transition. To reduce carbon emission from production activities, we need to adopt low-carbon and renewable energy technologies[3] and increase energy and

[3] Though, nuclear power generation is indeed a low-carbon technology, but considering the low social acceptance (Siegrist and Visschers, 2013) due to its other substantially harmful characteristics such as radioactive and thermal pollution, nuclear power is not incorporated into the conceptual framework towards a low-carbon society.

resource efficiency at the same time. The implementation of such technologies is highly dependent on social acceptance with respect to socio-political, community and market dimensions. To change our consumption patterns, the adoption of policies promoting low-carbon lifestyle and reducing the consumption of material goods are needed.

In this thesis the following three major social keystones of the framework are analysed in-depth: (1) social acceptance of renewable energy technologies, (2) promoting low-carbon pro-environmental behaviour, and (3) service economy.

3.2. Social acceptance of renewable energy technologies

Renewable energies typically receive wide public acceptance due to their CO_2-reducing potential and positive impacts on energy security. Yet, the installation of low-carbon technologies is often hampered by legal constraints or a low willingness to adopt or install renewable energy technology. The social acceptance as one of the major hurdles of implementation has largely been neglected in the 1980es and 1990es, because public opinion on RES projects was regarded as non-technical and marginal issue (Carlman, 1982). However, during this time some authors put emphasis on social constraints as well (Wolsink, 1987; Bosley and Bosley, 1988; Thayer, 1988). Small-scale energy generation such as solar photovoltaic raises a number of questions and decisions to make by individuals: siting decisions, visual impact, decentralization of energy supply, investment decisions etc. In other words, energy generation has become the part of households' everyday life. In recent years the research of social acceptance towards RES projects has become an issue and opened a new research field. While these studies specifically build upon public, political, and regulatory issues (Carlman, 1984), the conceptual model introduced by Wüstenhagen et al. (2007) takes a more holistic approach. Social acceptance framework provides a comprehensive basis for conducting research with a specific focus on specific social angles of renewable energy technologies by integrating three dimensions:

(1) socio-political acceptance; (2) community acceptance; and (3) market acceptance.

Socio-political acceptance of renewable energy technologies considers the acceptance of low-carbon energy technologies by the public, key stakeholders, and policy makers. This is the broadest dimension embracing all barriers to implementing low-carbon projects. At policy level, well-established institutionalization of policy instruments, such as reliable financial supporting mechanisms are required to effectively boost market and community acceptance. However, opinion polls show that the vast majority of people support renewable energies, even in countries where the government does relatively little to support them (Wüstenhagen et al., 2007). Batel et al. (2013) draw attention to the conceptual distinction in the two different meanings of public acceptance; a reaction (passive) to something external or supporting something (active). They empirically examined the difference between acceptance and support of high voltage power lines and found that acceptance and support are different. They state that support implies a more active position, whereas acceptance implies a passive reception of power lines, rather only tolerating but not supporting them. They also suggest that other types of responses to energy infrastructures should be studied such as support, opposition, resistance, agreement, etc. (Batel et al., 2013).

Community acceptance involves mostly the acceptance towards siting decisions of renewable energy projects by local stakeholders, particularly residents and local authorities, which also brings along the well-known NIMBY (not in my backyard) problem regarding such projects (Wüstenhagen et al., 2007). To overcome this issue we need to establish trust and fairness among stakeholders by minimizing damages due to siting decisions and the use of natural resources that potentially have negative effects on community's social well-being. So, NIMBY problem seems to be more complex as being assumed before and there is some evidence found that social fairness or justice have a major impact on social acceptance. Two essential types of environmental justice can be discussed: distributive and procedural justice (Manaster, 1995). The former refers to the equitable distribution of outcomes (public goods or burdens) and the latter one means processes by which decisions are made (rights of participation, access to information, and lack of bias on the part of the decision-maker). Gross (2007) investigated the significance of procedural justice regarding the social acceptance of wind power and found that community perceptions of fairness influences how people perceive the legitimacy of the outcome, and that a fairer process increases acceptance of the outcome (procedural justice).

Finally, the last dimension of social acceptance is the market acceptance, which embraces the process of market adoption of an innovation by investors and consumers. Investor's acceptance research is also crucial for the transition to low-carbon energy systems that may require not only public engagement, but also significant financial investments (Loock, 2012; Hampl, 2012). Venture capital and private equity investments are important sources of financing for low-carbon technologies to bring new technologies from research laboratories to market (Bürer and Wüstenhagen, 2009). To overcome the challenge the commercialization phase of succesful prototypes ("technology valley of death"), venture capital and private equity investors are of utmost importance (Moore and Wüstenhagen, 2004). Although there has been recently a remarkable increase in attention to the renewable energy technology sector from the private investment community, these type of investments are affacted by government policies at various stages of venture capital, thus investors' perceptions of such risks need to be scrutinized (Bürer and Wüstenhagen, 2008). The role of consumers has changed in energy market, besides their classical consumer position, they have become investors as well (Zhai and Williams, 2012). Thus, consumers' perceptions and preferences for adoption renewable energy technologies in their homes as well as green energy tariffs provided by energy utilities are in the focus of recent research. Therefore, consumer acceptance is one of the most important components of market acceptance dimension that has not been exploited in the literature yet.

3.3. Promoting low-carbon pro-environmental behavior

To support top-down climate policy instruments, bottom-up social support is needed that promotes low-carbon pro-environmental behavior. Low-carbon pro-environmental behavior embraces all types of actions people undertake to maintain their lifestyle.

Research conducted on consumer behavior has usually two initial assumptions; the first one is that most choices are made by individuals and the second one is that these decisions are based on individual's personal attitudes, beliefs, and preferences (Simpson et al., 2012). While psychological studies stress the role of social and psychological factors, other studies place structural conditions in the searchlight (Sanne, 2002). Thus, the structural lock-in causes situations where consumers cannot act according to their preferences. Some actions, however, can almost always be substituted for lower carbon-intensive analogs, e.g. the use of a running machine that consumes electric power can be avoided by outdoor running or short-distance transportation activities, in which case one can usually choose from several options such as train, public transportation, passanger car etc. Of course, energy-intensive activities are not always interchangeable with low-carbon ones out of various reasons.

The main barrier to picking up low-carbon behaviour is the fact that people are keen on consuming. In economic theories higher income leads to better-covered needs, which also means a higher subjective wellbeing, but in sociology and social psychology the relative economic position (compared to reference group) is considered the carrier of utility, not absolute consumption; this is often called the theory of „relative deprivation" (Ravallion and Lokshin, 2005; Guillen-Royo, 2011). Ferrer-i-Carbonell (2005) analyses the importance of „comparison income" (the income of a reference group) for individual well-being or happiness and found that those individuals are happier that have larger income than in comparison with the income of the reference group. Happiness research is rooted in the Easterlin paradox named after Richard Easterlin (1974), who conducted surveys of human happiness in nineteen developed and developing countries to investigate the connection between happiness and income. He concluded that within countries there is a positive association between income and happiness, but in international comparisons this association is much weaker (Easterlin, 1974), which opened a new field of research in economics.

Measures and policies targeting energy efficiency among residents are frequently hampered by a low willingness to invest in such technologies because of misconceptions about the effectiveness of such measures (Gardner and Stern, 2008) or lack of knowledge about climate change (Sterman and Sweeney, 2007). The lack of information leads to general inertia and the support of wait-and-see policies that is highly promoted by the US government. It hampers the adoption of low-carbon pro-environmental behavior and investments in low-carbon technologies.

3.4. Theoretical roots of servitization

In the literature several authors pointed out that the reason of unsustainable economic system roots primarily in our overconsumption (e.g. Shove, 2004; Tóth and Szigeti, 2013). To tackle this problem, there are two main streams of research; the first is to reduce demand and the second one is to reduce the consumption of material goods by servitization.

The concept of services often creates a challenging, sometimes a puzzling situation for practioners as well as for researchers. In economic theory, services are mostly regarded as non-material, immaterial or intangible goods. Services' non-materiality dates back to Adam Smith's theory where he divides the economy on the basis of productive and unproductive labour. Latter refers to activities that have no tangible outcome and which are nowadays called services (Fourcroy et al., 2012). Even though Smith did not explicitly use the word 'non-materiality' as the basis for distinction, it has been spread and adopted as the main charactersitic for separating goods and services. According to OECD (2000) services are "*a diverse group of economic activities not directly* *associated with the manufacture of goods, mining or agriculture. They typically involve the provision of human value added in the form of labour, advice, managerial skill, entertainment, training, intermediation and the like"* (OECD, 2000, p. 7.). It adds that the main characteristic that distinguishes services from other activities is that they cannot be stored and have to be consumed at the point of production. There are, however, economists who have come up with other approaches to capture the essence of services, for example, Hill (1977) proposes the following definition: "*A service may be defined as a change in the condition of a person, or of a good belonging to some economic unit, which is brought about as the result of the activity of some other economic unit, with the prior agreement of the former person or economic unit*" (Hill, 1977, p. 318). Hill stresses that services cause a change in the condition of a person or a good, which provides a comprehensive definition covering most service activities, but in some cases it makes difficult to differentiate them from goods (Parrinello, 2003). Parrinello (2004) suggested that the concept of services should be grasped through economic process analysis. He concluded that services are distinct category from immaterial and material goods; service can be described as an "*activity, which requires not only labour as input, but also other means of production*" (Parrinello, 2004, p. 387.). This is considered as a parallel input-output relation, where an activity performed by one process can be an input of another process at the same time. In this study the process-based approach is applied and reflected during the calculations to capture the actual impacts of services on the whole economy.

There are lots of highly-linked notions spread related to the latest stage of economic developement in the literature such as service economy, post-industrial economy, knowledge-based economy, new economy, etc.

The term service economy roots in the notion that was first introduced as the "post-industrial society" by Daniel Bell in 1973 that refers to the stage when services overweight the manufacturing sector in the economy in terms of wealth. He particularly emphasized the role of knowledge-based services and foresaw the increasing importance of scientists shaping the future economies (Bell, 1973). Service economy originally does not imply the greening of economy, it simply states that there would be a shift towards services in terms of monetary value and employment in developed countries (e.g. Buera and Kaboski, 2012). In the 1990s another term, the so-called 'knowledge-based economy' has emerged. It describes '*economies which are directly based on the production, distribution and use of knowledge and information*' (OECD, 1996, p. 7.). These notions have been of interests among environmental researchers. Chichilnisky (1998) concluded that knowledge-intensive growth leads to the mitigation of environmental damages since it does not require intensive use of the resources. She calls it the knowledge revolution that means a transformation from a resource-intensive to a knowledge-intensive economy and not the transformation from industrial production to services. All revolutions need to adopt a new fuel, which is in case of the knowledge revolution the information technology. However, other authors, e.g. Ehrlich et al. (1999) pose the question if there is a knowledge explosion and if so, whether it would help the environment. They concluded that if knowledge is defined as only useful and accurate information, then the evidence for a knowledge explosion becomes mixed or does not imply an actual growth of environmentally beneficial knowledge. They claim that '*the ability to shift economic activity from goods toward services only partly eliminates the need for fundamental natural resources and must eventually encounter limits. Knowledge can never be a sole antidote to the increasing pressures on the environment posed by increasing population and per-capita consumption*' (Ehrlich et al., 1999). Cogoy (2004) investigates the environmental impacts of human capital and knowledge-based services based on the assumption that consumption is a time-requiring activity and consumers' goal is to spend time in a pleasant way. He describes the dematerialization process of the economy as the structural change in time, which is structured in four parts in his theoretical model: enjoyment, production, services and research. Assumingly, if time were shifted to research, then due to the accumulation of human capital, there would be a change induced from production to services. He adds that individuals' wellbeing is increased more by means of services and knowledge than by means of commodities (Cogoy, 2004).

In general, servitization is believed to lead us to a sustainable pathway, because it focuses on final user needs, rather than on selling products, which could reduce environmental load (Tukker, 2013). Theoretically, the transition to a service economy is supposed to bring less energy-intensive activities to reduce energy demand. Another approach pertaining to natural capitalism appears to define service economy in the literature introduced by Paul Hawken, Amory Lovins and Hunter Lovins (1999). Unlike industrial capital that only includes financial and manufacturing capital, it also places emphasis on both natural and human capital. It proposes four strategies that enable business to increase profit while behaving environmentally responsible. One principle is the so-called flow economy that '*involves shifting from a perception of wealth as goods and purchases to a perception of value as desired services and satisfaction of human needs*' (Hawken et al., 1999). This idea practically captures the essence of sustainable Product-Service Systems (PSS). Currently, PSS stands in the research focus of a lot of studies in the field of industrial ecology. The product-service system can be defined as '*a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs'* (Tukker and Tischner, 2006). Initially, the aim of PSS is to increase the value of a product by adding services and an additional favourable side-effect is proven to be the reduction in consuming of energy intensive physical products (Beuren et al., 2013). Nowadays, PSS is usually described as '*a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models*' (Mont, 2002). The most common examples in PSS are sharing, renting, and leasing. It has to be noted that PSS does not necessarily mean a sustainable solution, only some PSS can provide real environmental improvement. It offers only an attractive concept to develop such solutions but there are a lot of constraints and barriers at the moment that vary on a case by case basis such as rebound effect or the social acceptance of such new services, which mostly pair up with the adoption of new behavioral patterns. For example, in case of car sharing a cultural shift is needed for consumers from having a car to using or renting it (UNEP, 2000). These hurdles make the implementation of such innovations very difficult, therefore the presence of such solutions in current economies is negligible.

4. Applied methodological background

The thesis contains both empirical and non-empirical research. Two studies rely on a representative survey and one study applies a quantitative model. This chapter specifically concentrates on the explanation of the chosen methodological approaches for measuring preferences and carbon impacts.

4.1. Methods for measuring preferences

In the literature, there are two main approaches to measuring consumer preferences; revealed and stated preference method (Adamowicz et al., 1994). Revealed preferences can be observed through actual choices made by individuals or households. Assuming that actions undertaken in the past reflect consumers' preferences are useful for studying existing products or services, but new settings or product features can be barely investigated by historical data (van Oel and van der Berkhof, 2013). Thus, stated preferences are theoretically eligible for investigating both marketable and non-marketable goods. There are several stated preference methods used in the literature, but the most prevalent ones are the contingent valuation method (CVM) and the discrete choice experiment (DCE). The CVM aims at estimating the benefits (or costs) resulting from a policy that improves (or worsens) the environmental quality (Mitchell and Carson, 1989). Respondents are asked in a hypothetical market about their willingness to pay (WTP) for receiving a public good or service or about their willingness to accept (WTA) a compensation for the loss of a good or service (Ramajo-Hernández and del Saz-Salazar, 2012). In other words, it always compares a (hypothetical) state to status quo and measures the change in wellbeing in terms of monetary value. Discrete choice experiments are widely-used in marketing research and are characterized by multinomial discrete choice questions arranged in a choice set. The theoretical background of DCE is derived from the classic microeconomic utility theory, which assumes that individuals always maximize their utility. This theory advanced by Lancaster (1966) shifts the focus from the product itself to product characteristics (Sammer and Wüstenhagen, 2006). DCE is the most suitable method for measuring the preferences for attributes of hypothetical products (or products that are before the commercialization phase), because it is not possible to observe the actual purchase behavior or measure preferences through revealed preference methods (Ewing and Sarigöllü, 2000).

In the first study a conjoint method is applied. Conjoint (trade-off) analysis belongs to stated preference methods (also referred to as discret choice modelling) that indirectly determine the importance of product attributes in consumer decision-making. The method has a long history that started in the 1920s, but its official starting point is agreed to be in 1964 when Luce and Tukey introduced the methodology in their seminal paper (Green and Srinivasan, 1978). Ever since conjoint techniques have received huge attention since the early 1970es among marketing and consumer researchers and practitioners as well (Green and Srinivasan, 1990). The major advantage of this method over other stated preference techniques is that it provides a real buying situation for respondents, where they are asked to choose from different products. The products vary in attribute levels and cannot be combined by the respondents, so they need to choose one ‘package’ from the choice set (Sammer and Wüstenhagen, 2006). In doing so, consumer preferences for product attributes are implicitly derived from stated choices. This indirect type of questioning method is more eligible for understanding how product attributes affect choices, thus it offers more accurate predictions about the future market reception of a new product. The indirect way of questioning about preferences gives the major strength of the method, hence the bias occurring during direct questioning can be eliminated (Zacharakis and Meyer, 1998).

Conjoint analysis has three main types; Choice-based conjoint (CBC), Adaptive conjoint (ACA) and Menu-based conjoint (MBC) analysis. Adaptive conjoint analysis can be more suitable than CBC, if the choice task involves a complex product with 5 or more attributes. Adaptive conjoint analysis main feature is that the survey is customized for each respondent, namely at each step respondents' utilities are re-estimated according to previous answers (Sawtooh, 2007). The main difference between CBC and ACA is that in CBC respondents are presented with several sets of options, and asked to chose one rather than the other by rating or ranking attributes. ACA starts with a set of questions to identify relevant attributes, which are used for creating options at the end of the survey. Menu-Based Conjoint (MBC) analysies is suitable for handling a variety of menu choice situations in which respondents build their preferred selection during the process. The first study applies the standard CBC method, which is the most-widely used conjoint technique. CBC method is described in detail in the next chapter.

4.2. Methods for measuring CO_2 impact

Carbon impacts are measured in the second and third studies both at residential and national level. To measure the carbon impact of a process, product, service, organization, city or national economy, carbon footprint analysis has to be carried out (Galli et al., 2012). Carbon footprint belongs to the footprint family along with the ecological footprint concept introduced by Wackernagel and Rees (1996) and the water footprint developed by Hoekstra and Hung (2002). Carbon footprint was firstly defined by Høgevold in 2003, but until recently various definitions and calculation techniques have come to life (Cucek et al., 2012). On the one hand, carbon footprint can be regarded as the part of ecological footprint, where the carbon footprint refers to a hypothetical land area (global hectare) needed for the substitution of one unit fossil fuel burned. By substitution is meant the area, which is required to absorb the CO_2 emitted from the burning process (GFN, 2008). Carbon footprint can also simply stand for the amount of CO_2 or CO_2-equivalent (including other GHGs) emitted within a defined system boundary.

Methodologically, carbon footprint analysis can be delivered in three ways; (1) IPCC method, (2) process-based life cycle analysis and (3) input–output analysis method (Dong et al., 2013).

The IPCC method provides detailed calculation formula and emission factors for various emission sources combusted at various sites. These factors consider only the direct emission from fuel combustion, namely they lack a life cycle perspective and they are also not suitable for calculation of embedded emissions (IPCC, 2006).

Life Cycle Assessment (LCA) is a methodological tool for assessing the environmental impacts of a particular product during the whole life cycle, i.e. it considers usually all impacts occurring from raw material acquisition, throughout production and to end users or to waste management (ISO, 2006). LCA is regarded as one of the most accurate and suitable approaches for the evaluation of the environmental impact of a particular product, though it suffers of some limitations (Crawford, 2008). The traditional process-based life cycle analysis can usually describe the main processes and inputs in detail, but system boundaries are mostly not well-defined. Defining boundaries in process-LCA has been discussed in many studies (Whittaker et al., 2013) using different ending and starting points of the analysis. In some special cases geographical and temporal distances are considered as system boundaries as well, but traditionally three major types of system boundaries in the life cycle inventory can be defined (Guinée et al., 2002); the first one is between the technical system and the environment, the second one lies between significant and insignificant processes, and finally there is one between the technological system under study and other technological systems. In relation to the system boundary between the technical system and the environment, e.g. the inputs should be considered raw materials as found in nature in unprocessed form (Finnveden et al., 2009).

The input-output analysis is a top-down technique and was first introduced by Wassily Leontief in the 1930s for the analysis of the inter-relationship of different economic sectors, where the sectorial transactions are based on monetary data and calculated at national level. Then, IO models have been extended in the course of time to measure physical units such as determining the pollution or the environmental load of different sectors and product groups (see Bicknell et al., 1998). IO analysis has its shortcomings as well. However, it takes into account capital goods and provides a complete analysis without system boundary issues (except for the end-of-use and end user phases are not included in IO tables), which is an advantage over process-based LCA.

Both process-based LCA and IO methods have drawbacks and benefits, so the combination of the two methodologies has therefore been applied in practice successfully (Suh et al., 2004; Treloar et al., 2001). LCA-IO analysis (or hybrid analysis) combines the traditional inventory analysis methods such as process and input-output analysis in order to mitigate the limitations of available data sources and the assessment methods (Crawford, 2008). In such hybrid LCA-IO, the impact of a certain product is analysed with LCA, and the impact of process is estimated with the help of IO. LCA-IO approach allows economic information to be linked to environmental data of each sector and can then be used to calculate the environmental impacts of products covering the full supply chain (Junnila, 2008). LCA-IO method provides several favorable features over process-LCA. Firstly, LCA-IO reconciles the system boundary issue of process-based LCA, since LCA-IO theoretically involves all processes across the whole supply chain. Furthermore, all inputs, materials, resources etc. have to be given only in monetary units, which are more easily and publicly available information. Finally, using IO tables combined with process data ease and accelerate the calculation of processes since a lot of process data is already included in LCA-IO tables (Junnila, 2008). The limitation of this method is that it underachieves the detailed process analysis, because it relies on average product data (Suh et al., 2004; Finnveden et al., 2009).

II. Consumer acceptance of green electricity – Segmentation analysis based on choice experiment in Germany

1. Introduction and Research Goal

With the liberalization of the electricity market in 1998, German residential customers were given the opportunity to freely choose their preferred electricity provider and electricity product from among several competitors. However, despite the fact that recent consumer research in Germany shows that many German citizens have strong preferences for renewable energy sources (Gerpott and Mahmudova, 2010; Kaenzig et al., 2011), the share of green electricity consumers is still in the "single-digit percentage range" (Litvine and Wüstenhagen, 2011). In other words, even when consumers demonstrate a strong preference for green electricity, they are passive in their purchasing decisions to a large extent.

The residential sector accounts for almost 25% of total final electricity consumption in Germany (BMU, 2009). Germany generated about 16 percent of this amount from renewable sources in 2009, with the share increasing to 23 percent in 2012 (BMWI, 2013). Generating electricity from renewable energy sources is fundamentally important in a sustainable and secure energy system (Madlener and Stagl, 2005), and also helps reduce dependence on foreign energy sources and hedge the risk associated with movements in oil and natural gas prices.

In this respect, consumers have the power to express their desire for a more sustainable future by subscribing to a green electricity tariff (Diaz-Rainey and Ashton, 2011). Identifying the consumer segments which are most receptive to purchasing green electricity, exploring what product features those segments value most, and analyzing what distinguishes them from consumers that have already undertaken the switch to green electricity is fundamentally important if targeted messaging is to be developed by policy makers and marketers in order to reach consumers “beyond the eco-niche” (Villiger et al., 2000).

In order to contribute to the existing literature in this field, a novel approach by applying a choice-based conjoint (CBC) analysis is chosen in order to indirectly elicit preferences of a representative sample of the German population for electricity product attributes. Based on CBC data, a latent class approach to market segmentation is then followed through capturing market heterogeneity in attribute preferences across a full set of attributes in order to identify segments with similar preferences (Desarbo et al., 1995).

The first goal of this research is to estimate the proportion of the market that can be reached with green electricity products by identifying different potential green electricity adopter segments with varying degrees of preference for green electricity and other attributes. These findings should help marketers to develop more effective and focused marketing strategies and to enhance product offerings by differentiating electricity products using features other than price, allowing marketers to more effectively satisfy consumers’ needs.

The second goal of the research is to identify factors that differentiate between consumers that have already subscribed to a green electricity tariff and those that display strong preferences towards a green electricity product but have not “walked the talk” (Litvine and Wüstenhagen, 2011). More precisely, an investigation of socio-demographic, psychographic and behavioral variables is used to examine whether those electricity consumers who have strong preferences for environmentally friendly attributes of electricity mixes (Potential Adopters) are significantly different from consumers that have already subscribed to a green electricity tariff (Adopters). The research is thus designed to generate a more sophisticated understanding of the main drivers of the adoption of green electricity and to develop recommendations for green electricity marketers and policy makers about how to better tailor their messages to different customer segments.

Whereas former research has mainly focused on the formation of purchase intention and propensity of customers to buy green products, this research takes a step forward by investigating customers who have already purchased a green product and contrasts them with three different potential adopter segments along socio-demographic variables, psychographic and behavioral characteristics.

2. Related research and development of hypotheses

2.1. Product differentiation of electricity products in liberalized markets

With the introduction of competition to the electricity market, consumers have become able to exercise choice over the electricity product that best fits their preferences, including having the option to choose energy generated from renewable sources. As the tailoring of products in line with customer demand can create competitive advantage, electricity companies are becoming more and more interested in understanding what product features customers prefer, such as green electricity (Kaenzig et al., 2013).

A very substantial stream of literature exists that shows that consumers are willing to pay a premium for electricity generated from renewable energy sources (Amador et al., 2013; Roe et al., 2001; Alvarez-Farizo and Hanley, 2002; Ek, 2005; Bergmann et al., 2006; Wiser, 2007; Longo et al., 2008; Litvine and Wüstenhagen, 2011; Zhang and Wu, 2012; Zoric and Hrovatin, 2012). In addition, different studies have shown that consumers attribute great importance to the energy source of the electricity product when compared to other important product attributes (e.g. price, location of electricity provider, etc.) in their purchasing decisions. Many pieces of research have used conjoint experiment methodology in their analyses (e.g. Cai et al., 1998; Goett et al., 2000; Burkhalter et al., 2009). Rather than directly asking respondents which attributes they consider most important in a product, conjoint analysis requires respondents to evaluate different hypothetical power products. This enables the indirect measurement of the impact of product features on consumer choices. For instance, a recent study by Kaenzig et al. (2013) investigated the relative importance of different product attributes in the purchasing choices of German households. They found that price and electricity mix were the two most important attributes for the average consumer, followed by the location of electricity generation, the price guarantee, certification with an eco-label, type of power provider (e.g. municipal utility or major national provider) and contract cancellation period. Research by Burkhalter et al. (2009) revealed similar findings for the Swiss market. Swiss consumers also considered the electricity mix to be the most important attribute, followed by monthly electricity costs and the location of the electricity generation. Other attributes, such as the electricity supplier, the pricing model, eco-certification and the duration of the contract only played a subordinate role. Rowlands et al. (2003) showed that price, reliability of power supply and environmental features were the most important factors that influence choice of power supplier. Goett et al. (2000) also found that customers were vitally concerned about the provision of renewable energies. A recent study into preferences for electricity attributes in Germany highlighted that the most important product attributes for German customers, besides price and price guarantee, were that the energy provider invests in renewable energy sources and that the power generation was regionally located (Mattes, 2012).

Previous choice-based conjoint research designed to measure the preference for features of electricity products has reported results at an aggregate level. However, measuring preferences for product features at the aggregate level risks masking important distinctions between different segments of consumers. Consumers interested in the energy mix of electricity products generally do not consist of a homogenous block but can be differentiated into several sub-segments. We extended the findings of previous research by identifying, via a post-hoc segmentation approach, three different market segments for potential green electricity consumers. We then explored what product features those different segments consider most desirable when choosing an electricity product.

2.2. Related research on potential adopters of green electricity

Many studies in green marketing attempt to define the characteristic of green consumers for segmentation purposes. In marketing literature, these factors are often classified into the categories of geographic characteristics (e.g. geographic region), demographic and socio-economic characteristics (e.g. age, sex, household size, etc.), psychographic characteristics (e.g. values, life-style and personality variables etc.) and behavioral variables (e.g. purchase occasion) (Kotler and Keller, 2006).

With regard to socio-demographic factors, several studies have focused on investigating the characteristics of potential consumers of green electricity that claim to be willing to pay a premium for green electricity. For example, several authors (Rowlands et al., 2003; Zarnikau, 2003; Ek and Soderholm, 2008; Diaz-Rainey and Ashton, 2011) showed that a higher income tends to increase reported willingness to pay (WTP) a premium for green electricity. Gerpott and Mahmudova (2010) positively correlate household size with WTP for green electricity. In addition, several authors have claimed that WTP for green electricity tends to be positively correlated with a higher level of education (Rowlands et al., 2003; Zarnikau, 2003; Wiser, 2007; Ek and Soderholm, 2008). Regarding other variables, Rowlands et al. (2003) showed that gender did not significantly explain higher WTP for green electricity. Finally, several studies have concluded that consumers who are younger are also more willing to pay a higher premium for green electricity (Zarnikau, 2003; Gerpott and Mahmudova, 2010). Another relevant socio-demographic factor is whether a respondent has undergone a significant life event or change in status such as a divorce or relocation (during relocation, power providers can seize the window of opportunity to encourage consumers to switch energy providers or products). Andreasen suggests that "measures of status change should be seriously considered as predictor variables in future consumer studies in marketing, particularly those concerned with developing market segments" (Andreasen, 1984, p. 794). Mathur et al. (2006) also support using life events in market segmentation.

Although these briefly-summarized findings are far from conclusive they indicate that socio-demographic variables do have an influence on WTP for green electricity and offer an easy way to segment a market. However, most authors agree that particularly psychographic and behavioral characteristics are more important in explaining ecologically friendly behavior (Straughan and Roberts, 1999).

In this respect, Diaz-Rainey and Ashton (2011) have pointed out that knowledge about green electricity has an important influence on preferences for green electricity. In addition, customers with a high price tolerance for green electricity have been characterized as having positive attitudes towards green electricity (Hansla et al., 2008), towards environmental protection (Gerpott and Mahmudova, 2010), or greater concern for environmental problems (Rowlands et al., 2003).

In addition, perceived consumer effectiveness in an environmental context (i.e. the extent to which consumers think their own behavior might help to preserve the environment) has been shown to correlate with higher preference for green electricity. For instance, Rowlands et al. (2003) found perceived consumer effectiveness to be a relatively strong explanatory variable for willingness to pay a premium for green electricity. In terms of behavioral variables, both Gerpott et al. (2001) and Wiser (2007) showed that consumers who are involved in pro-environmental activities have a higher willingness to pay for green electricity. Another relevant factor is whether a respondent has undergone a significant life event or change in status such as a divorce or relocation, which is supported by Mathur et al. (2006) in market segmentation. For instance, Arnold (2011) found out that relocation is correlated to a readiness to pay a surcharge for sustainable products.

2.3. Related research on adopters of green electricity and hypotheses development

In contrast with research that has profiled potential adopters of green electricity, research into the profiles of subscribers of green electricity (Adopters) is relatively scarce; only a few studies have attempted to explore this topic so far (Rose et al., 2002; Clark et al., 2003; Arkesteijn and Oerlemans, 2005; Kotchen and Moore, 2007).

For example, Clark et al. (2003) found that participants in green electricity programs tend to have higher incomes and fewer household members than consumers that have not opted for green electricity. In contrast, Kotchen and Moore (2007) found that demographic variables were not statistically significant in explaining adoption, although attitudinal factors such as environmental concern had a positive effect. Moreover, Arkesteijn and Oerlemans (2005) found a negative correlation between the perceived difference in price of grey and green power and the probability of adoption of green electricity. This finding is in line with a study by Clausen (2008) that found that green electricity buyers in Germany were overestimating the price of green electricity four-fold, whereas non-adopters were on average overestimating the real price by up to ten times. Finally, in a recent study by MacPherson and Lange (2013), it was found that respondents with incomes in the highest income quartile, those with higher levels of education, those who supported the Green party and those who exhibited strongly pro-environmental behaviour were all more likely to have signed up to be supplied with green electricity. Based on former research, the following hypothesis shown in Table 4 were defined.

Table 4: Hypotheses

Variables	Hypotheses
Socio-demographics (H1)	Adopters... • are better educated (H1a), • have higher incomes (H1b), • live in smaller households (H1c) than Potential Adopters.
Psychographical and behavioral characteristics (H2)	Adopters… • are more sensitive to environmental issues (H2a), • perceive the price differential between green and conventional energy to be lower (H2b), than Potential Adopters.

With respect to socio-demographic variables, it is hypothesized (H1) that consumers who have already purchased green electricity are: better educated; have higher incomes and live in smaller households than Potential Adopters.

With regard to psychographic and behavioural variables it is also hypothesized that (H2) Adopters are significantly more sensitive to environmental issues and based on former research, we also hypothesize that a lack of price awareness would be one of the most influential psychographic characteristic that influences adoption of green electricity.

Research has shown that the perception of the price of a certain product or service plays a major role in making purchasing decisions (e.g. Kalwani and Yim, 1992; Kalwani et al., 1990). Several studies have highlighted the role of the gap that may exist between the real and the perceived prices of products (Jacoby and Olson, 1977). Price awareness relates to the ability of the customer to recall, more or less correctly, the price of a product (McGoldrick and Marks, 1987). A recent piece of research regarding grocery products found that between 40% and 50% of the purchases under study were made due to consumers' expectations about prices rather than real, posted prices (Murthi and Rao, 2012). Green electricity, in the past, was typically sold at a higher price (typically from 10 - 30 percent more) than conventional energy (Kotchen and Moore, 2003). Although the real price difference between green electricity and conventional power has significantly decreased over the last decade in Germany, consumers who have not opted for green electricity might still implicitly assume that electricity generated from renewable energy sources costs significantly more. This cost perception may be a component of the attitude-behavior gap, in that the perceived price difference results in an obstacle to the acceptance and uptake of the environmentally-friendly product alternative.

3. Methods

3.1. Chosen stated preference methodology: choice-based conjoint analysis

There are two main approaches of measuring consumer preferences for a certain good or service: (a) the revealed preference and (b) the stated preference methodology (Adamowicz et al., 1994). Revealed preferences can be observed through actual choices made by individuals or households. Assuming that actions undertaken in the past reflect consumers' preferences, this approach is useful for studying preferences for existing products or services. However, new product features can be barely investigated by using historical data (van Oel and van der Berkhof, 2013). In contrast, stated preferences are eligible for investigating both goods available on the market and hypothetical products. The most prevalent stated preference methods are the contingent valuation method and choice experiments. The former approach aims to obtain an economic value for the provision of public goods or services (Mitchell and Carson, 1989). In contrast, choice experiments are widely used in marketing research and are characterized by multinomial discrete choice questions in a choice set. The theoretical background of choice experiments is derived from the classic microeconomic utility theory, which assumes that individuals maximize their utility. This theory was advanced by Lancaster (1966) with shifting the focus on product characteristics from the product itself (Sammer and Wüstenhagen, 2006). This approach is a very suitable for measuring the preferences for hypothetical products or attribute combinations, because when it is not possible to observe the actual purchase behavior or measure preferences through revealed preference methods (Ewing and Sarigöllü, 2000). More precisely, this method provides a real buying situation for respondents, where one or more products are offered to choose one of them. These products differ in their attributes and cannot be combined by the respondents, but they need to choose one 'package' from the choice set (Sammer and Wüstenhagen, 2006). Consumer preferences for product attributes are implicitly derived from the stated choices by indirect type of questioning.

In this study a Choice-based conjoint (CBC) analysis is applied. The CBC method uses hierarchical Bayes (HB) estimations (Orme, 2007) that estimates the distribution of part-worth utility values across the population and combines with the information on individuals' choices to derive posterior or conditional estimates of the individuals' values[2]. With hierarchical Bayes estimations, it is possible to determine individual part-worth utilities to assess heterogeneity among customer segments. This is an advantage in comparison to traditional conjoint approaches based on aggregated preferences measures. The HB model is hierarchical because it applies a lower and an upper level model to calculate the utilities of individual respondents. At the lower level, the probability a respondent selects a particular choice option is assumed to be governed through use of a multinomial logit model. At the upper level, it is assumed that respondents have a single multivariate normal distribution (Rossi and Allenby, 2003; Sawtooth Software, 2009), which can be described as follows:

$$\beta_i \approx Normal(\alpha, D)$$

where β_i is a vector of part-worth utility of individual i; α is a vector of means of the distribution of individuals' part-worth utilities; and D a matrix of variances and covariances of the distribution of part-worth utilities across individuals. The utility (u_k) function of individual i is defined as $u_k = x_k' \beta_i$. The probability of the *k*th alternative that individual *i* selects in a given choice task is:

$$p_k = \frac{exp(x_k' \beta_i)}{\sum_j exp(x_k' \beta_i)}$$

where x_j is a vector of attribute values describing the *j*th alternative in the choice task. The parameters to be estimated are the vectors β_i. The estimation of the part-worth vector is conducted by an iterative process using Markov Chain Monte Carlo method (Rossi et al., 2005).

3.2. Selected product attributes for choice experiment

Choice-based conjoint analysis was used by several scholars to identify which attributes consumers considered most relevant for an electricity product (e.g.

Kaenzig et al., 2013; Cai et al., 1998; Goett et al., 2000; Burkhalter et al., 2009). Research by Burkhalter et al. (2009) revealed similar findings for the Swiss market. Swiss consumers considered the electricity mix to be the most important attribute, followed by monthly electricity costs and the location of the electricity generation. Other attributes, such as the electricity supplier, the pricing model, eco-certification and the duration of the contract only played a subordinate role. Rowlands et al. (2003) showed that price, reliability of power supply and environmental features were the most important factors that influence choice of power supplier. Goett et al. (2000) also found that customers were vitally concerned about the provision of renewable energies. A recent study into preferences for electricity attributes in Germany highlighted that the most important product attributes for German customers, besides price and price guarantee, were that the energy provider invests in renewable energy sources and that the power generation was regionally located (Mattes, 2012).

This study builds on the findings of above-mentioned studies and investigates the relative importance of different product attributes in the purchasing choices of German households. Electricity mix, electricity cost, the location of electricity generation, the type of power provider, price guarantee, certification with an eco-label, (e.g. municipal utility or major national provider) and contract cancellation period are the selected attributes for choice experiment (see Table 10 in Appendix).

Levels of Electrictiy mix are designed to demonstrate the whole offerings from brown to pure green energies. Mix 2 represents the default electricity mix in Germany when the study was carried out, which is dominated by non-renewable energy sources such as coal and nuclear. Mix 3 demonstrates the nuclear phaseout substituting it for natural gas. Mix 4 and 5 are the green mixes with different types of renewable energy sources. Monthly electricity costs varying based on real prices in Germany. The attribute location of electricity generation aims to measure consumers' preferences for domestic, regional or imported electricity. Similarly, the type of power provider offers from small local to big national companies investigates the importance of local energy generation. The attribute price guarantee tries to measure preferences for price stability and attribute cancellation period assesses consumers' commitment to their providers. The attribute certification presents three eco-labels for electricity that exist in Germany and a no certification option (Kaenzig et al., 2013). In Germany the use of different ecol-labels for endorsing products has become more and more popular in the last decades. Certified green electricity products are assumed to be an important factor among customers when choosing energy supplier. Currently, three eco-labels have emerged and become dominant players in green power market certification; ok power, Grüner Strom Label (GSL) and TÜV SÜD. Grüner Strom label is restricted to electricity products generated from renewable sources and it certifies green electricity products. GSL differentiates two levels; Gold and Silver GSL reflecting different environmental quality levels in terms of financial support paid by supplier to eligible RES plants. GSL can only be awarded to those plants, which generate electricity from renewable energy sources and to those CHP plants that are fed with biomass (fossil fuelled CHP plants are excluded). Ok power label accepts energy generation from gas-fired CHP plants as long as the share of electricity does not exceed 50% and fulfills specific emission limits. TÜV is an expansive umbrella organization and operated by regional branches. In green power labeling TÜV Süddeutschland and TÜV Nord are active and award certificates at generation and product levels as well. TÜV label also allows electricity from fossil fuelled CHP plants (maximum of 50%). Eco-labeling is expected to increase market transparency for green electricity products whereby demand for green electricity can be strengthen (Truffer et al., 2001).

3.3. Market segmentation with Choice Based Conjoint analysis

The concept of segmentation, which presupposes heterogeneity in buyer preferences, is not novel. More than three decades ago two main approaches to market segmentation were identified (Wind, 1978; Green, 1977). With *a priori* segmentation respondents are classified into groups on the basis of demographic or socioeconomic variables; using *post hoc* segmentation respondents are clustered according to some interrelated variables (e.g. preferences associated with a product). With conjoint analysis such a post-hoc segmentation approach to market segmentation can be followed by capturing market heterogeneity in attribute preferences across a full set of attributes in order to obtain segments with similar preferences (Desarbo et al., 1995). By knowing the socio-demographic and psychographic and behavioral variable of a segment, marketers are better enabled to define marketing strategies that more closely match consumers' needs.

3.4. Design of study, dataset and method of data collection

An existing data set of a representative sample of German electricity customers was used for the present study. The results obtained for the average electricity customers were reported in Kaenzig et al. (2013). These data are a subsample of a larger representative consumer survey among 1257 German households that was carried out in June 2009 through the project seco@home. For quality and representativity purposes, the market research company GfK was responsible for implementing the survey that recruited along pre-defined quota the respondents via telephone and conducted face-to-face interviews using the computer-assisted personal interview (CAPI) method at the respondents' homes. The interviews lasted approximately one hour on average and contained questions about attitudes towards the environment, questions about the household' energy use and questions on socio-demographic, psychographic and behavioral factors. Whereas these general survey questions were applied to the whole sample, the survey was then split into three different representative subsamples of approximately 400 respondents. Each sample was asked to participate in a choice experiment that was dedicated to a specific theme: heating systems, electricity and household appliances. More precise information regarding the questionnaire and sampling can be found in Rennings et al. (2012).

The research at hand makes use of the data of 414 respondents of the sub-sample that received the choice experiment on electricity products. The data set is based on

4968 choice observations, based on 12 choices completed by each of the 414 respondents. The survey design, the data collection process and the sample are described in detail in Kaenzig et al (2013). The choice experiment was set up in such a way where respondents received a series of 12 choice tasks involving comparisons of different electricity products with varying levels of attributes. By making use of a full-profile design, each choice task presented three different electricity products defined by seven attributes (see Appendix) where respondents had to choose their preferred alternative. The choice tasks that were randomly generated for each respondent were the inputs to a hierarchical Bayesian analysis, which allowed the estimation of part-worth utilities at the individual level. Kaenzig et al. (2013) show that the energy source and monthly electricity costs are the two most important attributes in the average electricity consumer's decision-making. In addition, the authors reveal an implicit average willingness to pay a premium of about 16% for electricity from renewable sources. Kaenzig et al. analyzed the dataset for the entire sample and they mainly reported on one model of preferences that was built for all respondents. The focus of the present study is to go a step further in the analysis of the same data set by identifying, via a latent class approach, the preferences and characteristics of different market segments for potential green electricity consumers. The present study contributes to previous research by generating a richer understanding of possible buyer segments that are likely to be influenced by green attributes of electricity products.

3.5. Selection of variables for profiling segments

In order to explore the characteristics of different consumer segments in the green electricity market, different socio-demographic, psychographic and behavioral variables were selected (Table 5).

Table 5: Selection of variables

<table>
<tr><th>Variables</th><th>Description</th></tr>
<tr><td>Demographics</td><td>
Gender (1= Male; 2= Female),
Age (years),
Household monthly net income (categorical; 1=under 1000 EUR, 2=1000-1499 EUR, 3=1500-1999 EUR, 4=2000-2499 EUR, 5=2500-3499 EUR, 6=more than 3500 EUR),
Education (categorical: 1= no formal education, 2=primary school, 3=secondary school, 4=polytechnic secondary school, 5=college, 6=high school, 7=university degree)
Household size (number of people living in the household)
</td></tr>
<tr><td>Psychographic and behavioral characteristics</td><td>
Relocation (Relocation within the last 5 years, dichotomous, yes/no)
Switching of electricity tariff during the last 5 years (yes/no)
The following variables were chosen to measure the sensitivity to environmental issues

Climate concern - The aggregate level of dis/agreement with the following statements (1: agree, 2:neutral 3: disagree):

Humans are solely responsible for any climate change effects that occur
As a consequence of climate change the quality of life of the population will worsen
Climate change threatens the livelihoods of humankind
There are no serious consequences from climate change

Support for eco-taxes and regulatory tools - Level of dis/agreement with the following statement (1: agree, 2:neutral 3: disagree): Environmental protection should be ensured through the introduction of mandatory eco-taxes and other legislation
Trust in science - Level of dis/agreement with the following statement (1: agree, 2:neutral 3: disagree): Science and technology will solve many environmental problems without requiring changes in our ways of life

</td></tr>
</table>

	▪ *Perceived consumer effectiveness* - Level of dis/agreement with the following statement (1: agree, 2:neutral 3: disagree): As citizens we are able to contribute significantly to protecting the environment through our purchasing behavior ▪ *Awareness of green electricity labels* - TÜV, Grüner Strom Label, ok power (1: knowledge of none of these labels 2: knowledge of at least one label, 3: knowledge of at least two labels) ▪ *Estimation of the cost of green electricity* - What is your estimate about the cost of green electricity compared to conventional electricity? (1: it is much more expensive (more than 10%), 2: a little more (up to 10%), 3: same price, 4: a little cheaper (up to 10%), 5: it is much cheaper (more than 10%) ▪ *Willingness to pay (WTP) for eco-friendly products* - Willing to purchase environmental friendly everyday products (dichotomous, yes/no)

3.6. Model selection for latent class analysis

We used Sawtooth Software and its Latent Class module to conduct the analysis and to reveal respondent segments with similar preference structures in choice data (Sawtooth, 2004). The latent class model included 414 respondents; the outcome of the model, involving four different class solutions (2-class through 5-class solutions), is summarized in Table 6. To determine best model fit we used four main criteria; Percent Certainty (Pct Cert), Consistent Akaike Information Criterion (CAIC), Chi-square and relative Chi-square.

Table 6: Summary of best replications

Groups	Pct Cert	CAIC	Chi Sq	Rel Chi Sq
2	34.18	7631.54	3731.28	79.39
3	37.38	7510.46	4080.62	57.47
4	**38.67**	**7598.59**	**4220.75**	**44.43**
5	39.63	7722.02	4325.57	36.35

Pct Cert is used to reveal how much better an identified solution is compared to the null solution. The process identifies the difference between the final log likelihood and the null log likelihood divided by the negative of the null log likelihood where CAIC is the broadly prevalent variable used for determining the number of groups. The smaller the value of CAIC, the better the solution. Chi-square was obtained by doubling the log likelihood for the solution and subtracting twice the log likelihood for the null solution. Best practice indicates that it is better to use relative Chi Sq (i.e., Chi Sq divided by the number of parameters estimated) to decide best fit because this allows for greater comparability (the higher the value, the better the fit [Sawtooth, 2004]). In this case CAIC was smallest for the three-group solution. However, it was also considered significant that CAIC decreased until the three group solution, remained nearly as low for the four-group solution and increased again in the case of the five-group solution.

The model thus finally chosen was the 4-class model with a Pct Cert of 38.67, a CAIC of 7598.59, Chi-square of 4220.75 and relative Chi-square of 44.43.

4. Results

In this section detailed results from the hierarchical Bayes (HB) estimation for the different segments identified via the latent class segmentation analysis are presented first. A presentation of the socio-demographic, psychographic and behavioral variables of the resulting segments then follows. Finally, the characteristics of

Potential Adopters that were significantly different from those of consumers that had already adopted green electricity are described.

4.1. Preferences for different product attributes

As described above, latent class analysis was conducted prior to using hierarchical Bayes estimation to identify segments. The resulting segment membership information was used to calculate the part-worth utilities and importance scores for the different segments using the underlying hierarchical Bayes utility runs. HB estimation is able to estimate part-worth utilities at the individual level (part-worth utilities describe how much one attribute level contributes to the overall utility of a product [Orme, 2010]).

Table 7 shows the part-worth utilities and the corresponding standard deviations of five different market segments. As described above, four main profiles were identified in the latent class analysis. A group of respondents (n=29) that had already subscribed to a green power tariff were excluded from the sample and thereafter given the name Adopters.

Part-worth utilities were re-scaled and expressed as zero-centered diffs for better comparability between groups. Positive values represent an increase in utility relative to the average level of that particular attribute, while negative values represent decreasing utility. Generally, utility values are dependent on the selected range of attribute levels and should thus primarily be used to compare the part-worth utilities of different levels of a given attribute.

Three out of the four main profiles identified can be described as Potential Adopters based on their clear preference for electricity products derived from a renewable energy source. The remaining segment is the Likely non-adopters segment that is fairly price-sensitive and places significant emphasis on the costs of the monthly electricity product in the decision-making. Members of this group are thus the least likely to choose to buy green electricity at the moment. However, the current segmentation of those consumers with high price sensitivity into Likely non-adopters might not be valid anymore if green electricity sources are able to generate electricity at a cost that would be less or equal to conventional energy sources.

For the next step of the analysis we then used the individual part-worth utilities from the HB analysis and computed attribute importance scores for each segment (see Table 8). Importances describe how much influence each attribute has on the purchase decision. The importance of attributes can be measured by comparing the difference between the highest and the lowest part-worth utility of its levels (Orme, 2010). Importance scores are standardized to sum to 100% across all attributes (Orme, 2010). Since this step is a normalization procedure that attempts to control for scale, the procedure allows for a comparison of the importance scores across segments.

Table 7: Hierarchical Bayes model estimation of mean utility values for five segments

	Adopters	Potential Adopters			Likely Non-adopters
		Truly Greens	Price Sensitive Greens	Local patriots	
Segment size	29	117	78	108	82
Re-scaled part-worth utilities by clusters					
Electricity mix[a]					
Mix 1 (60%C, 25%N, 15%U)	-179.0 (51.7)[b]	-179.8 (38.4)	-135.4 (35.2)	-25.9 (67.3)	-26.7 (45.7)
Mix 2 (60%C, 25%N, 5%H, 5%W, 5%B)	-105.69 (44.3)	-114.7 (26.4)	-67.6 (29.9)	-3.5 (47.1)	-8.7 (33.7)
Mix 3 (60%C, 25%G, 5%H, 5%W, 5%B)	-4.08 (35.2)	-7.3 (34.3)	31.4 (36.9)	16.4 (45.6)	8.3 (30.6)
Mix 4 (50%W, 30%H, 15%B, 5%S)	147.79 (54.8)	141.0 (37.9)	87.0 (36.0)	10.6 (54.5)	10.5 (38.3)
Mix 5 (100%W)	140.99 (70.8)	160.8 (42.9)	84.7 (33.8)	2.5 (67.9)	16.8 (49.0)
Power provider					
Big, national provider	-6.56 (10.3)	-7.2 (10.8)	-7.0 (12.3)	-1.2 (19.7)	-2.8 (12.6)
Medium-sized, regional provider	3.16 (15.6)	4.0 (15.1)	-0.2 (14.6)	2.4 (25.1)	0.4 (15.2)
Municipal	5.27 (13.6)	4.7 (14.7)	7.8 (20.1)	3.4 (25.6)	0.7 (17.3)
Specialized provider	-1.87 (15.1)	-1.5 (15.6)	-0.6 (15.6)	-4.6 (23.4)	1.6 (17.1)
Location of electricity generation					
Local region	16.05 (17.5)	21.0 (21.8)	21.0 (22.9)	54.3 (38.3)	16.9 (18.2)
Germany	19.98 (16.7)	18.7 (19.9)	21.8 (23.2)	53.4 (40.8)	14.8 (19.7)
Switzerland	-3.76 (17.3)	-5.0 (20.6)	-10.4 (24.0)	-37.9 (42.0)	-11.8 (20.8)
Eastern Europe	-32.28 (26.5)	-34.7 (28.2)	-32.5 (30.2)	-69.8 (44.5)	-19.9 (24.9)
Monthly electricity costs					
Costs	-7.98 (5.6)	-6.7 (3.2)	-11.1 (2.7)	-7.9 (4.1)	-18.83 (3.9)

Certification					
Ok power	4.18 (16.5)	1.1 (11.5)	1.4 (14.0)	2.5 (21.2)	-4.1 (13.4)
TÜV	0.91 (12.7)	3.1 (13.1)	7.1 (13.9)	4.6 (22.3)	-0.5 (12.5)
Grüner Strom Label	2.72 (12.9)	1.7 (12.7)	6.6 (11.8)	9.8 (19.0)	11.3 (12.4)
No certification	-7.81 (14.9)	-5.9 (16.8)	-15.1 (16.7)	-16.9 (23.9)	-6.7 (18.2)
Price guarantee					
None	-10.04 (16.9)	-12.0 (14.1)	-21.3 (18.0)	-32.0 (28.1)	-25.0 (18.4)
6 months	-5.57 (13.3)	-1.8 (13.9)	-0.3 (14.9)	3.6 (23.0)	1.5 (14.3)
12 months	9.35 (13.9)	6.4 (15.3)	9.1 (15.9)	5.7 (27.0)	10.9 (13.9)
24 months	6.26 (13.8)	7.4 (17.1)	12.6 (15.8)	22.6 (29.3)	12.6 (19.6)
Cancellation period					
Monthly	4.66 (13.1)	2.5 (14.3)	4.4 (17.8)	9.1 (25.1)	6.2 (17.1)
Quarterly	4.54 (10.0)	4.2 (13.3)	-4.1 (14.6)	0.3 (23.9)	-3.5 (11.9)
Bi-annually	-3.86 (14.1)	-0.9 (15.1)	3.6 (15.5)	-5.3 (23.4)	-0.3 (14.3)
Yearly	-5.34 (11.8)	-5.8 (13.4)	-4.0 (17.2)	-4.1 (26.5)	-2.4 (14.7)
None (would not buy)	158.30 (119.6)	115.8 (106.3)	61.8 (121.2)	126.0 (170.3)	99.5 (151.0)

[a] C=Coal; G=Natural gas; N=Nuclear power; H=Hydropower; W=Wind; B=Biomass; S=Solar; U=Unknown origin.

[b] Standard deviations are shown in parentheses.

Table 8: Attribute importances

	Adopters	Potential adopters Truly Greens	Price Sensitive Greens	Local Patriots	Likely Non-adopters)
Electricity mix	48.6%	50.8%	34.2%	20.9%	14.9%
Power provider	4.8%	4.9%	5.3%	7.8%	5.1%
Location of electricity generation	9.0%	10.0%	10.5%	21.1%	8.4%
Monthly electricity costs	23.2%	19.4%	31.8%	22.8%	53.8%
Certification	4.6%	4.6%	5.5%	8.0%	5.5%
Price guarantee	5.4%	5.6%	7.0%	11.2%	7.4%
Cancellation period	4.4%	4.8%	5.5%	8.1%	4.9%
Total	100%	100%	100%	100%	100%

As shown in Table 8, the most important attribute is the composition of the electricity mix for the three segments Adopters, Truly Greens and Price Sensitive Greens. The second and third most important product attributes are also identical for these three clusters (namely, the monthly electricity cost and the location of electricity generation, respectively). In contrast, Local Patriots consider monthly electricity costs to be the most important product attribute, followed by the location of electricity generation and the electricity mix. The Likely Non-adopters segment regards the monthly electricity costs of an electricity product also to be the most important attribute (54%). In order to detect significant differences in the selected variables described among the five clusters, Mann-Whitney U non-parametric tests were performed. Truly Greens possess similar product attribute preferences to Adopters ($p>0.05$ when comparing preferences at all attribute levels). Adopters significantly more favor an electricity mix consisting of renewable energy resources (Mix 4 and 5) compared to the other three clusters of Potential Adopters. Adopters also significantly negatively prefer electricity mixes containing fossil and nuclear energy resources (compared to all other clusters at $p<0.05$ except compared to Truly Greens). Adopters are significantly less price sensitive compared to Price Sensitive Greens. No significant differences compared to Truly Greens and Local Patriots could be found in this respect. When comparing the differences in preferences between the three segments of Potential Adopters, we can reveal that Price Sensitive Greens attach less importance to the electricity mix and more importance to monthly electricity costs compared to Local Patriots. Local Patriots show the strongest preferences for local electricity generation (within their region or within Germany) compared to all other clusters ($p<0.001$ all cases). Interestingly, the attribute certification was valued the most by Local Patriots in comparison to the other identified segments although it was not statistically significant. Likely non-adopters can be distinguished from other clusters by their low interest in green electricity and their high sensitivity to monthly electricity costs.

4.2. Market segments analyzed by socio-demographic, psychographic and behavioral characteristics

The following step is to analyze whether differences exist between Subscribers[4] of green electricity tariffs and the different segments of Potential Adopters in terms of the characteristics analyzed. Mean values are summarized in Table 9 (in Table 23 in Appendices details the p-levels of selected pairwise comparisons).

Socio-demographic characteristics such as gender, age, household net income and household size were similarly distributed across the five identified clusters with the exception of the level of education. Results show that Adopters were on average better educated, a finding, which correspond to existing research, with one third of the respondents of this group holding a university degree. In contrast, the share of respondents with a university degree from the other four clusters ranged between 7 and 12 percent. Interestingly, the Truly Green segment had on average the least formal education of all the clusters (almost 80% of these respondents had only completed secondary education) yet enjoyed the highest average household net

[4] Adopters and Subscribers are used interchangeably.

income of all the clusters (however, it was not significantly different compared to Adopters). Worth mentioning here is the fact that, while in all clusters income followed a more or less normal distribution, 30% of Adopters could be placed in the highest and 40% in the first and second lowest income categories. This finding should be further explored in future research in order to generate a better understanding of the Subscribers. However, the average income of the Truly Greens segment significantly differed from the average of the Local Patriots and the Likely Non-adopters. Results are therefore in line with those of many other authors (Rowlands et al., 2003; Zarnikau, 2003; Gossling et al., 2005; Wiser, 2007; Ek and Soderholm, 2008; Diaz-Rainey and Ashton, 2011) and reinforce the evidence that preferences for green electricity significantly differ across income groups. 66% of Adopters live alone (i.e. have a smaller household size on average compared to respondents from other clusters) but no statistically significant difference could be found compared to other Potential Adopters. However, the relatively smaller household size might explain the smaller household net income of this group.

With regard to psychographic and behavioral characteristics, segments with a high preference for electricity mixes sourced from renewable energy could be characterized by their higher degree of concern for climate change related issues. Decreases in climate concern are correlated to a decrease in the preference for green electricity. However, no significant difference could be found between Adopters and Truly Greens. Significant differences were, on the other hand, found with variables that measure the sensitivity to environmental issues. More precisely, Potential Adopters agree to a higher extent that science and technology will solve many environmental problems without requiring changes in our ways of life than Adopters do. In addition, supporting eco-taxes is also significantly higher with Adopters than it is with Local Patriots whereas no significant difference could be found in contrast to Truly Greens and Price Sensitive Greens.

In line with previous research that found that perceived consumer effectiveness plays a major role in forming pro-environmental behavior, a significant difference was identified between Potential Adopters and Adopters with regard to the investigated statement.

The perceived price level of green electricity (in contrast to conventional electricity products) differed significantly between Adopters and all other clusters. Only about 10% of Adopters but 25% of the Truly Greens and 43% of the Likely Non-adopters believed that the cost of green electricity would be 10% or more than conventional electricity products. Whereas at the beginning of the process of the liberalization of the electricity market in Germany, green electricity was typically sold at a significantly higher price than electricity produced from conventional energy sources, the price difference has significantly decreased over the last decade. At the time this research was conducted, green tariffs in Germany showed high variability in cost depending on the provider, with some offering cheaper green electricity than conventional electricity. Results are therefore in line with previous research, which showed that erroneous perceptions about the price difference between grey and green power decrease the probability of the adoption of green electricity (Arkesteijn and Oerlemans, 2005). Consumers who have not yet opted for green electricity may still be implicitly assuming that electricity generated from renewable energy sources is significantly more costly, even though reality tells a different story.

In addition, a weak (but significant at 10% significance level) difference between Adopters and Truly Greens with regard to the share of respondents who had moved house within the last five years was found. A more pronounced difference (significant at 5% significance level) was found when comparing Adopters to Local Patriots.

Awareness of green electricity labels also differed significantly between Adopters and two segments of Potential Adopters, the Price Sensitive Greens and the Local Patriots. No significant differences could however be found between Adopters and Truly Greens. Finally, the general willingness-to-pay for eco-friendly products also differed significantly between Adopters and the three segments of Potential Adopters.

Table 9: Descriptive statistics by segment

		Potential Adopters			
	Adopters	**Truly Greens**	**Price Sensitive Greens**	**Local Patriots**	**Likely Non-adopters**
Socio-demographics					
Gender (Females, %)	41.40%	51.30%	52.60%	45.40%	42.70%
Age (years)	47.4 (14.1)	49.1 (12.1)	49.95 (14.5)	51.29 (14.8)	50.93 (12.9)
Level of education	4.5 (2.1)	3.2 (1.5)	3.6 (1.8)	3.5 (1.7)	3.3 (1.6)
Level of income	3.5 (1.9)	3.8 (1.5)	3.5 (1.5)	3.2 (1.6)	2.9(1.4)
Household size	1.86 (0.9)	2.08 (1.1)	2.05 (1.2)	2.18 (1.2)	2.04 (1.1)
Psychographic and behavioral characteristics					
Relocation (yes, %)	45%	27%	33%	25%	25%
Switch of electricity contract (yes, %)	69%	12%	17%	20%	16%
Level of climate concern (high, %)	93%	89%	84%	75%	64%
Perceived consumer effectiveness (agreed, %)	90%	66%	69%	59%	46%
Trust in science (disagreed, %)	72%	45%	35%	35%	40%
Support for eco-taxes (agreed, %)	72%	54%	60%	46%	38%
Awareness of green electricity labels (2 or more, %)	21%	14%	12%	9%	5%
Estimated price premium for green electricity	2.3	1.9	1.9	1.9	1.7
Willingness-to-pay for eco-friendly products (yes, %)	79%	53%	42%	37%	21%

5. Conclusions

Many customers exhibit positive attitudes towards renewable electricity mixes but only a small percentage of them have already opted for green electricity tariffs. The research described in this study was designed to reveal what characteristics distinguish subscribers of green electricity tariffs from potential green electricity adopters in order to provide marketers and policy makers with important information, which might encourage potential adopters to walk the talk. Based on the 4968 experimental choices of a representative sample of 414 German consumers, different consumer segments were identified based on their preferences for different electricity product attributes. Results suggest that the majority of respondents (80%) clearly have a preference for electricity mixes derived from renewable energy sources but only 7% of the sample had already translated their preferences into the purchase of green electricity. The main goal of the research was, correspondingly, to highlight how Adopters differ from those who show interest in renewables but have not subscribed to a green electricity product yet (i.e. Potential Adopters).

Demographic variables were found to play a marginal role in explaining the difference between Adopters and Potential Adopters, which corresponds to findings that emerged from former research (Kotchen and Moore, 2007). With regard to the hypotheses regarding socio-demographic characteristics, the subhypotheses concerning the higher income (H1a) and smaller households (H1c) of Adopters cannot be confirmed by the analysis. On the other hand, results of this study show that Adopters can be characterized by a significantly higher average level of education (i.e. H1b can be confirmed). We can also highlight that gender and age show an equal distribution across the sample.

Results suggest that psychographic and behavioral factors have great explanatory power when it comes to understanding why consumers who evince strong preferences towards electricity produced from renewable energy sources do not act according to their preferences by opting to purchase green power. As for the subhypothesis on the perceived price differential between electricity tariffs, Adopters estimate that the price difference between green and standard electricity tariffs is lower than Potential Adopters (H2b). The subhypothesis regarding Adopters' higher sensitivity to environmental issues is only partly underpinned by the findings since these characteristics are proven to be similar when compared to Truly Greens, but significantly different when compared to the other segments (H2a). Similarly, Adopters show higher awareness of green electricity labels than other segments except for Truly Greens. Adopters also change their place of residence significantly more often than two segments of Potential Adopters and have recently switched more often their electricity tariffs. Adopters can be further characterized by their higher level of perceived consumer effectiveness compared to all other segments of Potential adopters. Regarding price-related variables, Adopters, in contrast to the other segments of Potential adopters, tend to be willing to pay significantly more for eco-friendly products.

For marketers, these findings indicate a major opportunity. Although the number of Adopters of green electricity might still be low, reported customer preferences suggest significant potential for the number of adopters to rise. We can underline the role of a multitude of factors which can be exploited in order to convince consumers to seal the green power deal. Education seems to play an utmost influential role in the purchasing decision and may also make a strong contribution to higher perceived consumer effectiveness. This highlights the necessity of communicating better about the actual impacts of opting for green power. Previous research shows that increasing perceived impact through providing information about social and private benefits can successfully modify purchasing behavior (Litvine and Wüstenhagen, 2011). Findings also draw attention to the existence of inaccurate perceptions about green electricity prices. Respondents were asked about the likely price premium between conventional and green tariffs. The majority of Potential adopters estimated a premium of more than 10%, even though the green tariffs at the time of conducting the survey did not always exceed prices for conventionally-derived energy on the German market. This indicates that more accurate marketing communication about the actual price could pay off in terms of increasing the uptake of green energy tariffs. Another interesting result for marketers is the strong preference of Potential adopters for domestically-produced electricity. This establishes the potential for the implementation of national or regionalized energy policies, such as for instance setting of standards that require the declaration of origin of the electricity source, even though trade-offs with the internal EU electricity market need to be considered. The Local Patriots segment identified in the research places almost the same emphasis on the location of power generation as on the cost of the electricity. Accordingly, advertising the regional origins of electricity might be particularly fruitful for this segment. The two segments Price Sensitive Greens and Truly Greens do not differ with regards to most investigated variables, so they could be targeted with similar messages, however, the Price Sensitive Greens are much more sensitive to an increase in electricity costs. Power marketers could respond to these findings by targeting this segment with lower prices and a slightly lower share of green electricity in the mix.

For policy makers, we can highlight that raising the level of the perceived consumer effectiveness and the feeling of being responsible for climate change can constitute the core of environmental policies. For instance, the segment of Truly greens might be targeted with awareness raising campaigns which draw attention to the importance of individual actions on safeguarding the environment or the responsibility of humans on climate change. Findings show low awareness of eco-labels among electricity consumers that could be an issue for policy makers to elaborate on and help disseminate information on the different certifications existing in the market.

6. Limitations

A standard limitation for any stated preference method is that there might be a gap between stated and revealed preferences. In stated preference methods such as contingent valuation method and discrete choice experiment, the difference of hypothetical and actual statements of value is often wide and this phenomenon is known as hypothetical bias. In other words, that people tend to overstate their economic valuation especially in estimating the value of non-market goods and services. Stated preference methods are often the only technique available for estimating the value of ecosystem services or goods. Since these goods and services are hypothetical in provision, hypothetical bias may often occur e.g. when individuals express how much they would pay for them in a hypothetical market (Murphy et al., 2005). Schläpfer and Fischhoff (2012) found that hypothetical bias can be overcome and the results of stated preferences can be consistent with revealed preferences if the goods and the context are familiar for respondents. This bias can also limited by using indirect questioning techniques for preferences such as discrete choice experiment and designing the survey as close as possible to real purchase situations.

With regard to preferences for product attributes, there is inconsistency detected in people's choices that can be derived from the format of information. Evidences found that people choose what is offered to them as the default. In other words, people's preferences depend mostly on the context of the choice and way it is presented (Pichert and Katsikopoulos, 2008; Chassot et al., 2013).

Finally, it can also be noted that to the fact that this work does not consider that a certain action (e. g. green electricity adoption) could potentially influence other behaviours in different contexts. For instance, participating in green electricity programs could have a knock-on or spill-over effect on other pro-environmental behaviour and lead to a generally wider behaviour or attitude change. In a similar vein, the first study did not consider the link between adopters' a priori and posteriori psychographic and behavioral characteristics e.g. adoption itself may have a transformative effect. It would be worth investigating this phenomenon in a longitudinal study, where the attitude change during the process could be analyzed over time.

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Appendix

Table 10: Choice experiment design: attributes and levels (Kaenzig et al., 2013)

Attribute		Attribute levels
Electricity mix	Mix 1 ('Brown power')	60% coal, 25% nuclear, 15% origin unknown
	Mix 2 ('Default')	60% coal, 25% nuclear, 5% water, 5% wind, 5% biomass
	Mix 3 ('No nuclear')	60% coal, 25% gas, 5% water, 5% wind, 5% biomass
	Mix 4 ('Green power mix')	50% wind, 30% water, 15% biomass, 5% solar
	Mix 5 ('Pure wind')	100% wind
Power provider		Major national provider Medium-sized regional provider Municipal utility Independent power marketer
Location of electricity generation		Local region In Germany In Switzerland In Eastern Europe
Monthly electricity cost		50 Euros 55 Euros 60 Euros 65 Euros 70 Euros
Certification (Eco-Label)		ok power TÜV Grüner Strom Label - No certification
Price guarantee		None 6 months 12 months 24 months
Cancellation period		Monthly Quarterly Bi-annually Yearly

Labels for electricity mixes ('brown power', 'no nuclear', etc.) are used for illustrative purposes here only and this nomenclature was not included in the original survey instrument. Instead, respondents were provided with the detailed percentages of ingredients indicated in the right-hand side column of the table

Table 11: Results of Mann-Whitney U pairwise tests for selected variables

	Adopters vs. Truly Greens	Adopters vs. Price Sensitive Greens	Adopters vs. Local Patriots	Adopters vs. Likely Non-adopters	Truly Greens vs. Price Sensitive Greens	Truly Greens vs. Local Patriots	Truly Greens vs. Likely Non-adopters	Price Sensitive Greens vs. Local Patriots	Price Sensitive Greens vs. Likely Non-adopters	Local Patriots vs. Likely Non-adopters
Socio-demographics										
Gender	0.341 (0.952)[a]	0.306 (1.024)	0.702 (0.383)	0.903 (0.122)	0.861 (0.175)	0.376 (-0.884)	0.233 (-1.192)	0.334 (-0.966)	0.212 (-1.247)	0.713 (-0.368)
Age	0.351 (0.932)	0.426 (0.796)	0.104 (1.627)	0.172 (1.367)	0.994 (0.008)	0.197 (1.290)	0.411 (0.822)	0.302 (1.032)	0.565 (0.575)	0.692 (-0.396)
Level of education	0.004** (-2.873)	0.044** (-2.018)	0.018** (-2.372)	0.006** (-2.768)	0.269 (1.106)	0.471 (0.720)	0.901 (-0.125)	0.646 (-0.459)	0.262 (-1.122)	0.472 (-0.719)
Level of income	0.581 (0.552)	0.843 (0.198)	0.435 (-0.780)	0.207 (-1.262)	0.257 (-1.133)	0.010** (-2.573)	0.000** (-3.758)	0.167 (-1.381)	0.015** (-2.433)	0.306 (-1.024)
Household size	0.396 (0.849)	0.682 (0.410)	0.294 (1.050)	0.476 (0.713)	0.627 (-0.486)	0.679 (0.414)	0.836 (-0.208)	0.428 (0.792)	0.756 (0.311)	0.577 (-0.557)
Psychographic and behavioral characteristics										
Relocation	0.069* (-1.818)	0.274 (-1.093)	0.038** (-2.077)	0.039** (-2.060)	0.372 (0.893)	0.689 (-0.400)	0.641 (-0.467)	0.215 (-1.239)	0.213 (-1.245)	0.923 (-0.096)
Change of electricity contract	0.000** (7.184)	0.000** (5.912)	0.000** (5.423)	0.000** (6.082)	0.491 (-0.688)	0.044** (-2.019)	0.567 (-0.572)	0.256 (-1.136)	0.911 (0.112)	0.204 (1.271)
Level of climate concern	0.455 (-0.748)	0.066* (-1.837)	0.003** (-2.973)	0.001** (-3.356)	0.094* (-1.677)	0.000** (-3.561)	0.000** (-4.000)	0.079* (-1.755)	0.016** (-2.402)	0.425 (-0.797)
Perceived consumer effectiveness	0.010** (2.580)	0.025** (2.244)	0.002** (3.090)	0.000** (4.111)	0.771 (-0.290)	0.277 (1.087)	0.001** (3.241)	0.230 (1.201)	0.003** (3.014)	0.027** (2.205)
Trust in science	0.009** (-2.626)	0.001** (-3.391)	0.000** (-3.518)	0.001** (-3.181)	0.142 (-1.468)	0.105 (-1.623)	0.153 (-1.428)	0.988 (-0.015)	0.949 (-0.063)	0.956 (-0.055)

Support for eco-taxes	0.106 (1.618)	0.268 (1.109)	0.015** (2.425)	0.001** (3.209)	0.508 (-0.662)	0.133 (1.501)	0.003** (3.012)	0.053* (1.933)	0.001** (3.192)	0.097* (1.657)
Awareness of eco-label	0.143 (-1.464)	0.033** (-2.131)	0.011** (-2.547)	0.002** (-3.146)	0.265 (-1.115)	0.083* (-1.734)	0.010** (-2.581)	0.647 (-0.458)	0.188 (-1.317)	0.348 (-0.939)
Price estimation of green electricity	0.008** (-2.670)	0.006** (-2.768)	0.003** (-3.018)	0.001** (-3.425)	0.593 (-0.534)	0.546 (-0.604)	0.047** (-1.988)	0.991 (0.012)	0.178 (-1.347)	0.127 (-1.527)
WTP for eco-friendly products	0.013** (2.495)	0.001** (3.441)	0.000** (4.132)	0.000** (5.761)	0.099* (1.647)	0.007** (2.675)	0.000** (4.893)	0.428 (0.793)	0.002** (3.067)	0.012** (2.503)

[a]Standardized test statistics in the brackets
*** p-level < 10%**

III. Measuring the carbon impacts of residential energy use linked to pro-environmental behavior

1. Introduction

Since many European countries are heavily energy dependent and about one-third of a country's carbon emissions stem from transport and the energy used in households (e.g., IEA, 2007; DEFRA, 2005), the need to encourage low-carbon activities in everyday life and reduce demand for fossil fuels has become the focus of energy and climate-related policies.

The success of such climate and greenhouse gas (GHG)-related policies is found to be highly dependent on the nature of different environmental activities and the positioning and communication of green products (Csutora and Zsóka, 2010; Litvine and Wüstenhagen, 2011). Raising awareness in the residential sector about using renewable energies and reducing energy consumption are both challenging goals. Energy-saving behaviour in private homes has been particularly well-addressed by research and surveys from the field of environmental psychology, as well as in environmental economics, with similar conclusions (e.g. Csutora et al, 2009; Thøgersen and Gronhoj, 2010; Sanne, 2002; Kerekes and Luda, 2011): in order for consumer behaviour to significantly change, both the socio-economic system and sociostructural factors need also to be modified.

The primary focus of the research described was to explore patterns of CO_2 emissions arising from residential energy use in Hungary, since there is considerable potential for energy conservation in this area. This chapter presents a latent cluster analysis of a group of Hungarian consumers in order to explore the effect of pro-environmental behaviour on energy saving and investigates the influence of related socio-demographic and structural characteristics.

The structure of the chapter proceeds as follows. Section 2 discusses the theoretical background behind measuring pro-environmental behavior. In section 3 the research goals and hypothesis are described. Section 4 presents the methodological approach which was used in the research to estimate the CO_2 emisssions of households. Section 5 presents the results of the survey and Latent cluster analysis. Finally, in Section 6 the discussion and main conclusions are drawn.

2. Measuring the effect of pro-environmental behaviour

How people chose to adopt one pro-environmental behaviour but not another is the result of a personal decision-making process with strong interference from an individual's attitude and values, prevailing social norms and assessment of personal costs (Diekmann and Preisendörfer, 1992; Blake, 1999; Stern, 2000). It was recognized even in the 1990s that there is a discrepancy between environmental attitudes and pro-environmental behaviour which can be attributed to the cost of a certain pro-environmental behaviour. Put simply, people usually choose to behave in the way that is the least costly, as expressed in money, time or effort (Diekmann and Preisendörfer, 1992). This finding was confirmed by Kaiser and Wilson (2004) who used the theory of goal-directed performance to characterize behaviour driven by personal effort.

Investigations into what factors trigger pro-environmental behaviour are still underway. Much research has highlighted the failure of environmental policies and has flagged up the idea that there is no linear correlation between reported environmental awareness and knowledge and actual pro-environmental behaviour, or in other words, claimed that there is a barrier between knowledge about environmental issues and pro-environmental action. This is the so-called 'awareness gap' which was identified in the 1980s by many sociologists, psychologists and environmental scientists (Rajecki, 1982; Burgess et al, 1998; Ajzen and Fishbein, 1980) and has been examined at both the individual and company level (Zsóka, 2008). Environmental policies usually focus on raising awareness though environmental education but even early research clearly indicated that education is only one single contributor to pro-environmental behaviour, although it is a very important factor (Owens, 2000; Marjainé et al, 2011). Pro-environmental behaviour is rather driven by a complex system of internal and external factors (Stern et al 1993; Kollmuss and Agyeman, 2002).

Stern (2000) identifies two types of pro-environmental behaviour which he classifies according to the purpose of the behaviour; namely, 'impact' and 'intent-oriented' behaviour. The first focuses on the identification of major human activities which contribute to the human impact on environment, which are regarded as the by-products of human lifestyles. Intent-oriented behaviour emphasizes the importance of an individual's beliefs and values in shaping pro-environmental behaviour leading to the development of the so-called value-belief-norm (VBN) theory of environmentalism. This theory suggests that values (egoistic, altruistic and biospheric values), beliefs (NEP, adverse consequences, acceptance of responsibility) and personal norms influence what environmental activities a person engages in (Guagnano et al, 1995; Stern, 2000). Since then, in environmental psychology the importance of these values for explaining pro-environmental behaviour has been stressed and studied in depth (e.g. de Groot and Steg, 2010; Whitmarsh and O'Neill, 2010). Stern (2000) also highlights the necessity of research into the discrepancy between environmental intent and impact through the following example: many people in the USA still believe that spray cans are harmful to the ozone layer and choose not to use them, even though such ozone layer damage-causing substances have not been used as propellants in the spray cans for many years (Stern, 2000).

Several studies have focused on the relationship between pro-environmental behavior and energy saving in households. Thøgersen and Gronhoj (2010) found that neither motivational nor structural factors independently influence the electricity saving of Danish households. However, they found that sociostructural factors (such as home size and family composition) have a significant effect on a household's electricity consumption, especially through the quantity of electric devices they own and use. Differences in electricity-saving behavior according to gender have also been reported; women report to doing more to save electricity than men, a situation which may be attributed to the fact that women undertake more domestic chores. Interestingly, men are more likely to copy the behaviour of the other members of the household than women. Motivational drivers are related to self-efficacy and outcome expectations (Thøgersen and Gronhoj, 2010). Wang et al. (2011) conducted empirical research in China on the relationship between the willingness and actual behaviour of Beijing residents to save electricity and concluded that economic benefits, comfort and convenience and information are important factors which affect a household's electricity-saving behavior, but the role of environmental awareness in electricity saving is limited. Sardianou (2007) came to the conclusion that income and family size are important variables for explaining energy conservation preferences, and that age and expenditure on energy seem to be negatively correlated to adopting energy-saving behaviours. The authors also concluded that environmentally-conscious respondents are those people who are likely to make efforts to save energy. Hori et al (2013) carried out a survey of energy-saving behavior across five major Asian cities. Their results show that awareness of global warming, environmental behavior and social interaction had a relatively significant role in shaping behaviour, and that income and age also had a weak positive effect.

A lot of surveys have been conducted recently about energy-saving behaviors and regardless of the exact focus of the research they have come to similar conclusions concerning the limited role of environmental awareness in energy-saving behavior. Some of them also focused on the relationship between actual energy use and pro-environmental behavior (Gatersleben et al, 2002; Poortinga et al, 2003; Csutora, 2012). Gatersleben et al (2002) conducted a representative survey among Dutch households which revealed that respondents who claim that they are more pro-environmental do not use less energy. The amount of energy a person uses seems to be more closely related to income and household size than pro-environmental behavior, which is more connected to attitudinal factors (Gatersleben et al, 2002). Poortinga et al (2003) investigates the relationships between values, general environmental concerns, specific environmental beliefs and household energy use. The authors find that environmental behaviors, as defined from an intent-oriented perspective, were related to attitudinal variables. In contrast, environmental behaviors defined from an impact-oriented perspective were not related to such variables. Household energy use appeared to be especially closely related to socio-demographic variables such as household size and income which influence an individual's ability to perform specific behaviors (Poortinga et al, 2003). Csutora (2012) introduced the notion of a 'Behaviour-Impact Gap' (BIG) problem which appears to exist beyond the gap between pro-environmental behavior and the actual environmental impacts of consumers. Her research indicated that there were no significant differences in the ecological footprint of green and brown consumers. This finding draws attention to the fact that individual pro-environmental behaviour does not always reduce the environmental impacts of consumption, which opens the way to an interesting field of research for environmental economics (Csutora, 2012).

3. Research goal and hypothesis

This study contributes to research about the behavior-impact gap problem (Csutora, 2012) by focusing on energy saving behavior in the residential sector. Several studies have been designed to reveal the factors which influence the energy saving behavior of households (Thøgersen and Gronhoj, 2010; Wang et al., 2011; Hori et al, 2013) but only a few of them have investigated the relationship between pro-environmental behavior and actual energy consumption (Gatersleben et al, 2002, Poortinga et al, 2003). This study focuses on profiling consumers according to their pro-environmental behavior and measures actual impacts on energy use (in terms of carbon emissions) between different groups of consumers. Csutora (2012) has also investigated the different environmental impact of green and brown consumers based on pro-environmental behavior in terms of overall ecological footprint. She found that there is no statistically significant difference between the overall ecological footprint of green consumers and brown consumers. Pro-environmental behavior was associated with only a small reduction in ecological footprint in specific areas (Csutora, 2012). The ecological footprint methodology provides a general overview of the environmental impact of human consumption through aggregating different areas such as the environmental impact of food, energy consumption and the impact of international trade etc. and fails to assist with the setting of focused policy targets. There is therefore a need to investigate energy consumption behavior more in detail so that it may better serve policy goals. Although the studies of Gatersleben et al (2002) and Csutora (2012) helped to define the gap between behavior and actual impact, this study takes a step forward in measuring the extent of this gap by presenting the results of latent cluster analysis based on pro-environmental behavior which is directly connected to the actual impact of the energy use of households. In addition, socio-demographic and structural attributes are also investigated based on previous research (Thøgersen and Gronhoj, 2010). The aim of the research presented herein is to identify social clusters whose members may be said to be acting in a (non)-environmentally-friendly way, to investigate the environmental impact of their energy use in terms of CO_2 emissions and finally, to profile these clusters through using their socio-demographic and structural characteristics. This allows the testing of the following hypothesis (H3): people who consciously act in a pro-environmental way (green consumers) are responsible for a similar level of CO_2 emissions to those created by people who do not undertake environmental activities (brown consumers). Confirmation of this hypothesis would serve to strengthen the contention that the positive impact of motivational drivers is offset by structural and socio-demographic factors and would have significant implications for policy makers regarding their efforts to reduce residential energy use. Changing attitudes is indeed a very important (but not the final) step towards creating a low-carbon society. Linking pro-environmental behavior to the carbon emitted through energy use enables the revision of current policy efforts and places the emphasis on undertaking action, which has major environmental impact.

4. Methodological approach

4.1. Pro-environmental behaviour, socio-demographic and structural variables measured in the survey

For measuring current pro-environmental behaviour the traditional methodology used by Eurobarometer was followed. This involves listing activities with both lower and higher environmental impact. The existence of pro-environmental behaviour was measured using 8 items which included all the important environmental activities highlighted by DEFRA (2008) as headline behaviours (energy and water use, waste behaviour, transport-related activity and shopping choices) to which respondents could only give binary – yes/no – answers (see Table 4). DEFRA (2008) has compared the environmental impacts of these different pro-environmental behaviours (expressed in kg of CO_2 emissions) and has identified the current take up of these behaviours in the UK. Reducing transport-related activities (especially using cars and air transport) has the most significant impact on CO_2 mitigation. Making energy savings and cutting back on consumption of food (especially meat) are of great significance as well but have lower impact. Recycling activities have a mid-level impact and the least effective activities of all involve buying energy efficient products, reducing the amount of water used and buying local food (DEFRA, 2008).

Recycling does not have a great impact on protecting the environment but is considered to be a very important component of pro-environmental behaviour. It is regarded as a ‘catalyst’ behaviour (Austin et al., 2011), which is assumed to positively affect the adaptation of other pro-environmental behaviours. Thøgersen (1999) examined the role of recycling in decreasing the amount of packaging waste in Danish households and concluded that it had a positive influence (also known as a positive spill over effect in the literature). On the other hand, other authors (Wenke, 1993; Tucker and Douglas, 2006) emphasize the fact that recycling may lead to negative spill over effects by providing people with an excuse to avoid undertaking more impactful actions such as reducing their household waste.

Relevant socio-demographic and structural variables were selected based on an overview of literature. In Table 10 the variables and description selected for the analysis are summarized.

Table 12: Selected socio-demographic and structural variables

Variables	Description
Socio-demographics	• *Gender* (1= Male; 2= Female), • *Age* (years), • *Household monthly net income* (categorical; 1 to 5 scale), • *Education* (categorical, 1: eight years of primary school or less, 2: technical college, skilled worker, 3: High school diploma or higher accredited qualification, 4: University degree), • *Household size* (number of family members including respondent)
Structural variables	• *Type of house* (categorical; 1: apartment house, 2:new estate, 3: Terraced house, 4: Detached and Semi-detached house, 5: Farmhouse) • *Number of rooms* • *Size of house* (square meters) • *Energy efficiency* (quantity of electrical devices, scale: 0-8 devices) • *Car ownership* (binary, yes/no) • *Travel to workplace* (categorical; car or other vehicle including bicycle, public transportation, motorcycle, by foot) • *Free time travel* (Binary; yes/no, Do you typically spend your free time travelling?)

4.2. Survey method

To determine the total CO_2 emissions of households, a survey-based approach was utilised in which data were collected about the direct and indirect fuel consumption of households, including their use of heating, transport activities and electricity.

This empirical research is based on a representative survey of 1012 respondents carried out in the first half of 2010 in Hungary. Data were collected about the expenditure, consumption patterns, environmental attitudes and life satisfaction of consumers. Personal (face-to-face) interviewing was undertaken by a surveying company (TARKI) which used a representative probability sample representative of the population aged 18 or older in terms of gender, education, type of settlement, and educational background. The random walk technique was used to select the dwelling and personal interviews were conducted with one member of each selected household using the Leslie Kish key method.

Questions about energy consumption focused on respondents' monthly or annually energy expenses for heating and electricity, since it was assumed that the respondents would identify these expenditures more accurately than they would be able to report on physical units of energy consumed. Besides providing details about their expenditure, the types of heating used and their share of total energy use were also investigated (respondents could choose as many heating sources as were relevant from the following list: LP-gas, district heating and coal and renewable energy sources (directly produced by households, e.g. PV, solar, geothermal)). Expenditures for heating were first converted into physical units (GJ) using the average price for a unit of energy (KSH, 2012) and CO_2 emissions were then calculated according to IPCC (2006) estimates about stationary combustion sources in the residential sector. Expenditure on electricity was first converted to TWh, then disaggregated by the different source (for electricity generation in different power plants) and finally also converted into CO_2 emissions according to IPCC estimates.

For transportation, details about the distances travelled by passenger car, coach and train and the hours spent using air transport and public transport were collected. Transportation data were converted firstly to passenger kilometres for vehicles. CO_2 emissions are based on IPCC (2006) estimates of mobile combustion values.

4.3. Statistical analysis

To investigate how reported environmental behaviours are connected to each other and how they are connected to actual environmental impacts in terms of CO_2, social clusters were identified with the use of a latent class model.

Latent cluster analysis is an analytical method which can be used to determine subgroups or classes of observations that are similar to each other along multiple observed variables using model-based, posterior membership probabilities (in opposition to traditional cluster analysis, which uses ad hoc distance definitions to create clusters). Latent cluster analysis also includes a K-category latent variable, with each category representing a cluster containing a homogeneous group of persons (cases). Moreover, a latent class model enables the user to cluster dichotomous as well as categorical and continuous variables. Model estimations were carried out using Latent Gold 4.5 software (Vermunt and Magidson, 2005).

In the analysis consecutive cluster models are compared on the basis of different model parameters. The indicator variables were the eight types of environmental activities, which respondents undertook during the last month for environmental reasons. All eight items were coded in a binary manner: either 0 (= have not done) or 1 (= have done). Selection of the model with the best data fit was done using the following model parameters: likelihood-ratio (L^2) and its p-value, the Bayesian Information Criterion (BIC) and the number of parameters (Npar).

The L^2 likelihood-ratio statistic shows the amount of association between the variables that remains unexplained by the model. The p-value of L^2 also measures the fit of the model and it assumes that the L^2 parameter follows a chi-square distribution (consequently, a p-value of greater than 0.05 is desired for an adequate fit). The Bayesian Information Criteria takes the number of parameters into account to compare the models; a smaller BIC indicates a better fit. Finally, the model with the fewest number of parameters (Npar) (i.e. the most parsimonious model) is selected (Vermunt and Magidson, 2005).

Because a number of variables were modelled and the data for individual response categories was in some cases sparse, the p-value by bootstrap of L^2 (n=500 iterations) was also estimated. This relaxes the assumption that the L^2 statistic should follow a chi-square distribution. Because these were nested models we also used a conditional bootstrap option (n=500 iterations) for computing the difference in the log-likelihood statistics between the two models (-2LL Diff) to see if adding another cluster significantly improved the model fit. In the final model, the bivariate residuals are examined to assess how well the model explained the correlation between each of the variables.

5. Results

6.1. CO_2 emissions from residential energy use

Figure 4 shows energy consumption and CO_2 emissions by method of heating, according to the results of the survey. Having several sources of heating (e.g. having piped gas and a fireplace in the house which is fed with wood or coal) is very typical of Hungarian homes. Gas heating is available almost everywhere in the country but its dominant role as a heat supply system has created political dependencies for the country. District heating is widespread, especially in new estates in Hungary, and it is not usually combined with the use of any other energy resources. 50% of respondents reported that they used natural gas, 38% wood, 20% district heating, 6% coal and 3% LP-gas (numbers do not sum up to 100% because of cases of combined use). Other sources of energy such as renewable energy technologies were being used in 6 cases so these data were excluded from the statistical analysis.

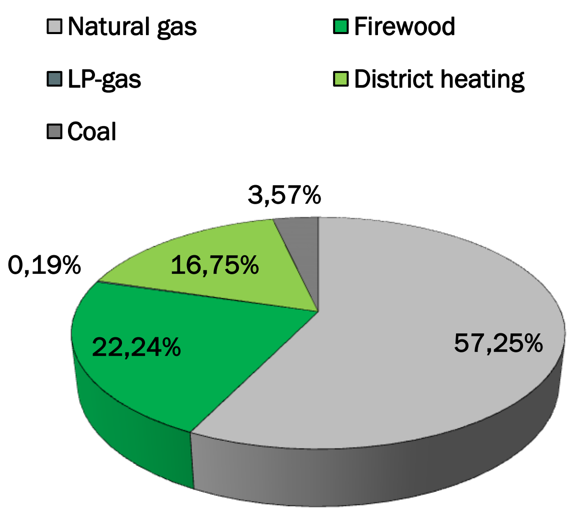

Figure 4: CO_2 emission by heating type

Firewood has a significant share in the residential sector both in terms of provision of energy (36.74%) and CO_2 emissions (22.24%). Statistics indicate a remarkable rise in the consumption of firewood in Hungary over the last two decades; in 1996 it accounted only for 17% of the domestic energy mix but by

2008 this had risen to 27% (KSH, 2012). This trend might be an indicator of illegal tree felling. According to estimates there is a significant difference between officially reported statistics about sales of wood and the actual firewood consumption of Hungarians. The actual firewood consumption as calculated by data from household panel surveys is approximately four times higher than reported in national statistical databases (Szajkó et al., 2009). According to EU Directive 2009/28/EC, the emissions which stem from renewable sources such as biomass should be accounted for at zero[5]. The IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories report (2006) also gives some attention to non-traded fuels, especially to firewood, and notes how inaccurate indirect estimations of its consumption may be. During the calculations made for this piece of research, emissions from firewood combustion were reduced by 30% from the original level because it was assumed that 30% of the firewood consumed is illegally-traded and is presumably not taken from areas where sustainable forest management is practiced.

Hungary is not an electricity-intensive country on a per capita basis. For instance, in 2008 electricity consumption per capita (all sectors included) amounted to about 4092 kWh, which is considerably lower than the European average of about 6000 kWh per capita (the world average is about 3000 kWh) (IEA, 2007). The Hungarian household sector is responsible for about 25.78% of all electricity consumed in Hungary. Using electricity for heating purposes is not common. However, electricity consumption has also increased by 25-28% in the residential sector over the past 15 years, mainly due to the increasing use of electrical devices in households. The share of renewable energy resources in the energy mix is still negligible, except for biomass which is mainly used in heat and CHP power stations. In Hungary electricity is generated primarily from natural gas (38%) and nuclear power (37%), and secondly from coal and oil (18%). The share of wind power, hydropower, biomass and other renewable energy resources is still not significant in the electrical energy mix (these sources

[5] EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources in Annex V: *"Emissions from the fuel in use shall be taken to be zero for biofuels and bioliquids"*. The manual of the EU Air Emission Account (2009) says that "*Countries are requested to separately report emissions of CO_2 from biomass (wood and wood waste, charcoal, bio-alcohol, black liquor, landfill gas, household waste, etc.) used as fuel. The emissions of CO_2 from biomass are not included in the total CO_2 emissions in greenhouse gas emissions inventories reported to the UNFCCC, they are reported only as a memo item. For the purposes of air emissions accounts these emissions should be reported separately from non-biomass CO_2*".

combined account for 6.51% of total energy) (MAVIR, 2008). Although the share of coal and oil is significantly lower, nuclear energy has a relatively large share of the energy mix and is hindering a switch to renewable energy technologies. However, it creates the lowest specific CO_2 emissions per GWh (see Figure 5).

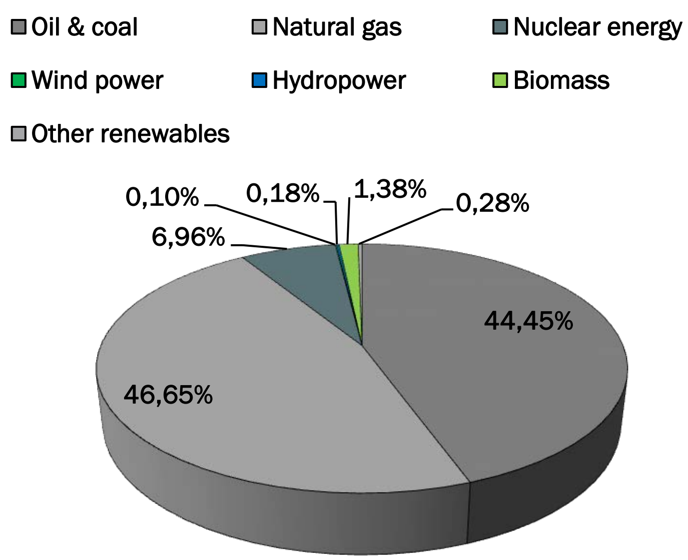

Figure 5: Calculated CO_2 emission from electricity generation by source

In the questionnaire, household transport activities were divided into the categories of passenger car, railway, coach and air transport and urban public transportation (including tram, bus and underground). According to the related responses 795 kgCO_2/capita is emitted annually on average for transport, of which almost two thirds is produced from the use of passenger cars. In Hungary, 63% of domestic passenger kms are travelled using passenger cars, 9% by railway transport, 13% by coach, 6% by air transport, and 9% by urban public transport (KSH, 2012). Figure 6 depicts the calculated carbon emissions of different types of passenger transport in terms of domestic passenger kms based on survey results.

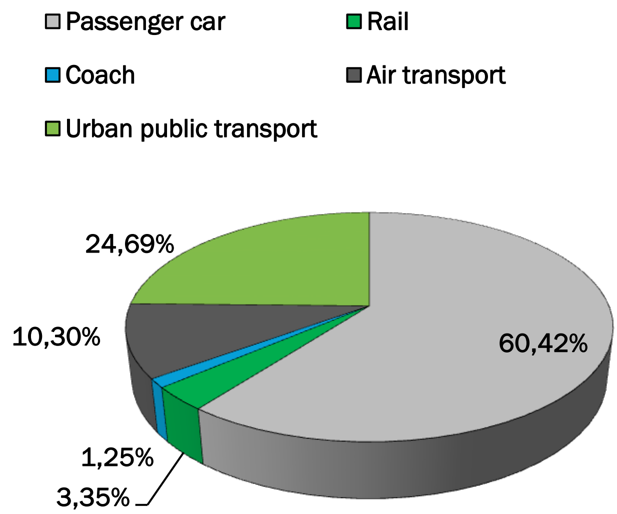

Figure 6: Calculated CO_2 emission of passenger transport types

In official statistics data usually are recorded according to the location of combustion and not the purpose. For the currently-described analysis all CO_2 emissions related to residential fuel use which could be consciously controlled by consumers were accounted for according to the reason for their consumption. Table 11 presents a summary of the emissions that occurred as a consequence of the domestic consumption of fuels by Hungarians.

Table 13: Direct and indirect CO_2 emissions from residential use of different fuels ($kgCO_2$/capita)

Residential CO_2 emission	Frequency	Percent within sample	$kgCO_2$/cap Mean (divided by frequency)	$kgCO_2$/cap Std. deviation	$kgCO_2$/cap Mean (divided by sample=1012)
…from heating activities					
Natural gas	505	50%	1 600	1 354	798
Firewood	380	38%	826	2 364	310
LP-gas	26	3%	104	140	3
Coal	56	6%	899	731	50
District heating	206	20%	1 148	775	234
…from transport activities					
Passenger cars	586	58%	830	1 815	481

Rail	302	30%	89	196	27
Coach	440	43%	23	55	10
Air transport	53	5%	1 566	3 268	82
Urban public transport	359	35%	554	565	196
… from electricity use					
Electricity generation	975	96%	416	349	401
Total CO_2 emissions					**2 591**

Adding up the mean values and dividing by the sample gives a total of 2591 $kgCO_2$/capita emitted from residential activities, the major components of which are heating, transport and electricity (53.8 %, 30.7 % and 15.5 %, respectively).

6.2. Results of Latent Cluster Analysis

Survey results show some correspondence with findings reported in DEFRA (2008); the most popular environmental activities of respondents include recycling (18.67%), using public transport (17.98%), undertaking energy reduction activities (17.79%) and water reduction measures (15.34%). Recycling and energy reduction are the most commonly-undertaken pro-environmental behaviours of respondents according to DEFRA (2008); this fact was also confirmed by the Hungarian results.

In the analysis, different groups of people may be identified based on their reported environmental activities from the past (i.e. based on the 8 survey items). Latent cluster model was applied to classify respondents into clusters.

The latent cluster analyses included 1005 cases and models which estimated 1-class through 5-class solutions and were compared (Table 12) using the four main criteria; L^2, its p-value, BIC and number of parameters estimated.

The best model is a 4-cluster model with values of L^2 of 243.78, a p-value of 0.13, BIC of 8368.90 and Npar of 35. The 4-class model was also assessed using an L^2 bootstrap procedure to estimate the p-value (p=0.13). From this, four statistically significant clusters were identified that show four profiles on the basis of environmental behaviour (Table 13). The profile output table contains the size of each cluster (for each one, the numbers sum to 100%). The body of the table consists of marginal conditional probabilities that show the relationship of the clusters identified to the indicator variables, and within each variable the probabilities sum to 1 (Vermunt and Magidson, 2005).

Table 14: Latent class model selection

	LL	BIC(LL)	Npar	L¿	df	p-value	Class.Err.
1-Cluster	-4364,09	8783,486	8	845,0104	247	1,90E-66	0
2-Cluster	-4136,14	8389,79	17	389,0997	238	2,20E-09	0,1235
3-Cluster	-4092,44	8364,613	26	301,7086	229	0,00089	0,1742
4-Cluster	-4063,48	8368,906	35	243,7869	220	0,13	0,2391
5-Cluster	-4045,78	8395,717	44	208,3826	211	0,54	0,2562

A total of 27.66% of all respondents were assigned to Cluster 1, 36.22% to Cluster 2, 24.08% to Cluster 3, and 12.04% to Cluster 4. The four clusters seem to generally differentiate respondents’ environmental behaviour very well. Cluster 4 contains the most environmentally active people; these individuals carry out the most environmental activities and there is a greater probability that they might undertake all environmental activities except for reducing their consumption of water. People from this group are from now on called the ’Supergreens’. Cluster 3 members have a lower probability of undertaking environmental activities than Cluster 4, excluding cutting back on consumption of water and energy. Members of this cluster seem to be very keen on saving energy, so these people are called the ‘Energy savers’. Respondents in Cluster 1 seem to be at the first stage of taking up environmentally friendly behaviours such as using greener methods of travelling or recycling and they have a medium, high or low probability of doing the rest of the activities (‘Beginners’). Cluster 2 (which accounts for more than the one third of the sample) represents so-called ‘Brown’ consumers, who were not willing to act in an environmentally-friendly way in any field of activity.

Table 15: The size of latent clusters and the profile output

		Cluster 1: Beginners	Cluster 2: Browns	Cluster 3: Energy savers	Cluster 4: Supergreens
Cluster Size		27.66%	36.22%	24.08%	12.04%
Profile					
Has chosen more environmentally friendly ways of travelling (on foot, bicycle or public transport)	0	0.53	0.88	0.70	0.06
	1	0.47	0.12	0.30	0.94
Has reduced their consumption of disposable items (plastic bags, certain kind of packaging, etc.)	0	0.78	1.00	0.71	0.42
	1	0.22	0.00	0.29	0.58
Has separated most of their waste for recycling	0	0.51	0.82	0.67	0.21
	1	0.49	0.18	0.33	0.79
Has cut down their water consumption (e. g. not leaving water running when washing the dishes or taking a shower, etc.)	0	0.90	0.97	0.19	0.30
	1	0.10	0.03	0.81	0.70
Has cut down their energy consumption (e. g. turning down air conditioning or heating, not leaving appliances on stand-by, buying energy saving light bulbs, buying energy efficient appliances, etc.)	0	0.74	0.94	0.29	0.20
	1	0.26	0.06	0.71	0.80
Has bought environmentally friendly products marked with an environmental label	0	0.89	1.00	0.88	0.72
	1	0.11	0.00	0.12	0.28
Has chosen locally-produced products or groceries	0	0.69	1.00	0.86	0.37
	1	0.31	0.00	0.14	0.63
Has used car less	0	0.91	0.99	0.92	0.64
	1	0.09	0.01	0.08	0.36

As reported above, recycling is the most prevalent form of environmental activity and it does seem to be a trigger behaviour, since it is done by many Browns and Beginners.

Statistical relationships were investigated between the CO_2 emissions of electricity use, heating and transport activities and pro-environmental behaviours for each of the four clusters. Figure 7 depicts the mean values for $kgCO_2$ per capita emissions stemming from transport, heating and electricity use of the residential sector according to the four clusters.

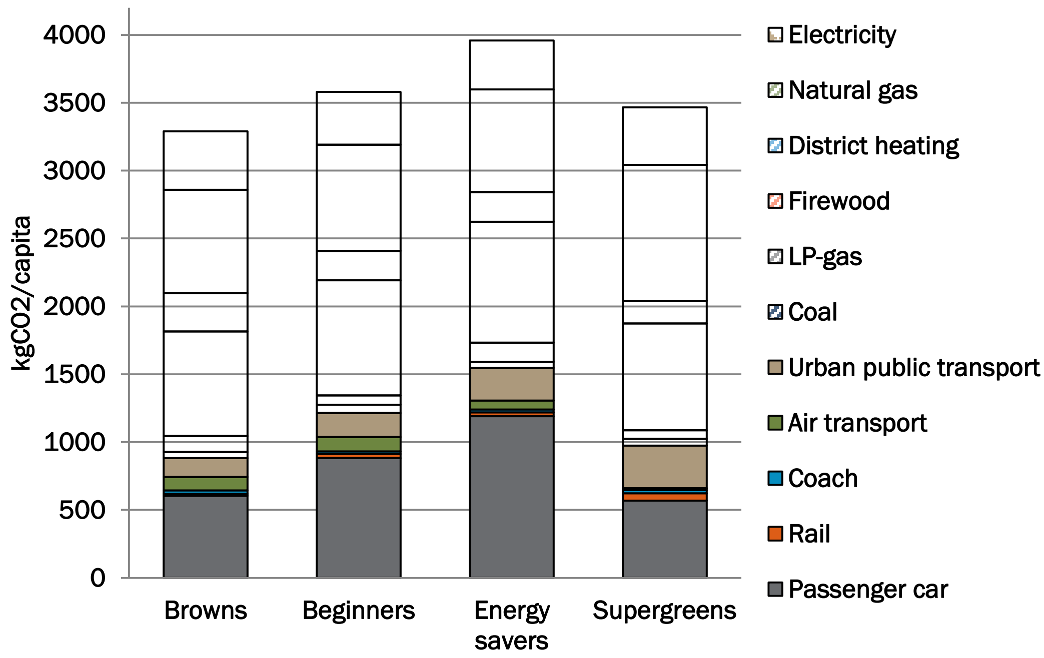

Figure 7: kgCO_2/capita emissions from energy consumption by cluster

The differences in medians among clusters were tested with a series of Mann-Whitney non-parametric tests (see Table 14). The total CO_2 emissions from the total energy consumption of the clusters Supergreens (3467 kgCO_2/cap) and Browns (3289 kgCO_2/cap) differ significantly from each other (p=0.010), which can be attributed to the use of urban public transport; Supergreens use this mode of transport significantly more often. Surprisingly, Energy savers have statistically significantly higher total CO_2 emissions (3959 kgCO_2/cap) than all other clusters; Beginners (3578 kgCO_2/cap) have slightly lower per capita emissions. Although the clusters basically do not show any difference according to electricity consumption, Browns along with Supergreens consume the most electrical energy (13% and 12% of total kgCO_2/cap emission, respectively). Energy savers use the least electricity (9%) and their consumption is statistically different from that of the Supergreens. Overall CO_2 emissions from heating are not statistically different between clusters, although Browns emit the lowest and Supergreens the most; 1977 and 2066 kgCO_2/cap, respectively. Structurally, 60% of total carbon emissions for Browns and Supergreens are produced through their use of heating, and 55% for Beginners and 52% for Energy savers. Browns emit the least CO_2 due to their lower demands for transportation (881kgCO_2/cap, 27% of total emissions). Energy savers use significantly less natural gas for heating than Browns or Supergreens do. While Energy savers cut back on their use of electricity and heating, they use cars more heavily (1190 kgCO_2/cap) than other clusters do and their carbon emissions from transportation are 1.7 times higher (1547 kgCO_2/cap) which accounts for 39% of their total emissions. Supergreens, according to their answers to survey questions, use their cars the least and use public transportation more (974 kgCO_2/cap, 28% of total emissions).

In order to test what relationship exists between clusters and socio-demographic and structural characteristics, Mann-Whitney non-parametric tests were conducted. Table 14 and Table 24 in Appendices show the socio-demographic and structural features of each cluster: gender, age, education, monthly net household income, household size, type of house, number of rooms, the size of the house, energy efficiency, car ownership, the method of travelling to the workplace and free time spent travelling.

In contrast to the work of Thøgersen and Gronhoj (2010), gender, age and household size do not seem to be related to pro-environmental behaviour or energy use. As discussed above, education can play an influential role in forming pro-environmental behaviour; i.e. better qualified people tend to act in a more environmentally-friendly way, although the relationship between education and pro-environmental behaviour should not be over-generalised and cannot be considered linear. Almost all the clusters differ from each other according to educational background; the most qualified people are Supergreens, of whom about 24% hold university degrees (in this group the fewest respondents from all the groups (14%) have had only 8 years of primary schooling). Brown consumers are on average least educated and there is a significant difference between almost all clusters except for Supergreens and Beginners in terms of education.

As might be expected, Supergreens have the highest average monthly net income while Browns are the poorest, on average. Energy savers have a similar income level to Supergreens and Beginners. The financial states of respondents are also underpinned by other features such as the size and type of their houses and number of rooms. ‘Supergreens’ possess the largest houses with the greatest number of rooms and the majority of them live in detached or semi-detached houses. Only 19% of the respondents of this cluster live in new estates where people of lower incomes typically reside. Energy savers have similar housing situations to Supergreens; 61% of them live in detached or semi-detached houses, but the size of their homes, along with the number of rooms differentiates them from Supergreens. Brown consumers differ significantly from Supergreens and Energy savers regarding the features of their houses.

'Energy efficiency' measures the quantity of electrical devices and appliances a respondent has (refrigerator, freezer, air-conditioner, washing machine, computers, etc.). This factor also differentiates clusters; Supergreens tend to have the most household devices of all clusters, which explains their higher consumption of electricity.

The most significant difference can be observed with ownership of cars and the way respondents travel to their places of work. Although more Supergreens have cars than other clusters, they still prefer to use alternative ways of travelling to work. Browns and Energy savers use their cars the most, presumably on a daily basis, for travelling to their workplaces. Browns spend their free time travelling the least of all clusters, but in other cases this variable does not seem to be strongly related to pro-environmental behaviour.

Table 16: Results of Mann-Whitney U pairwise test by cluster

	Browns vs Supergreens	Browns vs Energy savers	Browns vs Beginners	Energy savers vs Supergreens	Energy savers vs Beginners	Supergreens vs Beginners
CO_2 emissions by electricity, heating and transport activities						
Electricity	0.200	0.291	0.693	0.034**	0.504	0.112
Natural gas	0.866	0.047**	0.203	0.060*	0.452	0.186
District heating	0.464	0.816	0.000**	0.499	0.001**	0.117
Firewood	0.711	0.322	0.941	0.744	0.471	0.805
LP-gas	0.837	0.209	0.407	0.667	0.429	1.000
Coal	0.401	0.879	0.681	0.234	0.763	0.186
Urban public transport	0.01**	0.598	0.826	0.052*	0.493	0.006**
Air transport	0.291	0.359	0.703	0.355	0.335	0.265
Coach	0.070*	0.627	0.141	0.133	0.281	0.485
Rail	0.310	0.985	0.126	0.251	0.071*	0.657
Passenger car	0.512	0.005**	0.833	0.003**	0.013**	0.364
Socio-demographic and structural variables						
Gender	0.355	0.384	0.738	0.822	0.261	0.257
Age	0.416	0.409	0.251	0.963	0.764	0.794
Education	0.000**	0.043**	0.000**	0.014**	0.088*	0.248
Household net income	0.001**	0.019**	0.014**	0.113	0.786	0.186
Household size	0.144	0.135	0.585	0.774	0.293	0.252
Type of house	0.061*	0.076*	0.140	0.620	0.730	0.464
Number of rooms	0.000**	0.075*	0.033**	0.004**	0.811	0.005**

Size of house	0.000**	0.045**	0.831	0.035**	0.090*	0.001**
Energy efficiency	0.000**	0.000**	0.000**	0.013**	0.867	0.016**
Car ownership	0.000**	0.000**	0.005**	0.046**	0.345	0.005**
Travel to workplace	0.011**	0.672	0.104	0.006**	0.050**	0.185
Free time travel	0.708	0.139	0.008**	0.455	0.302	0.111

**** p-level < 0.05**
***   p-level < 0.10**

7. Discussion and conclusions

The main finding of this study is that undertaking environmental activities does not necessarily result in tangible overall decreases in environmental impact or CO_2 mitigation.

Four main profiles were identified on the basis of the environmental actions taken by respondents. Two clusters describe people who undertake energy-saving behaviour; Energy savers and Supergreens. Respondents from the latter cluster undertake a range of environmental activities, including reducing their energy consumption and travelling in more environmentally friendly ways instead of using cars. In accordance with these statements, this cluster has the lowest carbon emissions for car use. However, their emissions due to energy consumption for heating and electricity are, on average, similar to those of Browns. Moreover, in some cases they exceed them.

It is notable that there is a trade-off between using natural gas and firewood for heating in Hungary. Since wood is a relatively inexpensive form of heating and has been promoted by EU Directives as a renewable source of energy it has become more and more popular over the last decade and now constitutes an important heating source, which may substitute for natural gas. In some cases respondents reported that they owned mixed-fuel boilers which can combine wood burning with gas heating systems. Energy savers use the most firewood in their heating mix. The use of coal and LP-gas no longer prevails in Hungary. District heating is the only form of heating which creates indirect CO_2 emissions, since combustion occurs in heat and CHP plants and not at the location of the end user. Having this form of heating means that a customer is locked-in from an infrastructural perspective (i.e. these consumers are not usually able to switch to using other energy sources, regardless of their wishes).

Energy-saving behaviour is one of the most popular environmental activities although it is difficult to specify the reasons for this; is it driven by environmental concern or a desire to reduce costs. This survey indicated that Energy savers generally have lower incomes. It is also remarkable that Energy savers appear willing to cut back on direct consumption of energy but they pollute significantly more through their use of passenger cars.

The central hypothesis of this research (H3), that people who consciously act in a pro-environmental way do not necessarily impact CO_2 emissions more than those who do not undertake environmental activities is partly confirmed; there were no significant differences found between groups in terms of electricity use or heating activities - only with transport activities. This finding has implications for environmental and energy policy-making.

There are two main approaches in the literature to reducing consumption and environmental load; voluntarism and structural approaches. Voluntarism can be increased through awareness-raising campaigns, education-related drives and increasing the willingness to live an environmentally-friendly lifestyle. Socio-structural approaches address the living conditions and circumstances that lock consumers into living unsustainable lifestyles and include factors such as working conditions, size of homes, family sizes, etc. (Sanne, 2002; Thøgersen and Gronhoj, 2010). Whilst studies emphasize that both approaches are needed to increase pro-environmental behaviour, fewer studies have paid attention to identifying how the approaches and behaviour changes *actually impact* the environment. Thus, the second finding of this research is striking: that there may actually be no difference between environmentally-conscious and environmentally indifferent individuals in terms of their energy-related CO_2 emissions. Browns and Supergreens emit almost the same amount of carbon because the voluntarism of Supergreens is offset by structural factors which, at the same time, reduce the consumption and carbon emissions of Browns. The finding indicates that pro-environmental behaviours are limited in impact and may be dominated by structural factors. Interestingly, this situation appears in the case of heating and electricity but not with transportation. There has been a remarkable increase in private car use in almost all European countries which is one of the main reasons for the increase in carbon emissions due to transportation (EUROSTAT, 2010). Supergreens appear to be using cars less, although they are more likely to own them than respondents from other clusters, and they are more likely to choose alternative ways of travelling to their workplaces than other respondents. This indicates that motivational factors can make a real difference in terms of CO_2 emissions. The consumption of energy for heating and electricity seem to be influenced rather by socio-structural factors, such as income, size of home and quantity of electric devices.

These inferences are important enough to merit attention in future research and draw the attention of policy makers and NGOs. The message is to focus on the real environmental impact of environmentally-friendly behaviour rather than examine the frequency of its occurrence. The cost of marginal environmental action can overcome its benefits in the long term. There is a lack of public understanding about the impact of environmental action which may lead to redundant efforts being made, a limit in the environmental benefits that are achieved and the demoralization of consumers.

The findings described have relevant implications for environmental and energy policies. For policy makers, the findings presented in this chapter suggest that, besides introducing policy measures that encourage environmentally friendly and energy-saving behaviour, especially in the transport sector, there is a need for instruments that also tackle socio-structural factors to be designed, not only those that address the promotion of pro-environmental behaviour.

8. Acknowledgements

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Appendix

Table 17: Socio-demographic and structural variables by cluster

	Beginners	Browns	Energy savers	Supergreens
Gender (woman, in %)	53%	54%	57%	59%
Age	44.33	46.24	44.64	44.39
Education				
8 years of primary school or less	17%	30%	24%	14%
Technical college, skilled worker	41%	39%	43%	45%
High school diploma or higher accredited qualification	26%	20%	14%	17%
University degree	16%	11%	18%	24%
Household net income (thousand HUF/month)	211.05	189.11	206.54	241.59
Type of settlement				
Capital	17%	17%	17%	20%
Suburbia	6%	4%	11%	10%
City	52%	50%	41%	48%
Village, farm	25%	29%	30%	22%
Type of house				
Apartment house	3%	8%	5%	4%
New estate	29%	26%	21%	19%
Terraced house	11%	6%	5%	7%
Detached and Semi-detached house	44%	51%	61%	61%
Farmhouse	14%	8%	8%	8%
Number of rooms	2.62	2.49	2.60	2.86
1	5%	6%	5%	1%
2	44%	53%	47%	39%
3	39%	31%	36%	36%
over 4	11%	10%	12%	24%
Size of house (m2)	75.73	76.86	78.52	84.96
Energy efficiency				
0-2	9%	17%	9%	3%
3-5	56%	59%	58%	55%
6-8	35%	24%	33%	43%
Do you have a passenger car?				
Yes	55%	44%	60%	70%
Work place travel				
Car	27%	35%	37%	19%
Free time spent travelling (yes, %)	50%	39%	45%	41%

IV. CO_2 impacts of servitization – a structural decomposition analysis of the Hungarian economy

1. Introduction

In this study one possible solution of changing consumption is examined towards a less energy-intensive future; the concept of service economy. It has been a common belief that changing consumption patterns towards bigger share of income spent on services – on the account of less spending for intensive goods – could help to reduce overall consumption related CO_2 emissions. Looking at the interactions between goods and services, which are regarded as the main components of the consumption system, a widespread view claims that service sector might displace the sector of material goods (Parrinello, 2004). This is the so-called ‘service economy’ concept that refers to the shift from the production of physical goods to services.

There are a plenty of papers trying to reveal the environmental impacts of shifting to service economy on different levels of investigation, using different assumptions and aspects. Yet, there is a lack in detailed economy-wide investigation on the interraletions between service and non-service industries. To measure CO_2 emissions throughout intersectorial relations within the economy is crucial for designing more effective sustainability and energy policy measures. It is especially imperative in developed countries, where the services are the main drivers of the economic growth both in terms of GDP and employment.

The goal of this study is to fill this research gap and to elaborate on the real carbon impacts of different types of services and to provide environmental policy recommendations based on empirical findings. In order to come to a deeper understanding of the (de)carbonisation effect of services, an environmentally extended input–output (EEIO) model and a structural decomposition analysis are conducted on the Hungarian economy.

This chapter is organized as follows: Section 2 describes the current trends in servitization and the hypotheses development. Section 3 presents the applied methodological background for the calculation of CO_2 emission generated by service sector. Section 4 delivers the results of input-output and structural decomposition analysis In Section 5 conclusions are drawn and in Section 6 the discussion the results is presented.

2. Latent factors behind the trends and hypotheses

2.1. Embedded emission of services

The environmental load on economy-wide scale induced by service sector stands only in the center of few studies (Suh, 2006; Alcàntara and Padilla, 2009; Butnar and Llop, 2011). Services enter the production process of commodities at several levels of supply chain, so the measurement of their impacts also needs to be placed into a process-based angle. To simulate the processes where services play a role, the best available method currently is the Input-Output analysis that allows us to take advantage of its life-cycle and process-based perspectives.

Suh (2006) analyses the GHG emission of 480 goods and services in the United States using environmental emission inventory database. He concludes that a shift to a service economy shows a decrease in GHG emission intensity per unit GDP but an overall increase in GHG emissions in absolute terms can be observed at the same time.

Alcàntara and Padilla (2009) use input-output analysis to study the CO_2 emissions associated with services. By means of a decomposition analysis they identify five different CO_2 components of service subsystem; own, demand volume, feedback, internal and spill over components. According to their findings transportation services are the main contributors to carbon emission among other services. Input-output analysis reveals that emissions stemming from the production of intermediate materials or services exceed the direct emissions of services, which is captured through the spillover component that refers to the demand of services from productive industries. In this respect, an outstanding role is played by sectors such as Wholesale and retail trade, and repair of vehicles and goods, Hotels and restaurants, Real estate, renting and business services, and Public administration services (Alcántara and Padilla, 2009). A similar structural decomposition analysis is applied on the Spanish service sector between 2000-2005, which reports a general increase in CO_2 emission with a strong pull effect exerted by the service sectors on non-service sectors. Results show that services increased their CO_2 emissions mainly due to the spillover emissions generated by non-service sector; the strongest pull effect is found in Commerce and reparations, Transport and Post and telecommunications (Butnar and Llop, 2011). Another study by Jansson (2009) draws the conclusion that the growing dominance of services is only a statistical illusion arising from the traditional definition of services used in national accounts (whether the nature of output is tangible or intangible) and the profound industrial reorganization that has happened in the last century (Jansson, 2009).

2.2. Structural changes in economies over the last century

Servitization and dematerialisation of economies are coupled together according to the observed trends during the last decades (Herman et al., 1990; Bernardini and Galli, 1993; Ruth, 1998; Fiksel, 2012). It is beyond dispute that employment rate in the service sector has been increasing and the economic growth in he last decades has been driven by services in many OECD countries in terms of GDP (OECD, 2000). This remarkable growth is also linked to the decline in energy intensity (energy/GDP, see Figure 8) in many economies (Romm et al., 1999). Thus, a number of studies in the 1990s jumped to the conlcusion that the current shift towards servitization is attached with less environmental load (Fourcroy et al., 2012).

The share of service sector in GDP has been risen from the second half of the 20th century in industrialized countries; trends show that Europe has shifted economic activities from industrial production to services (see Figure 9). In EU-

28 countries, the 73% of GDP was produced by the service sector in 2012 (which was only 68% in 1995).

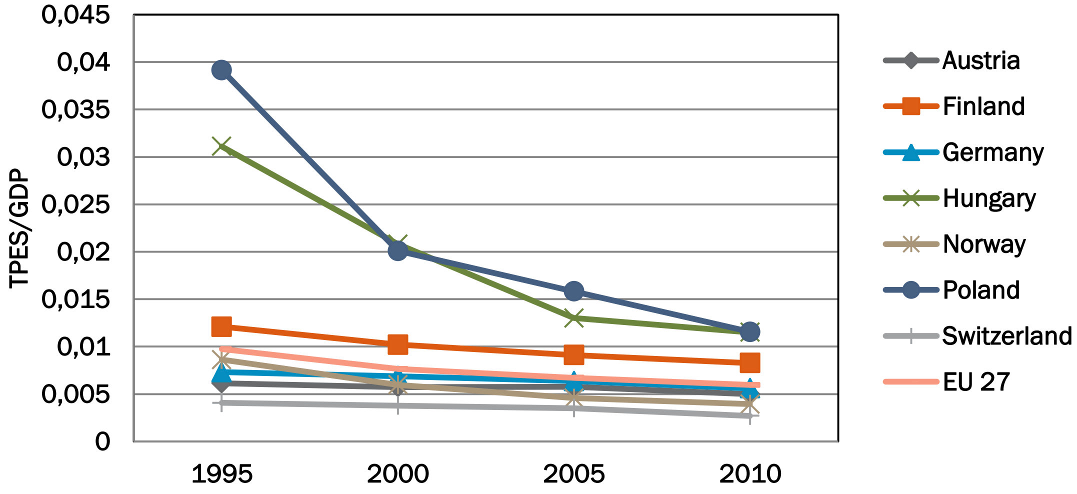

Figure 8: Energy/GDP rate 1995-2010 in selected countries (Data source: IAE, 2012 and Eurostat, 2014)

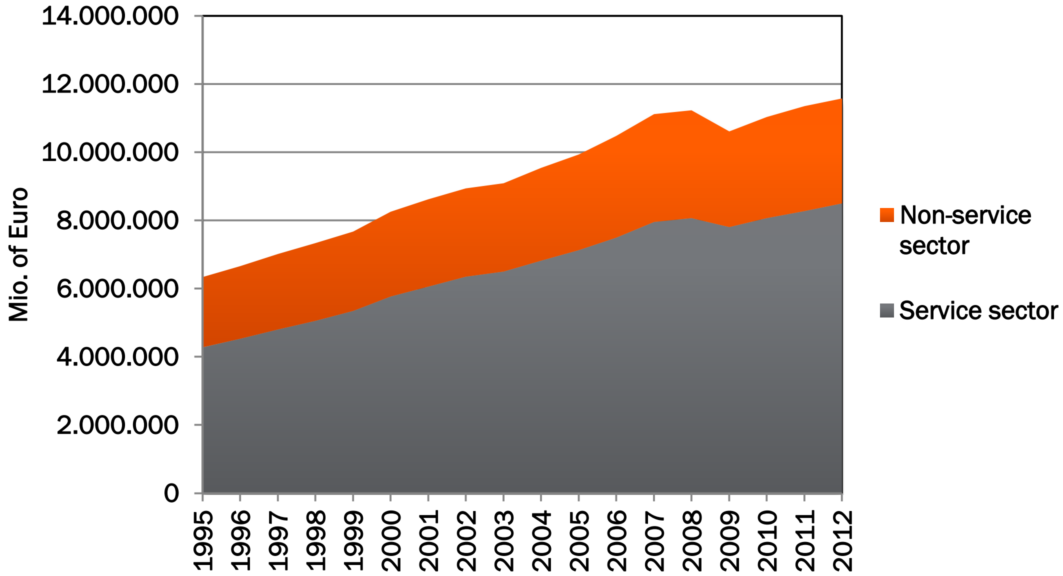

Figure 9: GDP growth in EU-28 between 1995-2012 (Data source: Eurostat, 2014)

Servitization is assumed to be displacing material goods (Parrinello, 2004), in other words, services substitute for production activities, which would result in less environmental load. This idea also appears in degrowth theory, where the downscaling of production activities through the cutback in private consumption and the increase in leisure activities supposed to lead us to a balanced path. Unfortunately, leisure activities are often resource-intensive, furthermore trimming work hours in the Western countries have brought more at least not less resource consumption and more economic growth (Kallis et al, 2012). By examining the volume of material troughput within the economy, no significant decrease can be observed during the last decade (see Figure 10). The advocates of degrowth theory see to overcome this effect by an over-optimistic view of the engagment in unpaid work (Kallis et al., 2012).

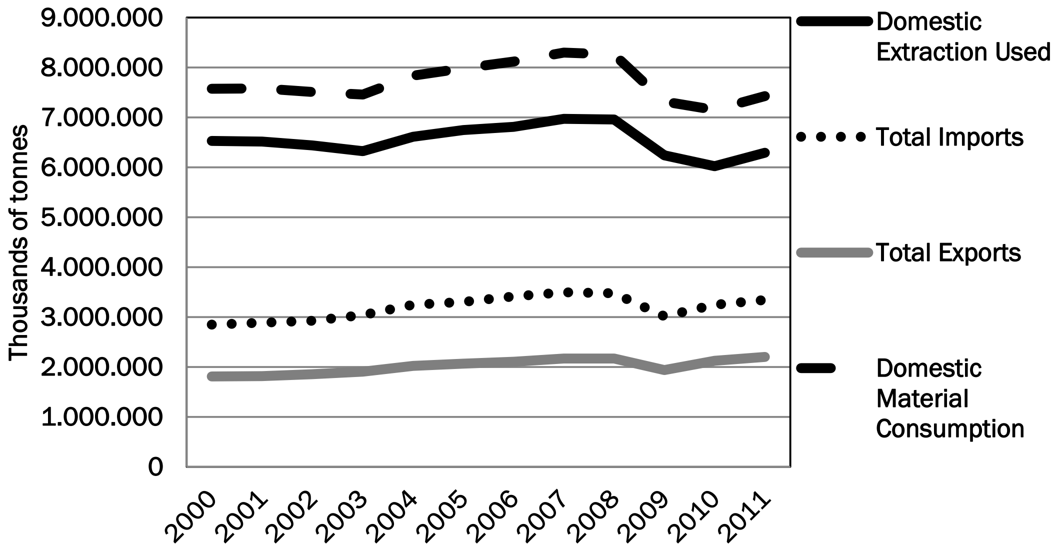

Figure 10: Material flow accounts for EU-27 countries 2000-2011 (Data source: EUROSTAT, 2014)

As mentioned above, the main argument that nurtures the advocates of service economy is the decline in energy intensity confirming the theoretical foundation of the concept. In the next part of this section this phenomenon is scrutinized.

Evidences show that the shift to service economy is largely based on a statistical illusion. One explanation is provided by Baumol's cost disease theory. Kander (2005) analyses the Swedish industry that is a textbook example of a typical EKC (Environmental Kuznets-curves[6]) slope for CO_2 (that grows until 1970 then declines afterwards). He found that this phenomenon could rather be attributed to the change in the mix of energy carriers and the stabilization of energy consumption than the expansion of service sector (Kander, 2005). The higher monetary output and employment in service sector can be explained by the concept of Baumol's cost disease theory (Henriques and Kander, 2010) that is based on the rationalization of labor time in industry. In industrial sectors the reduction of labor time is feasible by applying more efficient machines and equipments leading to higher wages in the long run. Altough labor time is rather stagnant in service sector, but the wage increase in industry triggers a demand in service sector that results in higher salaries without real efficiency improvement. In the long run, this leads to a relative rise in services to industrial product prices increasing its relative share of GDP at the same time. Attractive salaries in service sector decoy the labor resulting in growing employment rate. Consequently, the energy/GDP ratio has been declined over time caused by a simple statistical illusion, namely, GDP has risen faster than energy consumption over time.

Another reason for the drastic expansion of services can be attributed to the outsourcing wave of service-related activities. In the last decades big firms decided to improve performance through outsourcing activities that were not related to their core competencies (OECD, 2000). Thus, a lot of activities that were accounted for the production sector have been transferred to services increasing its share in GDP, which has only reinforced the statistical distortion in favour of services.

Furthermore, the delocalisation of industrial activities into emerging countries took place that led to a virtual decrease in CO_2 emission in national accounts. Industrialised world replaced their own manufactured products by imported ones and at the same time the pollution from production have been also delocated to other regions. China accounts for over 70% of total USA imports in manufactured

[6] The Environmental Kuznets Curve (EKC) hypothesis postulates an inverted-U-shaped relationship between different pollutants and per capita income, i.e., environmental pressure increases up to a certain level as income goes up; after that, it decreases. (Dinda, 2004, p.431.). U-shaped curve refers to the structural change over time; in the first part there is the industrialisation phase with increasing energy intensity then after the peak, the curve shows a decline attributed to the shift to service economy (Henriques and Kander, 2010).

products like clothing and footwear, toys and wood products and over 50% in items like furniture, tableware and glassware. In Europe, China's share of total imports amounts to around 50% in consumer goods as well (Dallas, 2014). Looking at the energy conversion rates in Table 15, we can see that China's energy conversion is much higher than the world average or in most European countries. Thus, the import induces higher CO_2 emission worldwide not only due to the transport of products but also through the delocalisation of production to countries with more polluting energy generation portfolio.

Table 18: Energy conversion rate in selected countries in 2000 and 2008 (tCO_2/TJ)

Countries	2000	2008
Sweden	26.5	21.4
France	35.7	33.4
Belgium	48.4	45.2
Slovakia	50.3	47.3
Austria	51.6	50.3
Hungary	51.8	47.9
Ukraine	52.1	54.4
Slovenia	52.5	51.7
Croatia	54.4	55.3
Netherlands	56.1	54.9
World	56.1	57.4
Romania	56.9	56.0
Russia	58.1	55.3
Germany	58.5	57.2
Italy	59.3	59.0
United States	59.9	58.6
China	66.3	73.4
Czech Republic	71.0	62.4
Bosnia and Herzegovina	74.2	79.9
Poland	78.0	72.8

Source: IEA (2012)

2.3. Hypotheses development

Based on previous findings, we can conclude that the connection between servitization and decarbonisation is rather unclear and influenced by several effects. In this study, it is therefore assumed that the decarbonization effect of servitization is overrated that is governed by incomplete data that lack a significant portion of use-related carbon emission induced by service industry. Structural effects such as the greening of electricity generation and the growing demand manifested in imported goods need to be seperatedly handled in order to reveal the actual carbon impacts of service sector. Both structural changes distort the environmental impacts of servitization that is underpinned by the constant increase of material throughput in developed economies and CO_2 emission worldwide.

During the studied period substantial changes have occurred in electricity generation portfolio in Hungary (see Figure 11). Liquid fuel consumption has drastically declined in total by 91% from 2000 until 2008. Oil has a relatively high carbon emission rate to other fuel types, thus its elimination has made an enormous reduction in carbon emission. Similarly, coal-fired plants have been equipped with gas turbines, which brought about a 28% decrease in total coal consumption. At the same time, the role of natural gas in energy supply has become more dominant and reached the level of nuclear power that has been more or less constant during the period. Energy generated from waste and renewable energy sources (mostly biomass) are the part of the electricity portfolio as of 2003. By 2008, the share of waste and renewables in electricity mix has reached 7%. These changes in energy mix are treated separately during the calculations.

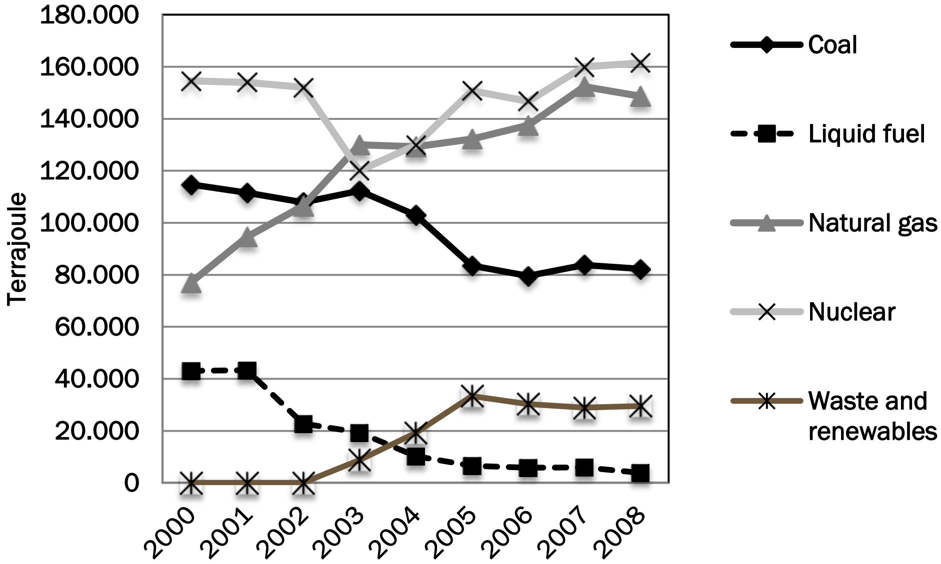

Figure 11: Energy source consumption of power plants in Hungary (Source: MVM, 2012)

In Hungary, the share of Chinese products in total import is only around 11% (KSH, 2014), but due to the inextricable trading systems of finished and unfinished products resulting in re-imported and re-exported goods that are difficult to be traced back. Thus, the actual volume of goods produced in China is assumingly much higher than in the statistical database. To simplify the model assumptions, the emission of imported goods is calculated using the energy conversion rate for China.

The total imported volume to Hungary has multiplied during the last decade. This can partly ascribed to the phaseout of heavy industries and manufacturing after the transition, and partly due to the increase in consumption demand. The delocalisation of dirty industries has substantially increased the import of manufactured products; between 2000 and 2008 the imported volume has doubled (from 22.43 Mt to 44.48 Mt). This indicates a substantial pull effect on imported physical goods.

Therefore, it is hypothesized that the service sector is the major driver of total CO_2 emission (H4) and the largest share of CO_2 emission generated by service sector can be attributed to the pull effect on non-service industries (H5). These hypotheses are tested and analysed using the dataset for the Hungarian economy.

3. Methodology

3.1. Calculating the CO_2 emission using Environmentally Extended Input-Output analysis

Servitization is usually measured through monetary values and not in physical terms. Unfortunately, the availability of material flow data is very limited, which makes the analysis of long-term structural changes impossible. Therefore, an Environmentally Extended Input–Output (EEIO) analysis is used instead. EEIO has become the most widely used tool in industrial ecology for conducting life cycle assessment of different products and services (Suh and Kagawa, 2009). Input-output model was originally introduced by Wassily Leontief in the 1930s for the analysis of the relationship between different economic sectors based on economic transactions. IO model has been extended in the course of time to capture physical flows through sectorial interrelationships such as determining the pollution or environmental load on national or regional scale (Wiedmann, 2009). Although the model is still based on monetary units and not on actual material flows the analysis can provide a useful estimation. In the IO approach economic information are linked to environmental data and can then be used to calculate the environmental impacts of products covering the whole supply chain (Junnila, 2008), which can therefore be used for life cycle assessment of a certain product. Bicknell et al. (1998) introduced an environmentally extended input-output (EEIO) framework for calculating the ecological footprint of economic activities in New Zealand with adding to the conventional input–output table a vector that expresses each sector’s impact in terms of a physical unit. They were the first to introduce modified input–output analysis, incorporating it into the method of the ecological footprint calculations. They proposed this method as an alternative to calculate the ecological footprint in a consistent way using data collected as part of the system of national accounts. The method is based on combining the Leontief inverse with land multipliers representing the environmental input in the system. The suggested environmentally extended input-output analysis proved to be extremely useful for analysing a wide range of problems, achieving unexpected level of popularity in environmental literature. Eurostat introduced this method in its official reports and database proving the usefulness of the approach to environmental policy analysis. The appeal of the method lies mainly in its ability to go beyond producer responsibility and to capture and share the responsibility between production and consumption in contributing to ecological problems (Lenzen and Murray, 2001; Lenzen et al., 2007). It is also able to capture spill over ecological impacts along the supply chain and push some responsibility from upstream sectors to downstream industries inducing those impacts through the multiplication effect.

Ferng (2009) argues against using land multipliers in ex ante input-output analysis based scenario analysis. Such kind of analysis is based on two linear assumptions, one of which does not hold: a change in sector's output requires proportional changes in its consumption of intermediate environmental inputs, and also in the land providing such environmental inputs. Environmental Leontief inverses represent the linear marginal effect of delivering one unit of sector output to final demand on the required environmental ecological services, a flow indicator, rather than on land, a stock indicator. This article follows suggestions of Ferng (2009) by employing CO_2 emission as an environmental indicator rather than using carbon footprint based land multipliers.

There are conceptual and technical differences between IO models using physical units in and monetary IO tables extended by a vector of physical factor per unit of output. Apart from the discrepancies shown between the two concepts, Weisz and Duchin (2006) concluded that if the two models operate with a single price vector, they bring equivalent results. Thus, EEIO tables based on monetary flows have been proven a very sufficient tool for analyzing environmental impacts embedded in sectorial relationships within a country and have been used for impact determination of different types of psychical flows (e.g. electricity use, carbon emission, ecological footprint etc.).

According to the traditional IO analysis, the total output of an economy can be expressed as the sum of intermediate consumption of sectors and of the final demand (Leontief, 1970):

$$x = Ax + y \quad or \quad x = (I-A)^{-1}y = By \tag{1}$$

$$a_{ij} = x_{ij}/X_j \tag{2}$$

$$B = (I-A)^{-1} \tag{3}$$

where Ax is the intermediate consumption of sectors and y represents the final demand. A is also called transaction matrix or technical coefficient matrix (Bicknell et al., 1998) that expresses the amount of inputs from sector i required to increase the output of sector j by one unit of currency. The B matrix represents the Leontief inverse matrix. The direct carbon intensity vector (DCIV) is calculated by dividing the carbon emission data of sectors by the total output of each sectors:

$$DCIV = E_j/X_j \tag{4}$$

The total carbon intensity vector (TCIV) is calculated as follows:

$$TCIV = DCIV\,(I-A)^{-1} \tag{5}$$

Total carbon intensity vector includes the embedded CO_2 emission of each economic sector. In the last step of the analysis the results of Equation (5) are placed in a diagonal matrix and multiplied by the final demand. Final results show the embedded carbon of each sector from life cycle assessment perspective. To obtain the total carbon emission of sectors, the direct CO_2 emission of final demand is added to final results.

3.2. Structural Decomposition of the Input–Output Model

Structural decomposition analysis is applied in the IO framework in numerous studies to identify different driving forces that contribute to changes in CO_2 emissions over time (e.g. Peters et al., 2007; Su and Ang, 2012; Tian et al., 2013; Brizga et al., 2014).

In order to examine service sectors, the economy (IO model) is first decomposed into two main subsystems; service (S) and non-service sectors (M) (Alcantara and Padilla, 2009; Butnar and Llop, 2011). A subsystem describes a group of sectors that are separated and individually analysed within the economy. The economy dissected into service and non-service subsystems is described as follows:

$$\begin{pmatrix} x^M \\ x^S \end{pmatrix} = \begin{pmatrix} A_{MM} & A_{MS} \\ A_{SM} & A_{SS} \end{pmatrix} \begin{pmatrix} x^M \\ x^S \end{pmatrix} + \begin{pmatrix} y^M \\ y^S \end{pmatrix} \tag{6}$$

$$\begin{pmatrix} x^M \\ x^S \end{pmatrix} = \left[\begin{pmatrix} I & 0 \\ 0 & I \end{pmatrix} - \begin{pmatrix} A_{MM} & A_{MS} \\ A_{SM} & A_{SS} \end{pmatrix} \right]^{-1} \begin{pmatrix} y^M \\ y^S \end{pmatrix} = \begin{pmatrix} B_{MM} & B_{MS} \\ B_{SM} & B_{SS} \end{pmatrix} \begin{pmatrix} y^M \\ y^S \end{pmatrix} \tag{7}$$

where x represents the sectorial output (production), A is the technical input-output coefficient matrix and y is the final demand. Furthermore, we can decompose matrix A into two matrices, A^D and A^0:

$$A = A^D + A^0 = \begin{pmatrix} A_{MM}^D & 0 \\ 0 & A_{SS}^D \end{pmatrix} + \begin{pmatrix} A_{MM}^0 & A_{MS}^0 \\ A_{SM}^0 & A_{SS}^0 \end{pmatrix} \tag{8}$$

$$\begin{pmatrix} A_{MM} & A_{MS} \\ A_{SM} & A_{SS} \end{pmatrix} \begin{pmatrix} B_{MM} & B_{MS} \\ B_{SM} & B_{SS} \end{pmatrix} \begin{pmatrix} 0 \\ y^S \end{pmatrix} + \begin{pmatrix} 0 \\ y^S \end{pmatrix} = \begin{pmatrix} x_S^M \\ x_S^S \end{pmatrix} \tag{9}$$

where A^D contains the diagonal elements of the technical coefficient matrix and A^0 consists of the rest of the elements of matrix A and has zeros in its main diagonal. From Eq. 6. and assuming that the non-service sectors produce only for intermediate demand for service sector (y^M=0) we can calculate the input-output flows of service sector subsystem in Eq. 9, where x_S^M means the production of non-service sector needed for service sector and x_S^S the service production provided for other service sector demand.

In the literature the so called backwards effect are measured with the calculation of inputs needed for a production of a certain good or service, thus two types of backward effect can be distinguished by calculating TCIV; the own demand (OD) or own backward effect, which is characterised by the impact of own outputs consumed in a certain industry, and the supply component (SC) or pure backward effect, which shows the impact of all inputs taken from other industries. Own demand share for service sector is calculated as follows:

$$OD_S = DCIV^{S\prime} A^D_{SS} B_{SS} y^S \tag{10}$$

and for the non-service sector

$$OD_M = DCIV^{M\prime} A^D_{MM} B_{MM} y^M \tag{11}$$

Supply component (SC) can be expressed as follows:

$$SC = DCIV' \begin{pmatrix} A^0_{MM} & A^0_{MS} \\ A^0_{SM} & A^0_{SS} \end{pmatrix} \begin{pmatrix} B_{MM} & B_{MS} \\ B_{SM} & B_{SS} \end{pmatrix} \begin{pmatrix} y^M \\ y^S \end{pmatrix} \tag{12}$$

The supply component of service sector can be decomposed in two main components that allow us to examine the demand stemming from different type of service (SC^S_S) and non-service (SC^M_S) sector. The non-service sector supply for the production of services is also called the spill over component in the literature (Alcantara and Padilla, 2009). The SC^S_S expresses all inputs from other service sectors except for electricity, gas, steam and air coinditioning supply that is also known as the internal component (Butnar and Llop, 2011). To be able to seperate the effect of changes in electricity mix, the electricity, gas, steam and air coinditioning supply (ED_S) is treated as a distinct component. In previous studies the electricity supply has not been separated from other components, thus the impact of change in electricity mix cannot be captured and followed up. It is crucial to see, whether the technological change can purely be attributed to the change in electricity mix or it is the result of a real technological development.

$$SC_S = SC^M_S + SC^S_S + ED_S \tag{13}$$

$$SC_S^M = DCIV^{M\prime}(A_{MM}\,B_{MS} + A_{MS}^0 B_{SS})y^S \quad (14)$$

$$SC_S^S = DCIV^{S\prime}(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^S \quad (15)$$

To examine the CO_2 emission from different types of services, the supply from service sector is decomposed into five subgroups:

- Supply from basic supply services (SC^{BSS})
- Supply from transportation and trade activities (SC^{TTS})
- Supply from entertainment and recreational services (SC^{RES})
- Supply from knowledge-based services (SC^{KS})
- Supply from other services (SC^{OS})

$$SC_S^S = SC_S^{BSS} + SC_S^{TTS} + SC_S^{RES} + SC_S^{KS} + SC_S^{OS} \quad (16)$$

The separation of different service activities is aimed to provide a possible channel of policy intervention. The first group of services contains basic supply services that can be availed by everyone and serve public purposes such as education, health care, electricity and water supply, etc. The second category consists of all services that are related to transportation and trade. The third group is for recreational and entertainment activities. The fourth group of services embraces the typical knowledge-based sectors that usually create market value without tangible outputs such as financial and banking activities. The fifth group of activities contains all other services that cannot be classified into the above-mentioned groups (these services are mainly related to households). The five subgroups of service sector can be expressed as follows:

$$SC_S^{BSS} = (DCIV_S^{BSS})'(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^{BSS} \quad (17)$$

$$SC_S^{TTS} = (DCIV_S^{TTS})'(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^{TTS} \quad (18)$$

$$SC_S^{RES} = (DCIV_S^{RES})'(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^{RES} \tag{19}$$

$$SC_S^{KS} = (DCIV_S^{KS})'(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^{KS} \tag{20}$$

$$SC_S^{OS} = (DCIV_S^{OS})'(A_{SM}\,B_{MS} + A_{SS}^0 B_{SS})y^{OS} \tag{21}$$

The third main component of the analysis is dependent on final demand of services (y) and its degree is related to direct carbon emission intensity. It can be calculated as:

$$FD_S = DCIV^{S\prime} y^S \tag{22}$$

The last component captures the role of service sector outputs that are utilized as inputs for non-service sector. The feedback component is calculated as:

$$FB_M^S = DCIV^{S\prime} A_{SM}^0 B_{MS} y^S \tag{23}$$

Thus, the total carbon impact of services can be measured as the sum of the above-mentioned components:

$$E_S = OD_S + ED_S + SC_S^S + SC_S^M + FD_s + FB_M^S \tag{24}$$

3.3. Structural changes over time

To capture further factors that cause changes in service subsystem over time, the structural decomposition analysis is extended as follows:

$$\Delta E_S = \Delta OD_S + +\Delta ED_S + \Delta SC_S^S + \Delta SC_S^M + \Delta FD_s + \Delta FB_M^S \quad (25)$$

The symbol Δ denotes the change over time that is calculated by deducting the final value from the initial value. Applying the temporal decomposition technique of the work by Butnar and Llop (2011), who followed Dietzenbacher and Los (1998) suggestions, the change in final demand component is expressed as follows:

$$\Delta FD_S = DCIV_1^{S\prime} y_1^S - DCIV_0^{S'} y_0^S = \Delta DCIV^{S'} y_{1/2}^S + DCIV_{1/2}^{S\prime} \Delta y^S \quad (26)$$

The first term in the right-hand side of Eq. 26 shows the impact of change in emission intensity (emission element, EE) and the second part of the equation depicts the impact of change in final demand (demand element, DE). Similarily, the other components can be decomposed as well. The temporal changes in supply and feedback components are expressed as follows (Butnar and Llop, 2011):

$$\Delta SC_S^M = DCIV_1^{M\prime}\left(A_{MM_1} B_{MS_1} + A_{MS_1}^0 B_{SS_1}\right) y_1^S - DCIV_0^{M'}\left(A_{MM_0} B_{MS_0} + A_{MS_0}^0 B_{SS_0}\right) y_0^S =$$
$$\Delta\left[DCIV^{M'}\left(A_{MM} B_{MS} + A_{MS}^0 B_{SS}\right)\right] y_{\frac{1}{2}}^S + DCIV_{1/2}^{S\prime}\left(A_{MM_{1/2}} B_{MS_{1/2}} + A_{MS_{1/2}}^0 B_{SS_{1/2}}\right) \Delta y^S \quad (27)$$

$$\Delta SC_S^S = DCIV_1^{S'}\left(A_{MM_1} B_{MS_1} + A_{MS_1}^0 B_{SS_1}\right) y_1^S - DCIV_0^{S'}\left(A_{MM_0} B_{MS_0} + A_{MS_0}^0 B_{SS_0}\right) y_0^S =$$
$$= \Delta\left[DCIV^{S'}\left(A_{MM} B_{MS} + A_{MS}^0 B_{SS}\right)\right] y_{1/2}^S + DCIV_{1/2}^{S\prime}\left(A_{MM_{1/2}} B_{MS_{1/2}} + A_{MS_{1/2}}^0 B_{SS_{1/2}}\right) \Delta y^S \quad (28)$$

$$FB_M^S = DCIV_1^{S'} A_{SM_1}^0 B_{MS_1} y_1^S - DCIV_0^{S'} A_{SM_0}^0 B_{MS_0} y_0^S =$$
$$\Delta\left[DCIV^{S'} A_{SM}^0 B_{MS}\right] y_{1/2}^S + DCIV_{1/2}^{S'} A_{SM_{1/2}}^0 B_{MS_{1/2}} \Delta y^S \quad (29)$$

The first term on the right-hand side of Eq. 27, 28, and 29 capture the technological changes that reflect the change in embedded emission. Hereafter it is called the technological element (TE). The second term in the equation refers to the change in final demand, so hereafter it is called the demand element (DE).

For measuring the carbon embodiment of services, a symmetric Input-Output table has been used that is extracted from the EUROSTAT database (2014). Data for 2008 have been chosen to investigate the carbon effects of servitization on the Hungarian economy to avoid the temporary downturn caused by the economic crisis in subsequent years. Data for sectorial carbon emissions are provided by the Hungarian Central Statistical Office (KSH) database. Import data are extracted from the Eurostat database (2014) and the embedded CO_2 emission rates for different products are gained from the Global Footprint Network database (GFN, 2008).

4. Results

4.1. The embedded emission of service sector in Hungary

Figure 12 depicts the summary of total carbon emission in Hungary for 2008. The total carbon emission accounts for 113.13 $MtCO_2$ in 2008 that is the sum of domestic emission (51.57 $MtCO_2$) and the embedded emission of imported goods (61.56 $MtCO_2$). It has to be noted that the emission of imported services are not incorporated in the analysis due to lack of data.

The share of carbon emission generated by final demand amounts to 56.26 $MtCO_2$ that almost covers the 50% of total carbon emission. Investment activities are responsible for the other half of CO_2 emission that cannot be analyzed in-depth in this study due to the lack of data. Results show that non-service sector accounts for only 38% of carbon emission and the rest can be attributed to service sector. The major emitter among services is not surprisingly the Electricity, gas, steam and air conditioning supply (11.08 $MtCO_2$) followed by Basic supply services (9.77 $MtCO_2$). The share of Transportation and trade (8.47 $MtCO_2$) stands only on the third place, because it excludes the direct emission generated by transport activities by households (3.33 $MtCO_2$). Total emission can be split into two main parts; direct and embedded emission. Direct emission shows the amount of CO_2 directly emitted by a certain sector during its core activity. The embedded emission represents the CO_2 emission occurring through the entire industrial supply chain up to the final demand (Wiedmann et al., 2009).

Manufacturing sectors show usually high direct carbon intensity that expresses the specific emission with respect to the total output. This is confirmed by the average carbon multiplier (total/direct carbon intensity) that is among manufacturing sectors is only 2.10 (see Table 25 in Appendix). The most carbon-intensive sectors are highlighted; Forestry and logging, Manufacture of other transport equipment, Manufacture of chemicals and chemical products, Mining and quarrying and Manufacture of paper and paper products.

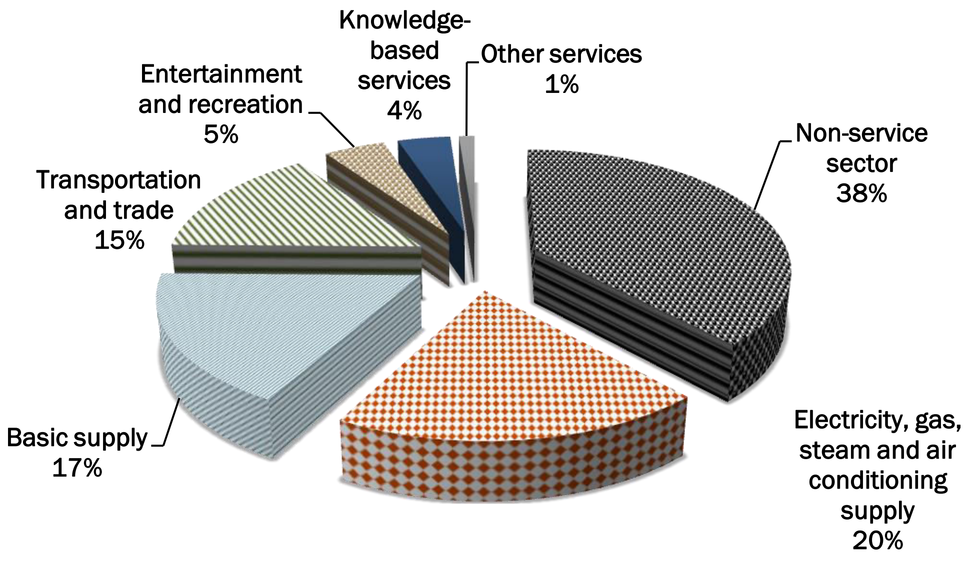

Figure 12: Total carbon emission in Hungary by sector in 2008

In contrast to non-service sector, the embedded emission of service sector shows rather a mixed picture; while services have very low (almost zero) direct carbon intensities, their total carbon intensities vary to a great extent (see Table 16). With respect to direct emission levels, the major carbon impact can be attributed to the Electrcitiy, gas, steam and air conditioning supply and transportation activities. All other sectors lag way behind regarding direct emissions. If we only consider direct impacts, we can observe that recreational and entertainment services as well as Knowledge-based sectors possess a close to zero direct emission. However, if we look at embedded emissions and the carbon multiplier of services such as Travel agency activties, Accommodation and food services and Creative, arts and entertainment and sport activities, we can see huge differences. Knowledge-based services are foreseen as the major drivers of modern economies and are also regarded as potential sectors that are able to contribute to lower CO_2 emission. However, Real estate activities as well as Publishing and advertising and market research have an enormous carbon multiplication effect.

Table 19: Direct and total carbon intensities and emissions of service sectors in 2008

	DCIV	TCIV	Direct emission	Embedded emission	Total emission by final demand
	$ktCO_2$/ Mio. NAC	$ktCO_2$/ Mio. NAC	$ktCO_2$/year	$ktCO_2$/year	$ktCO_2$/year
Electricity, gas, steam and air conditioning	10.23	11.69	5,064.38	6,010.94	11,075.32
Basic supply services					
Water collection, treatment and supply, sewage, waste mangement services	1.78	3.91	205.06	449.50	654.56
Sewerage; waste collection, treatment and disposal activities	1.78	3.03	192.27	326.52	518.79
Postal and courier activities	1.54	2.08	58.36	78.76	137.12
Public administration and defence	0.16	0.76	395.59	1870.56	2,266.15
Education	0.79	1.39	1,051.21	1,834.49	2,885.69
Human health and social work activities	0.68	1.64	967.66	2336.88	3,304.54
Transportation and trade					
Wholesale and retail trade and repair of motor vehicles and motorcycles	0.01	1.17	13.36	2,679.17	2,692.54
Land transport and transport via pipelines	5.08	6.10	2,366.48	2,841.22	5,207.70
Water transport	0.00	0.68	0.00	2.99	2.99
Air transport	2.64	3.64	201.77	278.42	480.18
Warehousing and support activities for transportation	0.00	0.91	0.00	89.04	89.04
Recreation and entertainment					
Accommodation and food service activities	0.07	1.90	65.67	1,727.66	1,793.33
Travel agency, tour operator reservation service and related activities	0.01	2.12	0.53	141.44	141.98
Creative, arts and entertainment and sport activities	0.05	1.19	23.23	569.21	592.44
Motion picture, video and television programme production, sound recording and music	0.16	0.65	9.41	37.04	46.45

Knowledge-based services					
Publishing activities	0.16	1.40	14.79	126.53	141.31
Telecommunications	0.16	0.74	84.57	383.95	468.53
Computer programming, consultancy; repair of computer and household goods	0.16	0.66	1.60	6.47	8.07
Financial service activities, insurance, reinsurance and pension funding	0.03	0.48	20.07	306.73	326.80
Real estate activities, rental and leasing	0.01	0.49	23.68	1,166.68	1,190.36
Legal and accounting activities	0.07	0.63	1.71	14.50	16.21
Architectural and engineering activities	0.07	0.85	0.77	8.83	9.60
Scientific research and development, advertising and market research	0.07	0.73	3.75	37.35	41.10
Other professional, scientific and technical activities	0.07	0.81	1.13	12.33	13.46
Other services					
Security and investigation activities; services to buildings and landscape activities	0.01	0.75	0.27	24.89	25.16
Employment activities	0.01	0.42	0.00	0.05	0.05
Repair of computers and personal and household goods	0.06	1.02	1.68	28.12	29.81
Other personal service activities	0.06	0.89	20.07	291.55	311.62
Activities of households as employers	20.59	20.59	63.83	63.83	127.66
Activities of membership organisations	0.06	0.88	10.65	152.59	163.25
Total service sector			**10,863.57**	**23,898.22**	**34,761.79**

4.2. Structural decomposition of the Hungarian service subsystem

The role of service subsystem within an economy is manifold; it is in relation with all sectors and provides final as well as intermediate outputs. To scrutinize the impact of services on different subsystems of the economy, a structural decomposition of the input-output system is carried out. Table 17 depicts the results of the structural decomposition analysis of the Hungarian service sector. The carbon emissions of service subsystem are decomposed into four main components; own demand, final demand, supply and feedback components. Adding up all these components, the total carbon impact of services accounts for 36.6 $MtCO_2$ that is 65% of the total emission from final demand.

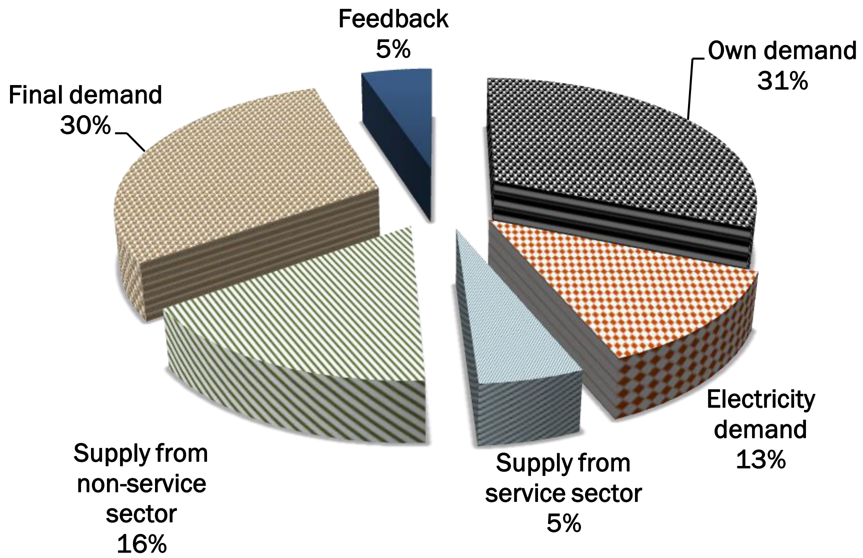

Figure 13: Total carbon emission of service subsystem by structural component in Hungary 2008

The own (OD_S) and final (FD_S) demand components have the largest share in total service sector emission (see Figure 13). Own demand component represents the sum of all carbon emissions that are generated by the use of own goods and services within sectors. The OD_S is remarkably high within Electricity, gas, steam and air conditioning supply (44%), Basic supply services (30%) and

Transportation and trade (30%). Conversely, the own demand component has marginal importance in Recreation and entertainment and Knowledge-based services.

The final demand component amounts to 30% of total service sector emission as the second largest component. Although the Electricity, gas and air conditioning supply is responsible for the 41% of FD_S as the major emitter. Direct emissions generated by Recreation and entertainment, and Knowledge-based services are also negligible.

The ED_S component shows the electricity demand from all sectors (except for itself). ED_S is responsible for the 13% of the total service sector emission. Basic supply services and Transportation and trade activities cover the 40% and 25% of this component, respectively. ED_S contributes to the emissions of Recreational services and entertainment (17%) and Knowledge-based services (15%) to a similar extent. Although these numbers seem large, but if we look at their whole emission (horizontally in Table 17), the ED_S component has a significantly lower relative share in Basic supply and Transportation and Trade than in Recreation and entertainment and Knowledge-based services.

The supply component (SC_S) has the share of 21.5% in total service sector emission. Not suprisingly, the 75% of SC_S component is the supply from non-service sector (SC_S^M), on the second place stands the Transportation and trade supply (SC_S^{TTS}) 22% and rest is allocated among the other components. Supply component from other service sectors are further decomposed according to the types of services. The meager share of Supply component from Entertainment and Recreational services (SC_S^{RES}) and Konwledge-based services (SC_S^{KS}) can be explained by the fact that these are mostly directly provided for consumers and usually do not serve as intermediate inputs for other industries. The resource-intensity of Recreational and entertainment and Knowledge-based services is reflected by their SC_S^M component, which account for 49% and 41% with respect to their total emission, respectively.

The SC_S^M component has also a relatively high share in total emission of services (16%) that implies a strong pull effect, in accordance with the findings of Alcantara and Padilla (2009). The major contributors to pulling non-service industries are Wholesale and retail trade and repair of motor vehicles and motorcycles and Accomodation and food service activities having the share of 19% and 17% from the component, respectively. In total, 28% of CO_2 emission from all non-service sectors is generated due to the pull effect of service activities (and its share in total final demand is 11%). As for transportation, these sectors have marginal importance in pull effect; Land transport amounts to only 4.6% of the total SC_S^M component.

The feedback component (FB_S) refers to the supply provided by service for non-service sector. Its significance is minor compared to the other components accounting for 5% in total emission form service sector. Electricity, gas, steam and air conditioning supply is responsible for the 70% of FB_S component. The role of Recreation and entertainment as well as Knowledge-based services is also negligible in providing inputs for non-service industries accounting for only 1% in the total service sector emission.

Table 20: Structural decomposition of Hungarian service sector in 2008

ktCO$_2$/year	OD_S	ED_S	SC_S^{BSS}	SC_S^{TTS}	SC_S^{RES}	SC_S^{KS}	SC_S^{OS}	SC_S^{M}	FD_S	FB_S	Total
Electricity, gas, steam and air conditioning supply	**5,436.92**	**0.00**	**10.71**	**118.26**	**0.27**	**5.09**	**0.15**	**439.54**	**5,064.39**	**1,306.10**	**12,381.42**
Basic supply services	**2,984.87**	**1,802.64**	**155.62**	**295.26**	**4.74**	**41.93**	**1.35**	**1,610.30**	**2,870.15**	**69.87**	**9,836.72**
Water collection, treatment and supply	208.95	151.56	5.68	9.30	0.08	1.38	0.06	72.49	205.06	13.37	**667.93**
Sewerage; waste collection, treatment and disposal activities	212.28	38.70	2.58	15.74	0.06	0.91	0.03	56.24	192.27	34.01	**552.80**
Postal and courier activities	61.31	5.47	0.33	4.41	0.03	0.30	0.01	6.92	58.36	12.80	**149.92**
Public administration and defence	405.63	754.72	85.10	128.13	2.04	20.75	0.46	473.72	395.59	3.00	**2269.15**
Education	1,082.34	419.73	23.76	56.40	0.76	9.82	0.25	241.43	1051.21	4.12	**2,889.81**
Human health and social work activities	1,014.37	432.46	38.17	81.30	1.78	8.78	0.54	759.50	967.66	2.57	**3,307.11**
Transportation and trade	**2,644.44**	**1,140.68**	**79.85**	**503.45**	**4.80**	**37.70**	**1.25**	**1,478.67**	**2581.61**	**463.68**	**8,936.13**
Wholesale and retail trade and repair of motor vehicles and motorcycles	13.76	995.25	68.70	491.56	4.37	32.57	1.10	1,160.91	13.36	1.65	**2,783.23**
Land transport and transport via pipelines	2,424.69	127.73	9.53	3.10	0.35	4.31	0.13	271.40	2,366.48	452.38	**5,660.08**
Water transport	0.00	0.74	0.06	0.47	0.00	0.05	0.00	1.67	0.00	0.00	**2.99**
Air transport	205.99	16.97	1.56	8.32	0.09	0.78	0.03	44.69	201.77	9.64	**489.83**
Recreation and entertainment	**104.52**	**775.80**	**56.49**	**243.96**	**5.63**	**18.12**	**0.78**	**1,270.03**	**98.85**	**3.53**	**2,577.72**
Accommodation and food service activities	68.37	463.67	29.54	130.49	1.23	8.87	0.52	1,024.96	65.67	0.44	**1,793.77**
Travel agency, tour operator reservation service and related activities	0.55	23.81	2.65	66.74	2.41	0.54	0.04	44.70	0.53	0.03	**142.00**
Creative, arts and entertainment and sport activities	24.74	277.73	23.49	43.27	1.96	7.66	0.20	190.15	23.23	0.18	**592.62**

Motion picture, video and television programme production, etc.	10.85	10.59	0.82	3.46	0.03	1.04	0.02	10.23	9.41	2.88	**49.33**
Knowledge-based services	**158.60**	**676.65**	**86.94**	**172.48**	**4.19**	**42.76**	**1.30**	**920.43**	**152.07**	**23.32**	**2,238.74**
Publishing activities	14.91	19.58	3.64	7.59	0.23	1.45	0.03	79.09	14.79	1.32	**142.63**
Telecommunications	87.77	119.83	13.57	33.58	2.03	6.98	0.24	119.95	84.57	3.34	**471.87**
Computer programming, consultancy and related activities	1.73	1.77	0.14	0.58	0.01	0.10	0.01	2.14	1.60	4.05	**12.12**
Financial service activities, insurance, reinsurance and pension funding, except compulsory social security	22.15	96.28	28.22	30.16	0.72	13.78	0.30	115.12	20.07	2.45	**329.24**
Real estate activities, rental and leasing activties	24.39	417.78	39.42	93.68	1.08	19.30	0.69	570.33	23.68	1.05	**1,191.41**
Legal and accounting activities	1.88	4.82	0.47	1.93	0.03	0.31	0.01	5.05	1.71	3.86	**20.06**
Architectural and engineering activities	0.85	2.55	0.17	0.70	0.01	0.10	0.00	4.44	0.77	2.21	**11.81**
Scientific research and development, advertising and market research	4.92	14.04	1.32	4.27	0.07	0.74	0.02	24.30	4.88	5.03	**59.59**
Other services	**96.61**	**169.92**	**20.05**	**47.29**	**3.14**	**6.51**	**0.12**	**217.40**	**96.51**	**1.31**	**658.85**
Security and investigation activities	0.28	6.14	1.08	2.73	0.03	0.46	0.01	14.16	0.27	0.58	**25.74**
Employment activities	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.10	**0.15**
Repair of computers and personal and household goods	1.68	5.80	0.43	2.93	0.02	0.47	0.01	16.79	1.68	0.10	**29.90**
Other personal service activities	20.11	109.00	10.24	17.56	2.16	2.32	0.08	130.09	20.07	0.05	**311.68**
Activities of households as employers	63.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.83	0.00	**127.66**
Activities of extra-territorial organisations and bodies	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Activities of membership organisations	10.71	48.96	8.30	24.05	0.92	3.27	0.02	56.35	10.65	0.48	**163.73**
TOTAL	**11,425.95**	**4,565.69**	**409.66**	**1,380.70**	**22.77**	**152.12**	**4.97**	**5,936.36**	**10,863.57**	**1,867.80**	**36,629.59**

In the following part, the empirical results of temporal structural changes in service subsystem components are presented. In order to examine the structural changes in subsystems and components over time, the 2000 is chosen as base year for comparison. Table 18 and 19 summerize the main changes in carbon emissions. Although the overall CO_2 emission from domestic prodution and imported goods shows an overall increase during the period, in final demand there is a slight decrease. Emission from imported goods substantially increased during the studied period, which means a growth of relative share in total CO_2 emission.

Table 21: Summary of emission changes directly linked to sectors between 2000 and 2008 ($MtCO_2$)

	2000	2008	Change
Total emission by origin	**89.06**	**113.13**	**+27%**
Domestic emission	30.52	32.60	+7%
Imported goods	35.69	60.76	+70%
Total emission by subsystem	**89.06**	**113.13**	**+27%**
Non-service sector emission	53.32	78.14	+47%
Service sector emissions	35.74	34.99	-2%
Electricity, gas, steam and air conditioning supply	22.85	19.78	-13%
Other service sectors	12.89	15.21	+17%

Table 22: Summary of total (embedded and direct) emission changes in final demand between 2000 and 2008 ($MtCO_2$)

	2000	2008	Change
Total final demand emission	**59.79**	**56.27**	**-6%**
Non-service sector emission	15.93	19.64	+23%
Service sector emission	43.86	36.63	-26%
Electricity, gas, steam and air conditioning supply	19.48	12.38	-36%
Basic supply services	13.94	9.84	-30%
Transportation and trade	6.87	8.94	+30%
Recreation and entertainment	2.00	2.58	+29%
Knowledge-based services	1.39	2.24	+61%
Other services	0.37	0.69	+86%

If we only take into account emissions directly linked to sectors, the share of service sector has a much lower significance. In Table 19 the summary of structural decomposition analysis are shown. The decline of service sector emission can primarily be ascribed to the cleaning of electricity generation and secondly to Basic supply services, whereas in all other services huge increase can be observed.

Table 20 and 21 show the structural changes in components over time in selected service sectors. In the European Union, the NACE classification (Statistical classification of economic activities in the European Community) is uniformly used. For the year 2000, the economic activities are classified according to the first version (NACE rev.1.) that contains 59 industries, whereas the new revised version (NACE rev. 2.) applies 64 industries (Eurostat, 2008). Thus, only the identical industries (and some of them in aggregated form) are compared. Table 21 shows the elements of the main components that are identified as the major drivers of changes over time as discussed in Section 3.3.

Results indicate a major decline in Electricity, gas, steam and air conditioning supply during these years. Altogether the overall CO_2 emission generated by this sector has been reduced by 36% from 2000 to 2008. The greening of electricity generation can be caught in own demand component that shows the major decline. Similarly, the final demand component significantly lowered the whole sectorial emission that is purely the result of the change in emission element (EE) that reflects the negative change in direct emission from electricity generation. The demand element (DE) of final demand component indicates, on the other hand, a significant increase in electricity consumption.

An enormous positive change in carbon emission can be detected in Land transport during the period; its CO_2 emission has been risen by 38% compared to the level in 2000, mainly due to the increase in final demand and own demand components. In final demand component the DE exceeds the EE almost three times, there is a little technological improvement, but its increase can mostly be attributed to the increasing demand. CO_2 emission from air transport has risen by 75% that is also the consequence of growing demand. However, the deregulation, market entry of low-cost carriers, increased destinations available to consumers led to downward prices (Eurostat, 2014).

As for Accomodation and food services, results show that this sector has been risen by 50% during the period. Its SC_S^M component contributes the most to the whole sectorial increase, whereas the DE of final demand component shows only a little growth referring to an inefficient change in supply management of Accomodation and food services. Recreational, cultural and sporting services show a moderate change (+11%) during the period that can be explained by the increased ED_S and SC_S^M components. The dominant role of SC_S^M component in both Recreation and entertainment confirms the importance of pull effect on productive sectors.

Basic supply services such as Public administration and defence, Education, Health and social work activities have gone through significant changes, they show a reduction in their total CO_2 emission by 18%, 23%, 21%, respectively, which are result of the reduction in own component and the emission and technological elements of final demand and supply from other services.

Table 23: Total CO_2 emission changes in the service subsystem by components between 2000 and 2008

$ktCO_2$	ΔOD_S	ΔED_S	ΔFD_S	ΔSC_S^S	ΔSC_S^M	ΔFB_M^S	Total	Change
Electricity, gas, steam and air conditioning supply	-3,442.55	0.00	-3,144.10	14.67	93.99	-625.10	**-7,103.08**	**-36%**
Water collection, treatment and supply	-216.50	-50.29	-212.84	3.08	34.52	-23.42	**-465.45**	**-41%**
Sewerage; waste collection, treatment and disposal activities	-302.81	-41.34	-321.64	-1.93	3.34	-18.95	**-683.34**	**-55%**
Public administration and defence; compulsory social security	-151.60	-201.45	-150.43	37.99	-5.92	-3.05	**-474.47**	**-16%**
Education	-363.00	-102.58	-369.80	-25.11	27.96	-7.47	**-840.00**	**-23%**
Health and social work services	-360.60	-110.90	-343.57	-18.20	-34.38	-10.53	**-878.19**	**-21%**
Land transport and transport via pipelines	771.90	-111.75	750.77	-16.66	7.56	144.32	**1,546.14**	**+38%**
Water transport	-0.66	-2.08	-0.65	-0.91	-2.38	-0.12	**-6.79**	**-69%**
Air transport	90.77	5.69	87.65	2.05	19.34	4.17	**209.66**	**+75%**
Wholesale and retail trade and repair of motor vehicles and motorcycles	-12.12	-10.49	-12.09	-18.24	248.33	-1.74	**193.65**	**+11%**
Accommodation and food services	-9.58	42.53	-8.55	63.27	514.66	-1.23	**601.10**	**+50%**
Recreational, cultural and sporting services	0.38	40.62	0.61	-24.75	41.02	-1.32	**56.55**	**+11%**
Real estate activities	-10.98	31.37	-11.43	20.23	90.82	-0.09	**119.91**	**+12%**
Scientific research and development	-16.61	-22.43	-16.57	-4.59	-14.12	-2.03	**-76.34**	**-48%**
Computer programming, consultancy and related activities	1.36	1.59	1.24	0.72	1.82	-2.79	**3.94**	**+48%**
Financial service activities, insurance and pension funding	4.98	41.60	4.92	21.38	68.76	-0.59	**141.05**	**+75%**

Table 24: Demand and technological elements by main components

	ΔFD_S		ΔSC_S^S		ΔSC_S^M		ΔFB_M^S	
	ΔEE	ΔDE	ΔTE	ΔDE	ΔTE	ΔDE	ΔTE	ΔDE
Electricity, gas, steam and air conditioning supply	-6,918.20	3,774.11	-52.58	67.25	-110.36	204.35	-1,536.05	910.95
Water collection, treatment and supply	-639.05	426.21	-13.74	16.82	-21.27	55.79	-59.45	36.04
Sewerage; waste collection, treatment and disposal activities	-649.26	327.62	-18.42	16.49	-39.85	43.19	-56.40	37.45
Public administration and defence; compulsory social security	-643.62	493.19	-168.22	206.20	-475.81	469.88	-8.11	5.07
Education	-1,522.38	1,152.57	-120.66	95.56	-168.10	196.06	-15.65	8.18
Health and social work services	-1,304.63	961.06	-132.63	114.43	-661.37	626.99	-18.29	7.76
Land transport	-470.37	1221.14	-34.98	18.32	-165.55	173.11	-88.78	233.10
Water transport	-0.81	0.16	-1.38	0.47	-3.65	1.27	-0.15	0.03
Air transport	-177.78	265.43	-16.46	18.51	-39.58	58.92	-8.56	12.73
Wholesale and retail trade and repair of motor vehicles and motorcycles	-26.68	14.58	-440.00	421.77	-395.34	643.67	-3.65	1.91
Accommodation and food service activities	-107.42	98.87	-105.28	168.55	-358.36	873.02	-3.11	1.88
Recreational, cultural and sporting services	-15.06	15.66	-88.39	63.64	-70.96	111.99	-2.04	0.72
Real estate activities	-34.79	23.36	-84.54	104.77	-289.42	380.24	-0.81	0.72
Scientific research and development	-22.63	6.06	-7.82	3.23	-25.19	11.07	-2.99	0.96
Computer programming, consultancy and related activities; information service activities	-2.56	3.80	-0.63	1.35	-1.83	3.65	-62.63	59.84
Financial service activities, insurance and pension funding	-24.77	29.69	-76.49	97.87	-45.34	114.11	-9.62	9.03

5. Summary

This study applies an environmentally extended input-output model combined with a structural decomposition analysis to examine the carbon impacts of the Hungarian service sector. The decomposition method allows us to identify structural effects associated with intersectorial relations to obtain a more complex picture of the overall impact of service activities.

The EEIO revealed the total (direct and embedded) emissions of different sectorial activities. The total emissions from non-service industries are characterized by the dominance of direct emission. In case of services the ratio is reversed, their direct emission has only a marginal share in total emission (except for electricity generation and transportation). Figure 14 summerizes the main results of EEIO analysis. Both non-service and service industries have various total carbon intensities. Non-service sectors have a relatively small share (<5%) in total CO_2 emission (except for the Manufacture of food products, 13%) and relatively higher carbon intensities on average compared to service sectors (carbon intensities are more than 1.5 $ktCO_2$/Mio.NAC in all cases). The total carbon intensities of services have a higher deviation. Not surprisingly, electricity generation has the biggest share in total emission and one of the highest total carbon intensities as well among all industries. Land transport has medium values with regard to carbon intensity and share in total CO_2 emission. The rest of services are scattered around 0-4 $ktCO_2$/Mio.NAC and 0-6% share in total CO_2 emission. These results are in line with the findings of Suh (2006).

In order to analyse the service subsystem in-depth, six groups of services are defined based on possible channels of policy intervention; (1) Electricity, gas, steam and air conditioning supply (2) Basic supply services, (3) Transportation and trade, (4) Recreation and entertainment, (5) Knowledge-based services and (6) Other services. By means of this separation, we could obtain a more detailed picture about the variety of carbon impacts across different type of services. Non-service sector and Electricity generation are responsible for more than 50% of total final demand emission.

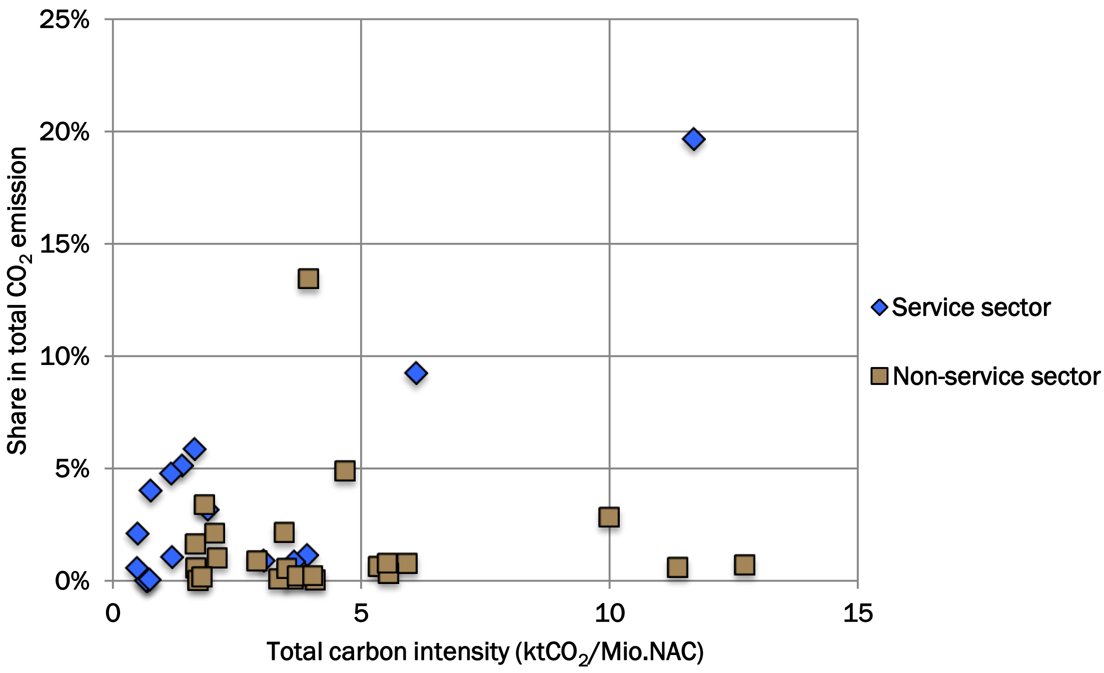

Figure 14: Summary of CO_2 impact of the Hungarian service and non-service sector (2008)

The structural decomposition of the EEIO model is used to identify the major drivers of CO_2 emissions across intersectorial relationships. Six main components are taken into account during the calculations: own demand, final demand, electricity demand, supply from service and non-service sectors and feedback components. The reason why electricity supply is separated from basic supply component is that electricity generation in Hungary has gone through substantial changes between 2000-2008, thus its separation is needed to detect real (de)carbonisation effects of the other sectors.

In total, the service sector accounts for the 65% of total final demand emission in 2008. Figure 15 depicts the distrbution of components within the major service groups. Emissions from Electricity supply are dominated by own and final demand components. The proportion of components is similar in case of Basic supply services and Transportation and trade, though final and own demand components have still the largest share. The sector groups Recreation and entertainment and Knowledge-based services' major CO_2 drivers are ED_S and SC_S^M.

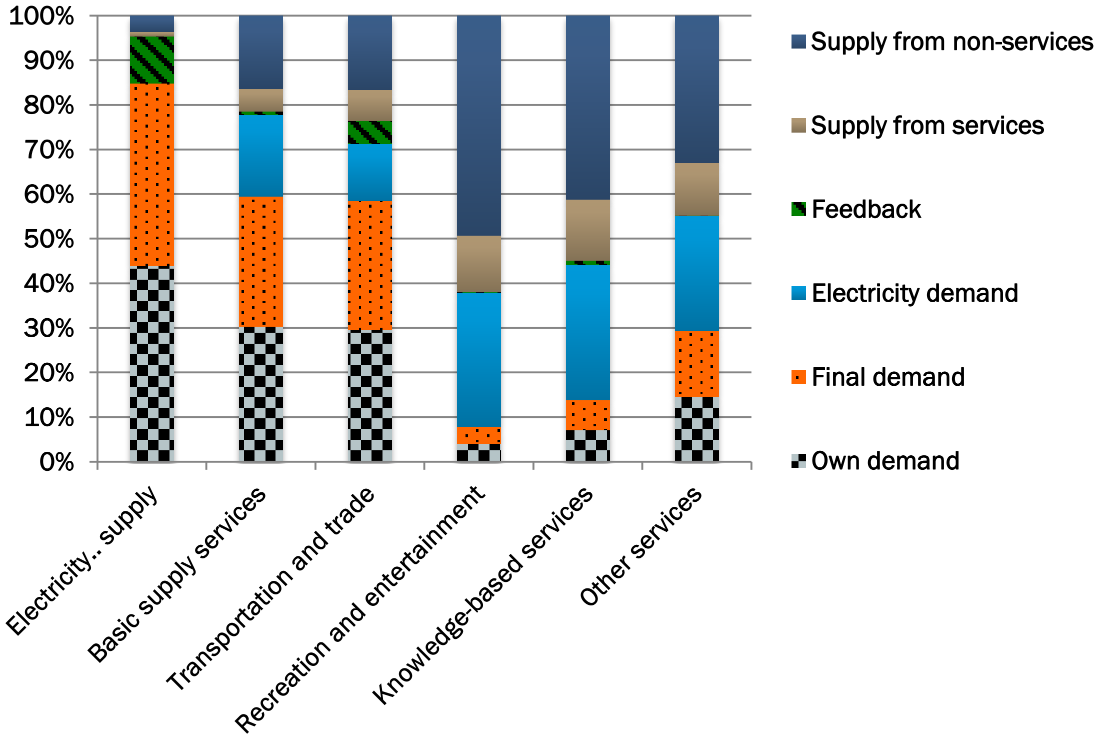

Figure 15: Distribution of structural components in main service groups, 2008

The own and final demand components have the largest share in total CO_2 emission of service subsystem, altogether they amount to the 60% of service sector emission. Supply from non-service sector and Electricity demand are responsible for the 30% of service subsystem emission.

Temporal structural changes are also elaborated between 2000-2008. Results reveal an increase (+27%) in overall CO_2 emissions during the studied period, which can mainly be attributed to the growing import share in national consumption. A significant decrease (-26%) can be observed in service sector, though it is primarily the consequence of greening electricity mix during the studied period. On the other hand, an enormous emission increase can be observed in Transportation and trade and also among Recreation and entertainment as well as Konwledge-based services. Although latter two sectorial groups have less significance in total CO_2 emission, but their relative growth is remarkable.

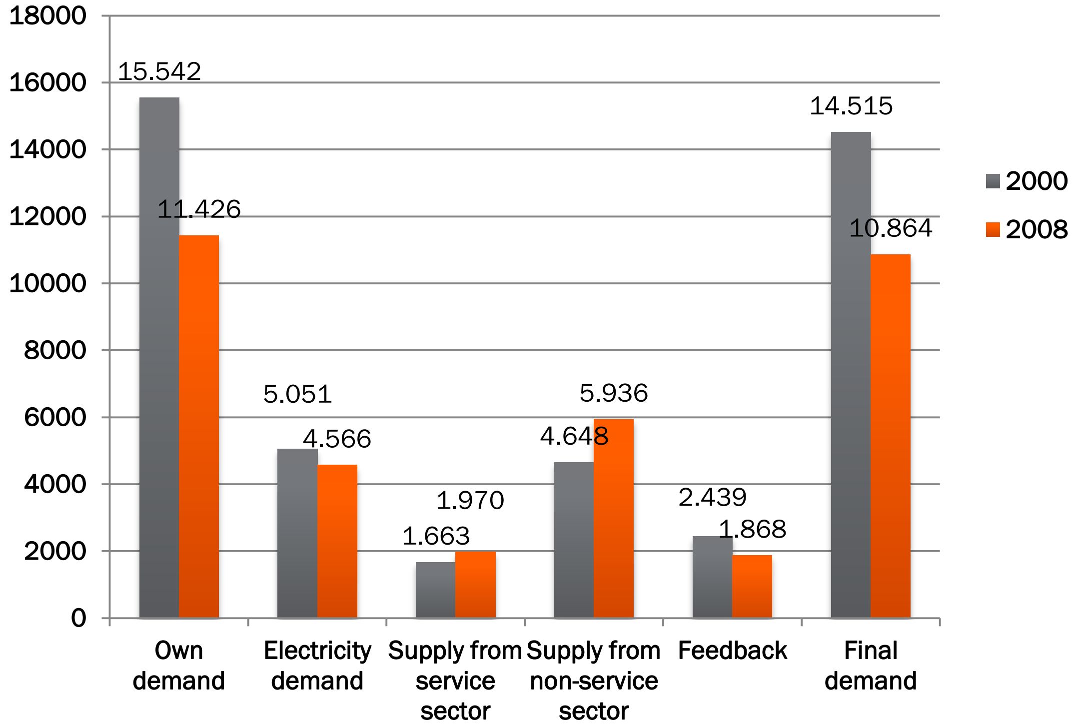

Figure 16: Changes in CO_2 emission from service sector by components over time ($ktCO_2$)

Figure 16 depicts changes in CO_2 emission by components occurred over time. We can observe that almost all components have decreased over the period, except for the Supply components from both service and non-service sectors. Remarkable declines occurred in Own and Final demand components.

Structural changes are further dissected into technological and demand changes. Technological elements (or Emission Element in case of FD_S component) show negative changes in all components that suggest efficiency improvements over time. The demand element, on the other hand, seems to have grown in all components. These findings draw attention that the growing demand can outbalance the achievements of efficiency improvements.

The extent of SC_S^M component refers to the pull effect of service subsystem on non-sevice sector. Service sectors with the strongest pull effect are Wholesale and retail trade and Accomodation and food services with a share in 2008 of 3.2 % and 2.8%, respectively. The overall pull effect accounts for 16% (5936 ktCO₂) of the total emissions of service sectors in 2008. Compering these results to the findings by Butnar and Llop (2011), the extent of CO_2 emission caused by services on non-service activities is less significant. The emission caused by in SC_S^M component show an increase by 1288 $ktCO_2$ between 2000 and 2008. Figure 17 shows the technological and demand elements of SC_S^M components of different service sectors. It shows that the demand level has grown faster than the technological improvements could have kept up with it.

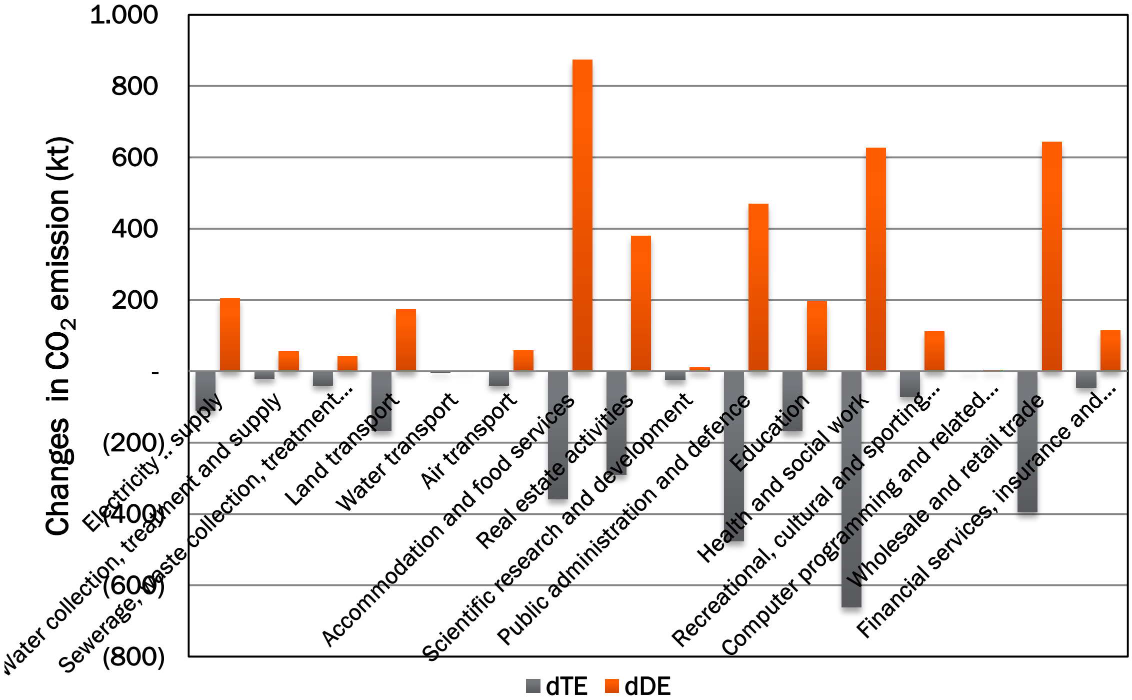

Figure 17: Changes in CO_2 emission of Supply from non-service sector (pull effect)

6. Conclusion

This study identifies the major drivers of CO_2 emission stemming from service sectors that can make a contribution to have a detailed picture about the sources of emission and also prepares the ground for policy intervention.

In total, the service sector accounts for the 65% of total final demand emission in 2008, without the emission from electricity generation the share decreases to 43%. From the analysis the major CO_2 drivers of different service activities can be highlighted. The main emitters in terms of direct and total emissions are the electricity generation and land transport. The pollution of these sectors is way more transparent than any of the other sectors, since their major share of emission occurs directly. However, the direct emission of most services is negligible and the major part of their emission are embedded in products and services they purchase from other industries. The two major emission sources in case of Recreation and entertainment activities and Knowledge-based services are ED_S and SC_S^M components. Latter component embodies the so-called pull effect of services on the other productive activities that shows an increasing trend in Hungary. According to the analysis undertaken, Wholesale and retail trade, Accommodation and food services, and Public administration and defence services play an outstanding role in pull effect. The impact of these sectors is overlooked and they are usually not targeted in policies as potential channels to curb CO_2 emissions. Results confirm the findings of previous studies measuring pull effect of service sector emission conducted in Spain (Alcantara and Padilla, 2009; Butnar and Llop, 2011). They also identified Wholesale and retail trade as the major puling service activities.

Looking at the structural changes over time, we can conclude that apart from the greening electricity generation the aggregated technological efficiency improvements at national level are much slower than the growth of demand for the time being.

To sum up, the findings of this research do not underpin the concept that servitization comes necessarily with lower carbon emission. The hypothesis regarding the major role in total CO_2 emission (H4) can be confirmed. The pulling effect of services on productive sectors covers the largest part only in cases of some services, but not in all services, thus the hypothesis concerning the leading role of the pull effect component among services (H5) can partly be confirmed.

The mitigation of climate change requires reduction of CO_2 emissions in absolute terms, which the present structure of economy cannot ensure. Currently, we can experience a growing demand in services with high embodiment that contributes to the rise in emission of productive activities. Real transition can only be achieved if services become independent of embedded CO_2-intensive products.

Appendix

Table 25: Carbon intensities and direct and embedded emission of non-service sectors in 2008

	DCIV	TCIV	Direct emission	Embedded emission	Total emission
	(ktCO2/Mio. NAC)			(ktCO2/year)	
Crop and animal production, hunting and related activities	2.28	4.67	900.75	1,847.19	2,747.94
Forestry and logging	9.27	12.72	170.52	233.8	404.32
Fishing and aquaculture	2.04	4.07	8.26	16.47	24.73
Mining and quarrying	4.54	5.34	166.17	195.45	361.62
Manufacture of food products, beverages and tobacco	1.55	3.94	2133.27	5,437.64	7,570.91
Manufacture of textiles, wearing apparel and leather products	2.25	3.45	478.23	732.47	1,210.70
Manufacture of wood except furniture	1.39	3.63	10.89	28.56	39.45
Manufacture of paper and paper products	4.09	5.92	178.34	258.12	436.46
Printing and reproduction of recorded media	0.99	3.34	12.19	41.17	53.36
Manufacture of coke and refined petroleum products	0.77	1.84	564.52	1,347.59	1,912.11
Manufacture of chemicals and chemical products	7.94	9.99	707.98	890.22	1,598.20
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.73	1.66	282.57	638.15	920.72
Manufacture of rubber and plastic products	1.38	3.5	89.66	227.74	317.40
Manufacture of other non-metallic mineral products	1.56	3.71	36.85	87.44	124.29
Manufacture of basic metals	3.82	5.55	76.78	111.51	188.29
Manufacture of fabricated metal products, except machinery and equipment	3.76	5.52	177.79	261.15	438.94
Manufacture of computer, electronic and optical products	0.67	1.67	91.26	228.99	320.25

Manufacture of electrical equipment	1.59	2.9	176.11	322.38	498.49
Manufacture of machinery and equipment n.e.c.	2.86	4.02	52.77	74.11	126.88
Manufacture of motor vehicles, trailers and semi-trailers	0.64	2.05	284.17	908.52	1,192.69
Manufacture of other transport equipment	9.1	11.37	148.98	186.13	335.11
Manufacture of furniture; other manufacturing	0.85	2.1	167.29	413.28	580.57
Repair and installation of machinery and equipment	0.3	1.71	0.97	5.58	6.55
Construction	0.04	1.79	2.08	92.39	94.47
Total non-service sector			**6,918.4**	**14,586.05**	**21,504.45**

V. Overall conclusions and implications

This doctoral thesis embraces a variety of societal determinants that play a role in low-carbon transition. All three studies that make up this dissertation show that low-carbon transition is highly dependent on social response that is subject to structural, socio-demographic and psychographic factors. The individual findings of each chapter are summerized below.

In the first study consumer preferences are investigated for green electricity product attributes broadening the literature on social acceptance research towards renewable energies. The aim of the research is to reveal socio-demographic, psyhographic and behavioural characteristics that distinguish green electricity adopters from potential green electricity adopters relying on a representative sample of German households. Although many customers exhibit positive attitudes towards renewable electricity mixes, but only a small percentage of them have already opted for green electricity tariffs. Applying a choice experiment, different consumer segments were identified based on their preferences for different electricity product attributes. Four non-adopter clusters were contrasted to Adopters along two main groups of factors; (1) socio-demographic and (2) psychographic and behavioral variables.

Demographic variables were found to play a marginal role in explaining the difference between Adopters and Potential Adopters. With regard to the hypotheses on socio-demographic characteristics, the subhypotheses concerning the higher income (**H1a**) and smaller households (**H1c**) of Adopters cannot be confirmed by the analysis. On the other hand, results of this study show that Adopters can be characterized by a significantly higher average level of education (i.e. **H1b** can be confirmed). Gender and age show an equal distribution across the sample. Furthermore, results suggest that psychographic and behavioral factors have a great explanatory power when it comes to understanding why consumers who evince strong preferences towards electricity produced from renewable energy sources do not act according to their preferences by opting to purchase green power. As for the subhypothesis on the perceived price differential between electricity tariffs, Adopters estimate that the price difference between green and standard electricity tariffs lower than Potential Adopters (**H2b** can be confirmed). The subhypothesis regarding Adopters' higher sensitivity to environmental issues is only partly underpinned by the findings since these characteristics are proven to be similar when compared to Truly Greens, but significantly different when compared to the other segments (**H2a**). The interplay of a multitude of factors in consumer acceptance for green power can be underlined.

In the second study the CO_2 emission of residential energy consumption is analysed based on a representative survey conducted among Hungarian households. Data were collected about the direct and indirect fuel consumption of households, including their heating and transport activities and electricity use. A latent class analysis was conducted and four main profiles were identified on the basis of the environmental actions taken by respondents. Two clusters describe people who undertake energy-saving behaviour; Energy savers and Supergreens. Respondents from the latter cluster undertake a range of environmental activities, including reducing their energy consumption and travelling in more environmentally-friendly ways instead of using cars. In accordance with these statements, this cluster has the lowest carbon emissions for car use. However, their emissions due to energy consumption for heating and electricity are, on average, similar to those of Browns. The central hypothesis of this study (**H3**), that people who consciously act in a pro-environmental way do not necessarily impact CO_2 emissions more than those who do not undertake environmental activities is partly confirmed; there were no significant differences found between groups in terms of electricity use or heating activities - only with transport activities. It seems that structural factors such as size of home, income, quantity of electric devices etc. might offset the effect of motivational-driven environmental actions resulting in intangible overall decreases in CO_2 impact.

The third study examines the concept of service economy. It has been a common belief that changing consumption patterns towards a bigger share of income spent on services could help to reduce consumption-related CO_2 emissions. In order to come to a deeper understanding of the (de)carbonisation effect of services, an environmentally extended input–output model and a structural decomposition analysis are conducted on the Hungarian industries between 2000 and 2008. The EEIO revealed the total (direct and embedded) emissions of different sectorial activities. The total emissions from non-service industries are characterized by the dominance of direct emission. In case of services the ratio is reversed, their direct emission has only a marginal share (except for electricity generation and transportation). In order to obtain a more detailed picture of the variety of carbon impacts across different type of services, six groups of services are defined based on possible channels of policy intervention; (1) Electricity, gas, steam and air conditioning supply (2) Basic supply services, (3) Transportation and trade, (4) Recreation and entertainment, (5) Knowledge-based services and (6) Other services. The structural decomposition of the EEIO model is applied to identify the major drivers of CO_2 emissions across intersectorial relationships. Six main components are taken into account during the calculations: Own demand, Final demand, Electricity demand, Service Supply, Non-service Supply (pull effect) and Feedback components. The changes in components over time are dissected into technological and demand elements. A substantial pull effect is found among some industries such as Wholesale and retail trade, Accommodation and food services, and Public administration and defence services. The overall pulling effect of services accounts for 11% in total emission and 16% of total service sector emission. Looking at the structural changes over time, we can conclude that the aggregated technological efficiency improvements (apart from the impacts of the greening electricity generation) at national level are much slower than the growth of demand.

To sum up, the findings of this research do not underpin the concept that a service economy comes necessarily with lower carbon emission. The hypothesis regarding the major role in total CO_2 emission (**H4**) can be confirmed. The pulling effect of services on productive sectors covers the largest part only in case of some services, therefore the hypothesis concerning the leading role of the pull effect among services (**H5**) can partly be confirmed.

The mitigation of climate change requires reduction of CO_2 emissions in absolute terms, which the present structure of economy cannot ensure. Currently, we can experience a growing demand in services with high embodiment that contributes to the rise in emission of productive activities. Real transition can only be achieved if services become independent from CO_2-intensive products.

This thesis also aims at providing policy recommendations based on the findings of the presented studies. For decision-makers and practitioners the following three major policy implications can be highlighted:

1) Green electricity adoption, as the most accessible way of supporting renewable energy production for the public, seems to be hampered more by psychographic factors such as the lack of awareness and information than socio-demographic factors
2) Even though consumers undertake a number of pro-environmental behaviors, the actual CO_2 impact of these actions is marginal, which can be attributed to the structural lock-in that can offset the positive effects of motivational-driven actions
3) Service sector shows high CO_2 embodiment and pull effect on productive activities that suggests overlooked CO_2 reduction potentials

The social acceptance, as pointed out by Wüstenhagen et al. (2007), is a keystone in promoting the technological change in energy sector. Results of the survey presented in the first study imply that consumers are usually ill-informed about the environmental significance of their actions. This is underpinned by the outstanding role of perceived consumer effectiveness among green electricity adopters and the low awareness of eco-labels among non-adopter segments. Eco-labelling is a well-designed policy tool to spread out information on environmentally friendly products among consumers. Recently, this policy instrument has received growing attention among academics, policy makers and industry professionals (e.g. Thogersen, 2000; Rubik et al., 2007). Whereas several eco-labels exist in the German market, there is still low awareness of energy labels detected among electricity consumers. *For policy makers, the enhancement of information channels on eco-labels and the development of their dissemination techniques are recommended to increase transparency and reliability.* Furthermore, education seems to play an utmost important role in the purchasing decision and may also make a strong contribution to higher perceived consumer effectiveness. *This highlights the necessity of communicating better about the actual impacts of opting for green power.*

The second study concludes that there may actually be no significant difference between environmentally conscious and environmentally indifferent individuals in terms of their energy-related CO_2 emissions. This implies that pro-environmental behaviors are limited in impact and might be dominated by structural factors. This statement applies to heating and electricity use but not to transportation activities. Besides the information gap between environmental actions and their carbon impacts the findings presented in the second study suggest that *subsidies and incentives targeting structural factors such as home size, type of house etc., can be efficient policy instruments to improve energy efficiency of heating activities and electricity use. Transportation activities can be targeted by awareness raising campaigns.* In line with the findings of the first study, the greenest consumers (Supergreens) have higher education level on average compared to other segments. *Therefore, we can conclude that a more efficient way of disseminating information on CO_2 impacts of environmental actions is also needed. Misleading or inaccurate information may lead to redundant efforts and in the long run to the demoralization of consumers.*

As it is demonstrated in the third study, the major part of CO_2 emission generated by service sector is embedded in the supply chain. Results of structural decomposition analysis show that the major share of CO_2 emission generated by services comes indirectly from the emission of non-service sector and electricity generation. The high embodiment of services gives room for improvement in policies targeting curbing CO_2 emission. Sectors such as energy generation, paper and pulp industry, cement, etc. are mainly associated with carbon emission and stand in the focus of climate regulation, although downstream sectors – mainly services – are significantly affected as well (Csutora and Dobos, 2012). The findings of this study provide relevant inputs for improvements in the field of carbon accounting as well as carbon pricing. Along with carbon emission, carbon costs (e.g. taxes or market-based mechanisms such as emission trading schemes) are accumulated in the supply chain. Downstream industries are affected by these policy regulations through purchasing carbon-intensive products such as energy, transportation and other intermediate products. Knowledge-based services and Recreational and entertainment activities, which have almost zero direct carbon emissions, purchase mainly electricity and products from non-service sectors for their activities. Due to the strong intersectorial dependency, these sectors might therefore be sensitive to changes in energy and carbon costs. *So it can be concluded that downstream service industries such as knowledge-based and recreational services are strongly affected by energy and carbon prices as well, which can provide a possible channel to regulate the indirect* CO_2 *impact of such industries.*

Related publications

1. Peer-reviewed articles

Tabi, A., Hille, S., Wüstenhagen, R., 2014. Preferences for green electricity and eco-labels: empirical results from a market segmentation analysis in Germany. Working paper

Tabi, A., 2013. Does pro-environmental behavior affect CO_2 emissions? Energy Policy, Volume 63, Pages 972-981.

Tabi, A., 2013. Using the stated preference method for the calculation of social discount rate. *Society and Economy*. DOI: 10.1556/SocEc.2013.0003

Mozner, Z., **Tabi, A.**, Csutora, M., 2012. Modifying the yield factor based on more efficient use of fertilizer—The environmental impacts of intensive and extensive agricultural practices. *Ecological Indicators* 16(2012) 58–66.

Tabi, A., Csutora, M., 2011. Representing forest management dilemmas in ecological footprint indicator. *Applied Ecology and Environmental Research* 10(1): 65-73.

2. Book chapters

Schaltegger, S., Harms, D., Hörisch, J., Windolph, S., Burrit, R., Carter, A., Truran, S., Crutzen, N., Rhouma, A., Csutora, M., **Tabi, A**., Kokubu, K., Kitada, H., Badrul Haider, M., Dae Kim, J., Lee, K., Moneva, J., Ortas, E., Alvarez-Etxeberria, I., Daub, C., Schmidt, J., Herzig, C., Morelli, J. 2013. International corporate sustainability barometer: A comparative analysis of 11

countries. Lüneburg: Center for Sustainability Management e.V., Leuphana University Lüneburg, 2013. 56 p. (ISBN:978-3-942638-38-8)

Tabi, A., Csutora, M., Benedek, Z., Ásványi, K., Marjainé Szerényi, Z., Molnár, A., Szabó, Z., Eszlári, N., Kardos, M., Kozma, Z., Derts Z. 2011. Gazdasági számítások alapjai a modellezett vízkészlet-változások mentén. In: Koncsos László (szerk.). Jövöképtöl a vízkészlet-kockázatig. Budapest: BME Építőmérnöki Kar Vízi Közmű és Környezetmérnöki Tanszék, 2011. pp. 95-137. (ISBN:978 963 313 060 5)

Tabi, A., Csutora, M. 2012. A temporális diszkontálási szokások vizsgálata - a társadalmi diszkontráta és a társadalmi preferenciák kapcsolata. In: Kerekes Sándor, Csutora Mária (edited) Fenntartható fogyasztás?: Trendek és lehetőségek Magyarországon. Budapest: Aula Kiadó, 2012. pp. 173-197.(ISBN:978 963 339 042 9)

Tabi, A., 2011. A magyar háztartások energia lábnyomának vizsgálata lakossági felmérése alapján (In: Az ökológiai lábnyom ökonómiája, 2011, ISBN 978-963-339-028-3, 75-88 pp.)

3. Other pertinent publications

Csutora, M., Mózner, Z., **Tabi, A**. 2009. Sustainable consumption: From escape strategies towards real alternatives. In: Kerekes, S., Csutora, M., Székely, M. (edited) Sustainable Consumption 2009 Conference: Sustainable consumption, production and communication: Proceedings: Budapest,. 63-74. (ISBN:978-963-503-399-7)

References

1. Adamowicz, W., Louviere, J., Williams, M., 1994. Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities, Journal of Environmental Economics and Management, Volume 26, Issue 3, May 1994, Pages 271-292. DOI: 10.1006/jeem.1994.1017
2. Ajzen, I., Fishbein, M., 1980. Understanding Attitudes and Predicting Social Behaviour. Englewood Cliffs, NJ, Prentice Hall.
3. Alcántara, V., Padilla, E., 2009. Input–output subsystems and pollution: An application to the service sector and CO2 emissions in Spain, Ecological Economics, Volume 68, Issue 3, 15 January 2009, Pages 905-914. DOI: 10.1016/j.ecolecon.2008.07.010
4. Ali, G., Abbas, S., Qamer, F. M., 2013. How effectively low carbon society development models contribute to climate change mitigation and adaptation action plans in Asia, Renewable and Sustainable Energy Reviews, Volume 26, October 2013, Pages 632-638. DOI: 10.1016/j.rser.2013.05.042
5. Alvarez-Farizo, B., Hanley, N., 2002. Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain. Energy Policy. 30(2), 107-116. DOI: 10.1016/S0301-4215(01)00063-5
6. Amador, F. J., Gonzalez, R. M., Ramos-Real, F. J., 2013. Supplier choice and WTP for electricity attributes in an emerging market: The role of perceived past experience, environmental concern and energy saving behavior. Energy Economics. 40, 953-966. DOI: 10.1016/j.eneco.2013.06.007
7. Andreasen, A. R., 1984. Life Status Changes and Changes in Consumer Preferences and Satisfaction. Journal of Consumer Research*,* Vol. 11, No. 3, pp. 784-794. DOI: 10.1086/209014
8. Arkesteijn, K., Oerlemans, L., 2005. The early adoption of green power by Dutch households: An empirical exploration of factors influencing

the early adoption of green electricity for domestic purposes. Energy Policy. 33(2), 183-196. DOI: 10.1016/S0301-4215(03)00209-X

9. Arroyo-Currás, T.,Bauer, N., Kriegler,E., Schwanitz,V. J., Luderer,G., Aboumahboub, T., Giannousakis, A., Hilaire,J.,2013. Carbon leakage in a fragmented climate regime: The dynamic response of global energy markets, Technological Forecasting and Social Change, Available online 10 November 2013, DOI: 10.1016/j.techfore.2013.10.002
10. Austin, A., Cox, J., Barnett, J., Thomas, C., 2011. Exploring catalyst behaviours: Full Report. A report to the Department for Environment, Food and Rural Affairs. Brook Lyndhurst for Defra, London.
11. Batel, S., Devine-Wright, P., Tangeland, T., 2013. Social acceptance of low carbon energy and associated infrastructures: A critical discussion, Energy Policy, Volume 58, July 2013, Pages 1-5. DOI: 10.1016/j.enpol.2013.03.018
12. Bell, D. 1973. The Coming of the Postindustrial Society. A Venture in Social Forecasting Basic Books, New York (1973).
13. Bergmann, A., Hanley, N., Wright, R., 2006. Valuing the attributes of renewable energy investments. Energy Policy. 34(9), 1004-1014. DOI: 10.1016/j.enpol.2004.08.035
14. Bernardini, O., Galli, R., 1993. Dematerialization: Long-term trends in the intensity of use of materials and energy, Futures, Volume 25, Issue 4, May 1993, Pages 431-448. DOI: 10.1016/0016-3287(93)90005-E
15. Beuren, F. H., Gomes Ferreira, M. G., Cauchick Miguel, P. A., 2013. Product-service systems: a literature review on integrated products and services, Journal of Cleaner Production, Volume 47, May 2013, Pages 222-231. DOI: 10.1016/j.jclepro.2012.12.028
16. Bicknell, K.B., Ball, R. J., Cullen, R., Bigsby. H. R. 1998. New methodology for the ecological footprint with an application to the New Zealand economy. Ecological Economics 27 (1998) 149–160. DOI: 10.1016/S0921-8009(97)00136-5
17. Blake, J., 1999. Overcoming the 'value–action gap' in environmental policy: tensions between national policy and local experience, Local Environment, 4(3), pp. 257–278. DOI:10.1080/13549839908725599

18. BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), 2009. Electricity from renewable energy sources – What does it cost? http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/brochure_electricity_costs_bf.pdf

19. BMWI (Federal Ministry of Economics and Technology), 2013. http://www.bmwi.de/DE/Themen/Energie/Energietraeger/erneuerbare-energien,did=20918.html

20. Böhringer, C., Balistreri, E. J., Rutherford, T. F., 2012. The role of border carbon adjustment in unilateral climate policy: Overview of an Energy Modeling Forum study (EMF 29), Energy Economics, Volume 34, Supplement 2, December 2012, Pages S97-S110, DOI: 10.1016/j.eneco.2012.10.003

21. Bosley, P., Bosley, K. 1988. Public acceptability of California's wind energy developments: three studies. Wind Engineering, 12 (5) (1988), pp. 311–318.

22. Branger, F., Quirion, P., 2014. Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies, Ecological Economics, Volume 99, March 2014, Pages 29-39, DOI: 10.1016/j.ecolecon.2013.12.010

23. Brizga, J., Feng, K., Hubacek, K., 2014. Drivers of greenhouse gas emissions in the Baltic States: A structural decomposition analysis, Ecological Economics, Volume 98, February 2014, Pages 22-28, DOI: 10.1016/j.ecolecon.2013.12.001

24. Broome, J., 1992. *Counting the Cost of Global Warming*. Cambridge: White Horse Press.

25. Buera, F. J., Kaboski, J. P., 2012. The Rise of the Service Economy, American Economic Review, American Economic Association, vol. 102(6), pages 2540-69, October. DOI: 10.1257/aer.102.6.2540

26. Bürer, M. J., Wüstenhagen, R., 2008. Cleantech Venture Investors and Energy Policy Risk: An Exploratory Analysis of Regulatory Risk Management Strategies, in: Wüstenhagen, R., Hamschmidt, J., Sharma,

S., Starik, M.: Sustainable Innovation and Entrepreneurship, Edward Elgar Publishing, pp. 290-309.

27. Bürer, M. J., Wüstenhagen, R., 2009. Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors, Energy Policy, Volume 37, Issue 12, December 2009, Pages 4997-5006, DOI: 10.1016/j.enpol.2009.06.071

28. Burgess, J., Harrison, C. Filius, P., 1998. Environmental communication and the cultural politics of environmental citizenship, Environment and Planning A, 30, pp. 1445–1460. doi:10.1068/a301445

29. Burkhalter, A., Kaenzig, J., Wüstenhagen, R., 2009. Kundenpräferenzen für leistungsrelevante Attribute von Stromprodukten. Zeitschrift für Energiewirtschaft, 33(2), 161-172.

30. Burniaux, J. M., Oliveira Martin, J., 2000. Carbon emission leakages: A general equilibrium view, OECD Economics Department Working Papers No 242, OECD Paris, May 2000. http://dx.doi.org/10.1787/410535403555

31. Butnar, I., Llop, M., 2011. Structural decomposition analysis and input–output subsystems: Changes in CO2 emissions of Spanish service sectors (2000–2005), Ecological Economics, Volume 70, Issue 11, 15 September 2011, Pages 2012-2019. DOI: 10.1016/j.ecolecon.2011.05.017

32. Cai, Y. X., Deilami, I., Train, K., 1998. Customer retention in a competitive power market: Analysis of a 'double-bounded plus follow-ups' questionnaire. Energy Journal. 19(2), 191-215. DOI: 10.5547/ISSN0195-6574-EJ-Vol19-No2-12

33. Cansino, J. M., Pablo-Romero, M. P., Román, R., Yñiguez, R., 2010. Tax incentives to promote green electricity: An overview of EU-27 countries, Energy Policy, Volume 38, Issue 10, October 2010, Pages 6000-6008, DOI: 10.1016/j.enpol.2010.05.055

34. Cape Grim Observatory database. 2014. http://www.csiro.au/greenhouse-gases/

35. Carlman, I., 1982. Wind energy potential in Sweden: the importance of non-technical factors. In: Fourth International Symposium on Wind Energy Systems. September 21–24, 1982, Stockholm, pp. 335–348.

36. Carlman, I., 1984. The views of politicians and decision-makers on planning for the use of wind power in Sweden. In: European Wind Energy Conference, 22–36 October 1984, Hamburg, pp. 339–343.

37. Cerin, P., 2006. Bringing economic opportunity into line with environmental influence: A discussion on the Coase theorem and the Porter and van der Linde hypothesis, Ecological Economics, Volume 56, Issue 2, 15 February 2006, Pages 209-225, DOI: 10.1016/j.ecolecon.2005.01.016

38. Chassot, S., Wüstenhagen, R., Fahr, N., Graf, P. 2013. Wenn das grüne Produkt zum Standard wird: Wie ein Energieversorger seinen Kunden die Verhaltensänderung einfach macht. Organisationsentwicklung, 2013(3), 80-87.

39. Chichilnisky, G., 1998. The knowledge revolution, J. Int. Trade Econ. Dev., 7 (1998), pp. 39–54.

40. Clark, C. F., Kotchen, M. J., Moore, M. R., 2003. Internal and external influences on pro-environmental behavior: Participation in a green electricity program. Journal of Environmental Psychology. 23 (3), 237-246. doi:10.1016/S0272-4944(02)00105-6

41. Clausen, J., 2008. Betrieber von Solarwärmeanlagen und Ökostromkunden in der Klimaschutzregion Hannover. Research project Wenke 2. http://www.borderstep.de/pdf/P-Clausen-Betreiber_von_Solarwaermeanlagen_und_Oekostromkunden_in_der_Klimaschutzregion_Hannover-2008.pdf.

42. Coase, R., 1960. The problem of social cost, The Journal of Law and Economics, 3 (1960), pp. 1–44.

43. Cogoy, M., 2004. Dematerialisation, time allocation, and the service economy, Structural Change and Economic Dynamics, Volume 15, Issue 2, June 2004, Pages 165-181. DOI: 10.1016/S0954-349X(03)00025-0

44. Crawford, R., 2008. Validation of a hybrid life-cycle inventory analysis method. Journal of Environmental Management 88 (3), 496–506. DOI: 10.1016/j.jenvman.2007.03.024

45. Csutora, M., 2012. One More Awareness Gap? The Behaviour–Impact Gap Problem. Journal of Consumer Policy (2012) 35:145–163 DOI: 10.1007/s10603-012-9187-8.

46. Csutora, M., Dobos, I., 2012. Calculating carbon cost sensitivity of companies using hybrid accounting. 15th EMAN Conference on Environmental and Sustainability Mana gement Accounting in collaboration with the CSEAR International Congress on Social and Environmental Accounting Research, ISBN 978-952-93-1238-2, ., Helsinki

47. Csutora, M., Mózner, Z., Tabi, A., 2009. Sustainable consumption: from escape strategies towards real alternatives. Sustainable Consumption Conference. Sustainable Consumption, Production, and Communication. Conference Proceedings, Budapest, 63-74.

48. Csutora, M., Zsóka, A., 2010. Maximizing the Efficiency of Greenhouse Gas Related Consumer Policy. Journal of Consumer Policy, Consumer Issues in Law, Economics and Behavioral Sciences 1, 67-90. DOI: 10.1007/s10603-010-9147-0.

49. Cucek, L., Klemes, J. J., Kravanja, Z., 2012. A Review of Footprint analysis tools for monitoring impacts on sustainability, Journal of Cleaner Production 34 (2012) 9-20. DOI: 10.1016/j.jclepro.2012.02.036

50. Dallas, M. P., 2014. Manufacturing Paradoxes: Foreign Ownership, Governance, and Value Chains in China's Light Industries, World Development, Volume 57, May 2014, Pages 47-62. DOI: 10.1016/j.worlddev.2013.11.015

51. de Groot, J.I.M., Steg, L., 2010. Relationships between value orientations, self-determined motivational types and pro-environmental behavioural intentions. Journal of Environmental Psychology 30 (2010) 368-378. DOI: 10.1016/j.jenvp.2010.04.002

52. DEFRA, 2005. Experimental statistics on carbon dioxide emissions at local authority and regional level. London: Department for Environment, Food and Rural Affairs.

53. DEFRA, 2008. A framework for pro-environmental behaviours. London: Department for Environment, Food and Rural Affairs.

54. Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

55. Deputy Secretariat of State for Green Economy Development and Climate Policy for the Ministry of National Development, 2010. Republic of Hungary National Renewable Energy Action Plan 2010-2020, ISBN 978-963-89328-0-8.

56. DeSarbo, W. S., Ramaswamy, V., Cohen, S. H., 1995. Market segmentation with choice-based conjoint analysis. Marketing Letters. 6(2), 137-147. DOI: http://dx.doi.org/10.1007/BF00994929

57. Diaz-Rainey, I., Ashton, J. K., 2011. Profiling potential green electricity tariff adopters: green consumerism as an environmental policy tool? Business Strategy and the Environment. 20(7), 456-470. DOI: 10.1002/bse.699

58. Diekmann, A., Preisendörfer, P., 1992. Persönliches Umweltverhalten: Die Diskrepanz zwischen Anspruch und Wirklichkeit, Kölner Zeitschrift für Soziologie und Sozialpsychologie, 44, pp. 226–251.

59. Dinda, S., 2004. Environmental Kuznets Curve Hypothesis: A Survey, Ecological Economics, Volume 49, Issue 4, 1 August 2004, Pages 431-455. DOI: 10.1016/j.ecolecon.2004.02.011

60. Dong, H., Geng, Y., Xi, F., Fujita, T., 2013. Carbon footprint evaluation at industrial park level: A hybrid life cycle assessment approach, Energy Policy 57 (2013) 298–307. DOI: 10.1016/j.enpol.2013.01.057

61. Easterlin, R., 1974. Does Economic Growth Improve the Human Lot? Some Empirical Evidence. In Paul A. David and Melvin W. Reder, eds., *Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz*, New York: Academic Press,

62. EEA (European Environemnt Agency), 2013. Technical report No 8/2013: Annual European Union greenhouse gas inventory 1990–2011 and inventory report 2013.

63. Ehrlich, P. R., Wolff, G., Daily, G. C., Hughes, J. B., Daily, S., Dalton, M., Goulder, L., 1999. Knowledge and the environment, Ecological Economics, Volume 30, Issue 2, August 1999, Pages 267-284, DOI: 10.1016/S0921-8009(98)00130-X

64. Ek, K., 2005. Public and private attitudes towards "green" electricity: the case of Swedish wind power. Energy Policy. 33(13), 1677-1689. DOI: 10.1016/j.enpol.2004.02.005

65. Ek, K., Soderholm, P., 2008. Norms and economic motivation in the Swedish green electricity market. Ecological Economics. 68(1-2), 169-182. DOI: 10.1016/j.ecolecon.2008.02.013

66. EU Progress Report, 2013. http://ec.europa.eu/clima/policies/g-gas/docs/com_2013_698_en.pdf

67. EU, 2008. Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan, http://ec.europa.eu/environment/eussd/pdf/com_2008_397.pdf

68. European Commission, 2011. A Roadmap for moving to a competitive low carbon economy in 2050, http://ec.europa.eu/clima/policies/roadmap/index_en.htm

69. European Commission, 2011. Energy Efficiency Plan, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF

70. European Union, 2013, The EU Emissions Trading System (ETS), doi: 10.2834/55480

71. EUROSTAT database, 2014.

72. Eurostat, 2008. NACE Rev. 2 - Statistical classification of economic activities in the European Community, Methodologies and working papers, ISSN 1977-0375.

73. Eurostat, 2014. Air transport services statistics, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Air_transport_services_statistics_-_NACE_Rev._2

74. EUROSTAT., 2010. Environmental statistics and accounts in Europe http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-32-10-283/EN/KS-32-10-283-EN.PDF

75. Ewing, G., Sarigöllü, E., 2000. Assessing Consumer Preferences for Clean-Fuel Vehicles: A Discrete Choice Experiment, Journal of Public Policy & Marketing, Vol. 19, No. 1, Privacy and Ethical Issues in Database/Interactive Marketing and Public Policy (Spring, 2000), pp. 106-118. doi: http://dx.doi.org/10.1509/jppm.19.1.106.16946

76. Farago, T., Lang, I., Csete, L., 2010. VAHAVA Report: Climate Change and Hungary: Mitigating the Hazard and Preparing for the Impacts; VAHAVA: Budapest, Hungary, 2010; p. 124.

77. Ferng, JJ., 2009. Applying input–output analysis to scenario analysis of ecological footprints, Ecological Economics, Volume 69, Issue 2, 15 December 2009, Pages 345-354. DOI: 10.1016/j.ecolecon.2009.08.006

78. Ferrer-i-Carbonell, A., 2005. Income and well-being: An empirical analysis of the comparison income effect. Journal of Public Economics, 89, 997–1019. DOI: 10.1016/j.jpubeco.2004.06.003

79. Fiksel, J., 2012. A systems view of sustainability: The triple value model, Environmental Development, Volume 2, April 2012, Pages 138-141. DOI: 10.1016/j.envdev.2012.03.015

80. Finnveden, G., Hauschild, M.Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., Suh, S., 2009. Recent developments in life cycle assessment. Journal of Environmental Management 91, 1e21. DOI: 10.1016/j.jenvman.2009.06.018

81. Fourcroy, C., Gallouj, F., Decellas, F., 2012. Energy consumption in service industries: Challenging the myth of non-materiality, Ecological Economics, Volume 81, September 2012, Pages 155-164, DOI: 10.1016/j.ecolecon.2012.07.003

82. Freire-González, J. 2010. Empirical evidence of direct rebound effect in Catalonia. Energy Policy 38 (2010) 2309–2314. DOI: 10.1016/j.enpol.2009.12.018

83. Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., Giljum, S., 2012. Integrating Ecological, Carbon and Water footprint into a “Footprint Family” of indicators: Definition and role in tracking human

pressure on the planet. Ecological Indicators, 16 (2012) 100–112. DOI: 10.1016/j.ecolind.2011.06.017

84. Gardner G.T., Stern, P.C., 2008. The short list: The most effective actions US households can take to curb climate change, Environment: Science and Policy for Sustainable Development, 50, 12–25 pp.

85. Gatersleben, B., Steg, L., Vlek, C., 2002. Measurement and determinants of environmentally significant consumer behaviour. Environment and Behaviour, 34, 335–362. doi: 10.1177/0013916502034003004

86. Gerpott, T. J., Mahmudova, I. 2010. Determinants of green electricity adoption among residential customers in Germany. International Journal of Consumer Studies. 34(4), 464-473. DOI: 10.1111/j.1470-6431.2010.00896.x

87. Gerpott, T. J., Rams, W., Schindler, A., 2001. Customer retention, loyalty and satisfaction in the German mobile cellular telecommunications market. Telecommunications Policy, (25): 249-69. DOI: 10.1016/S0308-5961(00)00097-5

88. GFN, 2008. National Footprint Accounts: Hungary. 2008 Edition for Year 2005., Global Footprint Network, Oakland, CA, USA.

89. Goett, A., Hudson, K., Train K., 2000. Customers' choice among retail energy suppliers: The willingness-to-pay for service attributes. Energy Journal. 21(4), 1-28. DOI: 10.5547/ISSN0195-6574-EJ-Vol21-No4-1

90. Gonzales, A., Dorwin, D., Gupta, D., Kalyan, K., Schimler, S., 2001. Outsourcing: Past, Present and Future, IT and Public Policy, Factor, Analyzing Application Service Providers. Prentice Hall, New York, 2001

91. Gossling, S., Kunkel, T., Schumacher, K., Heck, N., Birkemeyer, J., Froese, J., Naber, N., Schliermann, E., 2005. A target group-specific approach to “green” power retailing: students as consumers of renewable energy. Renewable and Sustainable Energy Reviews. 9(1), 69-83. DOI: 10.1016/j.rser.2004.01.005

92. Green P. E., Srinivasan V., 1990. Conjoint analysis in marketing: new developments with implications for research and practice. *Journal of Marketing* 54(4): 3-19. DOI: 10.2307/1251756

93. Green, P. E., Srinivasan, V., 1978. Conjoint Analysis in Consumer Research: issues and Outlook. Journal of Consumer Research, 5, 103-123. DOI: 10.1086/208721

94. Green, P.E., 1977. A new approach to market segmentation, Business Horizons, Vol. 20 pp. 61-73. DOI: 10.1016/0007-6813(77)90088-X

95. Greening, L. A., Greene, D. L., Difiglio, C., 2000. Energy efficiency and consumption — the rebound effect — a survey, Energy Policy, Volume 28, Issues 6–7, June 2000, Pages 389-401. DOI: 10.1016/S0301-4215(00)00021-5

96. Gross, C. 2007. Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance, Energy Policy, Volume 35, Issue 5, Pages 2727-2736. DOI: 10.1016/j.enpol.2006.12.013

97. Grubb, M., Neuhoff, K., 2006. Allocation and competitiveness in the EU emissions trading scheme: policy overview, Climate Policy, 6 (1) (2006), pp. 137–160. DOI: 10.3763/cpol.2006.0602

98. Guagnano, G. A., Stern, P. C., Dietz, T., 1995. Influences on attitude–behavior relationships: A natural experiment with curbside recycling. Environment and Behavior, 27, 699–718. doi:10.1177/0013916595275005.

99. Guillen-Royo, M., 2011. Reference group consumption and the subjective wellbeing of the poor in Peru, Journal of Economic Psychology, Volume 32, Issue 2, March 2011, Pages 259-272. DOI: 10.1016/j.joep.2009.12.001

100. Guinée, J.B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., de Haes, H.A.U., de Bruijn, H., van Duin, R., Huijbregts, M.A.J., Lindeijer, E., Roorda, A.A.H., van der Ven, B.L., Weidema, P.P., 2002. Handbook on Life Cycle Assessment, Operational Guide to the ISO Standards. Kluwer Academic Publishers, Dordrecht, The Netherlands.

101. Hampl, N., 2012. Energy investment decision-making under uncertainty: The influence of behavioural and social effects. Doctoral dissertation, No. 4083, D-Druck Spescha, St. Gallen 2012.

102. Hansen, J., Sato, M., Kharecha, P., Beerling, D., Masson-Delmotte, V., Pagani, M., Raymo, M., Royer, D.L., Zachos, J.C., 2008. Target atmospheric CO_2: where should humanity aim? Open Atmospheric Science Journal 2, 217–231, doi:10.2174/1874282300802010217.

103. Hansla, A., Gamble, A., Juliusson, A., Gärling, T., 2008. Psychological determinants of attitude towards and willingness to pay for green electricity, Energy Policy, Volume 36, Issue 2, Pages 768-774. DOI: 10.1016/j.enpol.2007.10.027

104. Harangozo, G., 2009. Fighting the rebound effect in energy consumption: doubts and opportunities. Sustainable Consumption 2009 Conference. 2009, Budapest.

105. Hardisty, D., Weber, E., 2009. Discounting Future Green: Money Versus the Environment. *Journal of Experimental Psychology: General Volume* 138(3): 329-340. doi: 10.1037/a0016433

106. Hartikainen, H., Roininen, T., Katajajuuri, JM., Pulkkinen, H., 2013. Finnish consumer perceptions of carbon footprints and carbon labelling of food products, Journal of Cleaner Production, Available online 24 September 2013, DOI: 10.1016/j.jclepro.2013.09.018

107. Hätönen, J., Eriksson, T., 2009. 30+ years of research and practice of outsourcing – Exploring the past and anticipating the future, Journal of International Management, Volume 15, Issue 2, June 2009, Pages 142-155, ISSN 1075-4253, http://dx.doi.org/10.1016/j.intman.2008.07.002.

108. Hawken, P., Lovins, A., Lovins, L. H., 1999. Natural Capitalism, Creating the Next Industrial Revolution.Boston, New York, London: Little, Brown and Company

109. Heinzle, S., Wüstenhagen, R., 2012. Dynamic Adjustment of Eco-labeling Schemes and Consumer Choice – the Revision of the EU Energy Label as a Missed Opportunity?, Business Strategy and the Environment, 21(1), 60-70, DOI:10.1002/bse.722.

110. Hens, H., Parijs, W., Deurinck. M., 2010. Energy consumption for heating and rebound effects. Energy and Buildings 42 (2010) 105–110. DOI: 10.1016/j.enbuild.2009.07.017

111. Herman, R., Ardekani, S. A., Ausubel, J. H., 1990. Dematerialization, Technological Forecasting and Social Change, Volume 38, Issue 4, December 1990, Pages 333-347. DOI: 10.1016/0040-1625(90)90003-E

112. Hill, T. P., 1977. On goods and services. Review of Income and Wealth, 23 (4) (1977), pp. 315–338. DOI: 10.1111/j.1475-4991.1977.tb00021.x

113. HM Government, 2009. The UK Low Carbon Transition Plan, ISBN: 9780108508394

114. Hoekstra, A.Y., Hung, P.Q., 2002. Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of Water Research Report Series No. 11. UNESCO-IHE. Delft, The Netherlands.

115. Höjer, M., Ahlroth, S., Dreborg, K., Ekvall, T., Finnveden, G., Hjelm, O., Hochschorner, E., Nilsson, M., Palm, V., 2008. Scenarios in selected tools for environmental systems analysis. *Journal of Cleaner Production* 16(18): 1958-1970. DOI: 10.1016/j.jclepro.2008.01.008

116. Hori, S., Kondo, K., Nogata, D., Ben, H., 2013. The determinants of household energy-saving behaviour: Survey and comparison in five major Asian cities. Energy Policy 52 (2013) 354–362. DOI: 10.1016/j.enpol.2012.09.043

117. Howells, M., Jeong, K., Langlois, L., Lee, M. K., Nama, K., Rogner, H.H., 2010. Incorporating macroeconomic feedback into an energy systems model using an IO approach: Evaluating the rebound effect in the Korean electricity system. Energy Policy 38 (2010) 2700–2728. DOI: 10.1016/j.enpol.2008.10.054

118. Hungarian Ministry for Environment and Water, 2007. National Climate Change Strategy 2008–2025. http://klima.kvvm.hu/documents/14/National_Climate_Change_Strategy_of_Hungary_2008.pdf

119. IEA (International Energy Agency), 2007. Energy Balances of OECD Countries 2008 Edition OECD, Paris.

120. IEA, 2012. CO_2 emissions from fuel combustion. https://www.iea.org/co2highlights/co2highlights.pdf

121. IEA, 2013. Trends 2013 in photovoltaic applications, ISBN 978-3-906042-14-5

122. IPCC (International Panel on Climate Change). 2006, Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

123. IPCC, 2013. Climate Change 2014: Mitigation of Climate Change. IPCC Working Group III Contribution to AR5, http://mitigation2014.org/

124. ISO, 2006. ISO14064-1:2006. Greenhouse Gases Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals. Switzerland, International Organization for Standardization (ISO), Geneva 1-20.

125. Izvercianu, M., Seran, S. A., Branea, AM., 2014. Prosumer-oriented Value Co-creation Strategies for Tomorrow's Urban Management, Procedia - Social and Behavioral Sciences, Volume 124, 20 March 2014, Pages 149-156, http://dx.doi.org/10.1016/j.sbspro.2014.02.471.

126. Jacoby, J., Olson, J. C., 1977. Consumer response to price: an attitudinal, information processing perspective. in Moving Ahead With Attitude Research, Y. Wind and M. Greenberg, eds., Chicago. American Marketing Association, 73-86.

127. Jansson, J. O., 2009. The myth of the service economy—An update, Futures, Volume 41, Issue 3, April 2009, Pages 182-189. DOI: 10.1016/j.futures.2008.09.018

128. Jin, S., 2007. The effectiveness of energy efficiency improvement in a developing country: Rebound effect of residential electricity use in South Korea. Energy Policy 35 (2007) 5622–5629. DOI: 10.1016/j.enpol.2007.05.028

129. Junnila, S. 2008. Life cycle management of energy-consuming products in companies using IO-LCA. The International Journal of Life Cycle Assessment, 13(5): 432-439. DOI: 10.1007/s11367-008-0015-y

130. Kaenzig, J., Friot, D., Saade, M., Margni, M., Jolliet, O., 2011. Using Life Cycle Approaches to Enhance the Value of Corporate Environmental Disclosures. Business Strategy and the Environment. 1(20), 38-54. DOI: 10.1002/bse.667

131. Kaenzig, J., Heinzle, S. L., Wüstenhagen. R., 2013. Whatever the customer wants, the customer gets? Exploring the gap between consumer preferences and default electricity products in Germany. Energy Policy. 53(0), 311-322. DOI: 10.1016/j.enpol.2012.10.061

132. Kaiser, F. G., Wilson, M., 2004. Goal-directed conservation behaviour: the specific composition of a general performance. Personality and Individual Differences, 36, 1531-1544. DOI: 10.1016/j.paid.2003.06.003

133. Kallis, G., Kerschner, C., Martinez-Alier, J., 2012. The economics of degrowth, Ecological Economics, Volume 84, December 2012, Pages 172-180, ISSN 0921-8009, http://dx.doi.org/10.1016/j.ecolecon.2012.08.017.

134. Kalwani, M. U., Yim, C. K., 1992. Consumer price and promotion expectations: an experimental study, Journal of Marketing Research, 29, 90-100. DOI: 10.2307/3172495

135. Kalwani, M. U., Yim, C. K., Rinne, H. J., Sugita, Y., 1990. A Price Expectation Model of Customer Brand Choice. Journal of Marketing Research. 27(August), 251-62.

136. Kander, A., 2005. Baumol's disease and dematerialization of the economy, Ecological Economics, Volume 55, Issue 1, 5 October 2005, Pages 119-130. DOI: 10.2307/3172584

137. Kerekes, S., 2012, A fenntartható fejlődésről válság idején. In: Kerekes, S., Jámbor, I., (edt.): Fenntartható fejlődés, élhető régió, élhető települési táj, Volume 1., Budapesti Corvinus Egyetem, Pages 15-36.

138. Kerekes, S., Luda, S., 2011. Climate or Rural Development Policy? Society and Economy in Central and Eastern Europe 1, 145-159. DOI: 10.1556/SocEc.33.2011.1.11

139. Kerekes, S., Szlávik J., 2001. Economic tools for environmental management (A környezeti menedzsment közgazdasági eszközei), Kerszöv, Budapest

140. Koch, N., Fuss, S., Grosjean, G., Edenhofer, O., 2014. Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything?—New evidence, Energy Policy, Available online 11 July 2014, ISSN 0301-4215, http://dx.doi.org/10.1016/j.enpol.2014.06.024.

141. Kollmuss, A., Agyeman, J., 2002. Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behaviour? Environmental Education Research, 8 (2002), pp. 239–260. DOI**:** 10.1080/13504620220145401

142. Kotchen, M. J., Moore, M. R., 2007. Private provision of environmental public goods: Household participation in green-electricity programs, Journal of Environmental Economics and Management, Volume 53, Issue 1, Pages 1-16. DOI: 10.1016/j.jeem.2006.06.003

143. Kotler, P., Keller, K. L., 2006. Marketing management, 12th edition, Prentice Hall, Upper Saddle River, NJ.

144. KSH (Hungarian Statistical Office) database, 2011. (http://portal.ksh.hu/pls/ksh/docs/hun/xstadat/xstadat_eves/i_qpt001.html, downloaded on 10. 06.2011)

145. KSH (Hungarian Statistical Office), 2012. Online database.

146. KSH (Hungarian Statistical Office), 2014. Online database.

147. Kuik, O., Hofkes, M., 2010. Border adjustment for European emissions trading: Competitiveness and carbon leakage, Energy Policy, Volume 38, Issue 4, April 2010, Pages 1741-1748, ISSN 0301-4215, http://dx.doi.org/10.1016/j.enpol.2009.11.048.

148. Lancaster, K. 1966. A new approach to consumer theory. *Journal of Political Economy* 74: 132–157.

149. Lazaro, A., Barberan, R., Rubio, E., 2002. The discounted utility model and social preferences: Some alternative formulations to conventional discounting. *Journal of Economic Psychology* 23(3): 317- 337. DOI: 10.1016/S0167-4870(02)00079-X

150. Lenzen, M., Wiedmann, T., Foran, B., Dey, C., Widmer-Cooper, A., Williams, M., Ohlemüller, R., 2007. Forecasting the Ecological Footprint of Nations: A Blueprint for a Dynamic Approach. ISA Research Report 07-01

151. Lenzen. M., Murray. S. A., 2001. A Modified Ecological Footprint Method and Its Application to Australia. Ecological Economics 37(2): 229−55. DOI: 10.1016/S0921-8009(00)00275-5

152. Leontief, W.W., 1970. Environmental repercussions and the economic structure: an input–output approach. Review of Economics and Statistics LII (3), 261–271. DOI: 10.2307/1926294

153. Litvine, D., Wüstenhagen, R., 2011. Helping "light green" consumers walk the talk: Results of a behavioural intervention survey in the Swiss electricity market. Ecological Economics, Volume 70, Issue 3, 15 January 2011, Pages 462-474. DOI: 10.1016/j.ecolecon.2010.10.005

154. Longo, A., Markandya, A., Petrucci, M., 2008. The internalization of externalities in the production of electricity: Willingness to pay for the attributes of a policy for renewable energy. Ecological Economics. 67(1), 140-152. DOI: 10.1016/j.ecolecon.2007.12.006

155. Loock, M., 2012. Going beyond best technology and lowest price: on renewable energy investors' preference for service-driven business models. Energy Policy 40 (2012) 21–27. DOI: 10.1016/j.enpol.2010.06.059

156. Lorek, S., Spangenberg, J. H., 2014. Sustainable consumption within a sustainable economy – beyond green growth and green economies, Journal of Cleaner Production, 63 (2014), Pages 33-44. DOI: 10.1016/j.jclepro.2013.08.045

157. Lucas, K., Brooks, M., Darnton, A., Jones, J. E., 2008. Promoting pro-environmental behaviour: existing evidence and policy implications, Environmental Science & Policy, Volume 11, Issue 5, August 2008, Pages 456-466, http://dx.doi.org/10.1016/j.envsci.2008.03.001.

158. Lyon, T.P., Maxwell, J.W., 1999. Voluntary approaches to environmental regulations: a survey, M. Franzini, A. Nicita (Eds.), Environmental Economics: Past, Present and Future, Ashgate Publishing, Hampshire (1999)

159. MacPherson R., Lange I., 2013, Determinants of green electricity tariff uptake in the UK. Energy Policy, Volume 62, November 2013, Pages 920-933. DOI: 10.1016/j.enpol.2013.07.089

160. Madlener, R., Stagl, S., 2005. Sustainability-guided promotion of renewable electricity generation, Ecological Economics, Volume 53, Issue 2, Pages 147-167. DOI: 10.1016/j.ecolecon.2004.12.016

161. Manaster, K., 1995. Environmental Protection and Justice: Readings and Commentary on Environmental Law and Practice Anderson Publishing Co, Cincinnati (1995)

162. Marjainé Szerényi, Z., Zsóka, Á., Széchy, A., 2011. Consumer behaviour and lifestyle patterns of Hungarian students with regard to environmental awareness. Society and Economy, 33, 89–110. DOI: 10.1556/SocEc.33.2011.1.8

163. Martin, R., de Preux, L. B., Wagner, U. J., 2014a. The impact of a carbon tax on manufacturing: Evidence from microdata, Journal of Public Economics, Volume 117, September 2014, Pages 1-14. http://dx.doi.org/10.1016/j.jpubeco.2014.04.016.

164. Martin, R., Muûls, M., de Preux, L. B., Wagner, U. J., 2014b. On the empirical content of carbon leakage criteria in the EU Emissions Trading Scheme, Ecological Economics, Volume 105, September 2014, Pages 78-88, http://dx.doi.org/10.1016/j.ecolecon.2014.05.010.

165. Mathur, A., Lee, E., Moschis, G. P., 2006. Life-Changing Events and Marketing Opportunities. Journal of Targeting, Measurement and Analysis for Marketing, 14(2), 115-128. DOI: 10.1057/palgrave.jt.5740174

166. Matiaske, W., Menges, R., Spiess, M. 2012. Modifying the rebound: It depends! Explaining mobility behavior on the basis of the German socio-economic panel. Energy Policy 41 (2012) 29–35. DOI: 10.1016/j.enpol.2010.11.044

167. Mattes, A., 2012. Potentiale für Ökostrom in Deutschland – Verbraucherpräferenzen und Investitionsverhalten der Energieversorger. http://www.diw-econ.de/de/downloads/DIWecon_HSE_Oekostrom.pdf

168. Mauna Loa Observatory database. 2014.

169. MAVIR, 2012. A Magyar villamosenergia-rendszer 2012. évi statisztikai adatai.

170. MAVIR., 2008. A Magyar villamosenergia-rendszer 2008. évi statisztikai adatai.

171. McGoldrick, P. J., Marks, H. J., 1987. Shoppers Awareness of Retail Grocery Prices. European Journal of Marketing. 21(3), 63-76. http://dx.doi.org/10.1108/EUM0000000004687

172. Meunier, G., Ponssard, JP., Quirion, P., 2014. Carbon leakage and capacity-based allocations. Is the EU right?, Journal of Environmental Economics and Management, Available online 17 July 2014, ISSN 0095-0696, http://dx.doi.org/10.1016/j.jeem.2014.07.002.

173. Miller, L., Meyer, D. E., Lanzetta, J. T., 1969. Choice Among Equal Expected Value Alternatives: Sequential Effects of Winning Probability Level on Risk Preferences, *Journal of Experimental Psychology*, 79(3), 1969, 419-423.

174. Ministry of National Development, Hungarian Government, 2011. National Energy Strategy 2030, Hungary, 2011.

175. Mitchell, R. C., Carson, R. T., 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method, Resources for the Future, Washington, DC (1989) DOI: 10.2307/3146688

176. Monjon, S., Quirion, P., 2011. Addressing leakage in the EU ETS: Border adjustment or output-based allocation?, Ecological Economics, Volume 70, Issue 11, 15 September 2011, Pages 1957-1971, ISSN 0921-8009, http://dx.doi.org/10.1016/j.ecolecon.2011.04.020.

177. Mont, O. K., 2002. Clarifying the concept of product–service system, Journal of Cleaner Production, Volume 10, Issue 3, June 2002, Pages 237-245. http://dx.doi.org/10.1016/S0959-6526(01)00039-7

178. Moore, B., Wüstenhagen, R., 2004. Innovative and sustainable energy technologies: the role of venture capital, Business Strategy and the Environment, 13 (2004), pp. 235–245, DOI: 10.1002/bse.413

179. Mulugetta, Y., Urban, F., 2010. Deliberating on low carbon development, Energy Policy, Volume 38, Issue 12, December 2010, Pages 7546-7549. DOI: 10.1016/j.enpol.2010.05.049

180. Murphy, J. J., Allen, P. G., Stevens, T. H., Weatherhead, D., 2005. A Meta-analysis of Hypothetical Bias in Stated Preference Valuation, Environmental and Resource Economics, March 2005, Volume 30, Issue 3, pp 313-325. DOI: 10.1007/s10640-004-3332-z

181. Murthi, B. P. S., Rao, R. C., 2012. Price Awareness and Consumers' Use of Deals in Brand Choice. Journal of Retailing. 88(1), 34-46. DOI: 10.1016/j.jretai.2011.07.001

182. Nakata, T., Silva, D., Rodionov, M., 2011. Application of energy system models for designing a low-carbon society, Progress in Energy and Combustion Science, Volume 37, Issue 4, August 2011, Pages 462-502. DOI: 10.1016/j.pecs.2010.08.001

183. NOAA (National Oceanic and Atmospheric Administration), 2013 http://www.esrl.noaa.gov/gmd/news/pdfs/7074.pdf

184. OECD, 1996. The Knowledge-Based Economy

185. OECD, 2000. The service economy. OECD Publications, Paris.

186. Orme, B. K., 2007. Software for Hierarchical Bayes Estimation for CBC Data, CBC/HB v4 Sawtooth Software Inc., Sequim, WA (2007)

187. Orme, B., 2010. Getting Started with Conjoint Analysis: Strategies for Product Design and Pricing Research. Second Edition, Madison.

188. Owens, S., 2000. Engaging the public: information and deliberation in environmental policy, Environment and Planning A, 32, pp. 1141–1148. doi:10.1068/a3330

189. Parrinello, S., 2003. The myth of the service economy. MPRA Paper No. 30829.

190. Parrinello, S., 2004. The service economy revisited, Structural Change and Economic Dynamics, Volume 15, Issue 4, December 2004, Pages 381-400, http://dx.doi.org/10.1016/j.strueco.2004.01.001.

191. Peters, G. P., Weber, C. L., Guan, D., Hubacek, K., 2007. China's growing CO2 emissions—a race between increasing consumption and efficiency gains, Environmental Science and Technology, 41 (2007), pp. 5939–5944. DOI: 10.1021/es070108f

192. Pichert, D., Katsikopoulos, K.V., 2008. Green defaults: Information presentation and pro-environmental behavior. Journal of Environmental Psychology, 28 (1), pp. 63-73. DOI: 10.1016/j.jenvp.2007.09.004

193. Pigou, A., The economics of welfare, (4th edition) Macmillan & Co, London, UK (1920/1938)

194. Poortinga, W., Steg, L., Vlek, C., Wiersma, G., 2003. Household preferences for energy-saving measures: A conjoint analysis. Journal of Economic Psychology 24 (2003) 49–64. DOI: 10.1016/S0167-4870(02)00154-X

195. Rajecki, D.W., 1982. Attitudes: themes and advances. Sunderland, MA, Sinauer.

196. Ramajo-Hernández, J., del Saz-Salazar, S., 2012. Estimating the non-market benefits of water quality improvement for a case study in Spain: A contingent valuation approach, Environmental Science & Policy, Volume 22, October 2012, Pages 47-59. DOI: 10.1016/j.envsci.2012.05.006

197. Ravallion, M., Lokshin, M., 2005. Who cares about relative deprivation? Washington DC: Development Research Group, The World Bank. DOI: 10.1016/j.jebo.2009.08.008

198. Roe, B., Teisl, M. F., Levy, A., Russell, M., 2001. US consumers' willingness to pay for green electricity. Energy Policy. 29(11), 917-925. DOI: 10.1016/S0301-4215(01)00006-4

199. Romm, J., Rosenfeld, A., Herrman, S., 1999. The internet economy and global warming. Tech. rep. The Center for Energy and Climate Solutions.

200. Rossi, P., Allenby, G., McCulloch, R., 2005. Bayesian Statistics and Marketing, Wiley, New York (2005)

201. Rossi, P.E., Allenby, G. M., 2003. Bayesian statistics and marketing. Marketing Science, 22 (2003), pp. 304–328.

202. Rowlands, I. H., Scott, D., Parker, P., 2003. Consumers and green electricity: profiling potential purchasers. Business Strategy and the Environment. 12(1), 36-48. DOI: 10.1002/bse.346

203. Rubik F, Frankl P, Pietroni L, Scheer D. 2007. Eco-labelling and consumers: towards a re-focus and integrated approaches. International Journal of Innovation and Sustainable Development 2(2): 175–191. DOI: 10.1504/IJISD.2007.016932

204. Ruderman, H., Levine, M. D., Mcmahon, J. E., 1987. The Behavior of the Market for Energy Efficiency in Residential Appliances Including Heating and Cooling Equipment, Energy J. 8:1, p p 101-24.

205. Ruth, M., 1998. Dematerialization in five US metals sectors: implications for energy use and CO_2 emissions, Resources Policy,

Volume 24, Issue 1, March 1998, Pages 1-18. DOI: 10.1016/S0301-4207(98)00003-8

206. Sagoff, M., 1997. Do we consume too much? The Atlantic Monthly, 80–96.

207. Sammer, K., Wüstenhagen, R., 2006. The Influence of Eco-Labelling on Consumer Behaviour – Results of a Discrete Choice Analysis for Washing Machines, Business Strategy and the Environment, 15, Pages 185-199. DOI: 10.1002/bse.522

208. Sanne, C., 2002. Willing consumers—Or locked-in? Policies for a sustainable consumption. Ecological Economics, 42, 273–287. doi:10.1016/S0921-8009(02)00086-1. DOI: 10.1016/S0921-8009(02)00086-1

209. Sardianou, E., 2007. Estimating energy conservation patterns of Greek households. Energy Policy 35, 3778–3791. DOI: 10.1016/j.enpol.2007.01.020

210. Sawtooth Software, 2004. The CBC Latent Class: Version 3.0. Technical Paper. Sequim, WA.

211. Sawtooth Software, 2009. The CBC/HB System for Hierarchical Bayes: Version 5.0. Technical Paper. Sequim, WA.

212. Sawtooth, 2007. The ACA/Web v6.0 – Technical Paper Series, 2007.

213. Schaltegger, S., Csutora, M., 2012. Carbon accounting for sustainability and management. Status quo and challenges, Journal of Cleaner Production, Volume 36, November 2012, Pages 1-16. DOI: 10.1016/j.jclepro.2012.06.024

214. Schinko, T., Bednar-Friedl, B., Steininger, K. W., Grossmann, W. D., 2014. Switching to carbon-free production processes: Implications for carbon leakage and border carbon adjustment, Energy Policy, Volume 67, April 2014, Pages 818-831, ISSN 0301-4215, http://dx.doi.org/10.1016/j.enpol.2013.11.077.

215. Schläpfer, F., Fischhoff, B., 2012. Task familiarity and contextual cues predict hypothetical bias in a meta-analysis of stated preference studies, Ecological Economics, Volume 81, September 2012, Pages 44-47. DOI: 10.1016/j.ecolecon.2012.06.016

216. Shove, E., 2004. Changing human behaviour and lifestyle: a challenge for sustainable consumption?. In: L. Reisch and I. Ropke. Editors. The Ecological Economics of Consumption. Edward Elgar. Cheltenham (2004).

217. Siegrist, M., Visschers, V. H. M., 2013. Acceptance of nuclear power: The Fukushima effect, Energy Policy, Volume 59, August 2013, Pages 112-119. DOI: 10.1016/j.enpol.2012.07.051

218. Simpson, J. A., Griskevicius, V., Rothman, A. J., 2012. Consumer decisions in relationships, Journal of Consumer Psychology, Volume 22, Issue 3, July 2012, Pages 304-314. DOI: 10.1016/j.jcps.2011.09.007

219. Skea, J., Nishioka, S., 2008. Policies and practices for a low carbon society, Climate Policy, 8, s5-s16. doi:10.3763/cpol.2008.0487

220. Sterman J.D., Sweeney, L.B., 2007. Understanding public complacency about climate change: Adults' mental models of climate change violate conservation of matter, Climatic Change, 80, 213–238 pp. DOI 10.1007/s10584-006-9107-5

221. Stern, P. C., 2000. Toward a coherent theory of environmentally significant behaviour. Journal of Social Issues, 56, 407e424. DOI: 10.1111/0022-4537.00175

222. Stern, P. C., Dietz, T. Karlof, L., 1993. Values orientation, gender, and environmental concern, Environment and Behavior, 25(3), pp. 322–348. doi: 10.1177/0013916593255002

223. Stocker, T.F., D. Qin, G.-K. Plattner, L.V. Alexander, S.K. Allen, N.L. Bindoff, F.-M. Bréon, J.A. Church, U. Cubasch, S. Emori, P. Forster, P. Friedlingstein, N. Gillett, J.M. Gregory, D.L. Hartmann, E. Jansen, B. Kirtman, R. Knutti, K. Krishna Kumar, P. Lemke, J. Marotzke, V. Masson-Delmotte, G.A. Meehl, I.I. Mokhov, S. Piao, V. Ramaswamy, D. Randall, M. Rhein, M. Rojas, C. Sabine, D. Shindell, L.D. Talley, D.G. Vaughan and S.-P. Xie, 2013: Technical Summary. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley

(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

224. Stram, B. N., 2014. A new strategic plan for a carbon tax, Energy Policy, Available online 11 June 2014, http://dx.doi.org/10.1016/j.enpol.2014.05.023.

225. Su, B., Ang, B.W., 2012. Structural decomposition analysis applied to energy and emissions: Some methodological developments, Energy Economics, Volume 34, Issue 1, January 2012, Pages 177-188, http://dx.doi.org/10.1016/j.eneco.2011.10.009.

226. Suh, S., 2006. Are services better for climate change?. Environmental Science and Technology 40 (21), 6555–6560. DOI: 10.1021/es0609351

227. Suh, S., Kagawa S., 2009. Industrial ecology and input–output economics: a brief history. In: Suh S, editor. Handbook of input–output economics in industrial ecology. 2009. p. 43–58. ISSN 1389-6970, ISBN 978-1-4020-4083-2.

228. Suh, S., Lenzen, M., Treloar, G.J., Hondo, H., Horvath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J. and Norris, G. 2004. System boundary selection in life-cycle inventories using hybrid approaches. Environmental Science & Technology 38(3): 657-664. DOI: 10.1021/es0263745

229. Szajkó, G., 2009. Erdészeti és ültetvény eredetű fás szárú energetikai biomassza Magyarországon. Working paper, 2009-5, Regionális Energiagazdasági Kutatóközpont, Budapesti Corvinus Egyetem.

230. Szlávik, J., Csete, M., 2011. Climate and Energy Policy in Hungary, Energies 5: (2) pp. 494-517. doi:10.3390/en5020494

231. Thayer, R.L., 1988. The aesthetics of wind energy in the United States: case studies in public perception. European Community Wind Energy Conference, Herning, DK, June 6–8. pp. 470–476.

232. Thogersen J. 2000. Psychological determinants of paying attention to eco-labels in purchase decisions: model development and multinational validation. Journal of Consumer Policy 23(3): 285–313. DOI: 10.1023/A:1007122319675

233. Thøgersen, J., 1999. Spillover processes in the development of a sustainable consumption pattern. Journal of Economic Psychology, 20, 53-81. DOI: 10.1016/S0167-4870(98)00043-9

234. Thøgersen, J., Gronhoj, A., 2010. Electricity saving in households—A social cognitive approach. Energy Policy 38 (2010) 7732–7743. DOI: 10.1016/j.enpol.2010.08.025

235. Tian, X., Chang, M., Tanikawa, H., Shi, F., Imura, H., 2013. Structural decomposition analysis of the carbonization process in Beijing: A regional explanation of rapid increasing carbon dioxide emission in China, Energy Policy, Volume 53, February 2013, Pages 279-286, http://dx.doi.org/10.1016/j.enpol.2012.10.054.

236. Toffler, A. (1980), The Third Wave, William Morrow.

237. Tóth, G., Szigeti, C., 2013. The Historical Ecological Footprint of Mankind from 10,000 B.C. to Today, Georgikon Conference, 2013, ISBN 978-963-9639-53-9.

238. Treloar, G. J., Love, P. E. D., Holt, G. D., 2001. Using national input/output data for embodied energy analysis of individual residential buildings, Construction Management and Economics, Vol. 19, Iss. 1, pages 49-61. **DOI:** 10.1080/014461901452076

239. Tucker, P., Douglas, P., 2006. Understanding Waste Reduction Attitudes and Behaviours. Proc. WASTE 2006, Stratford Upon Avon, September 2006.

240. Tukker, A., 2013. Product services for a resource-efficient and circular economy – a review, Journal of Cleaner Production, Available online 7 December 2013, http://dx.doi.org/10.1016/j.jclepro.2013.11.049.

241. Tukker, A., Tischner, U., 2006. Product-services as a research field: past, present and future. Reflections from a decade of research. J. Clean. Prod. 14 (17), 1552e1556. DOI: 10.1016/j.jclepro.2006.01.022

242. UNEP, 2000. Product-Service Systems and Sustainability, ISBN:92-807-2206-9

243. UNFCCC, 2009a. Fact sheet: The need for mitigation. https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf

244. UNFCCC, 2009b. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf

245. UNFCCC, 2010. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010 - Decisions adopted by the Conference of the Parties http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2

246. Upham, P., Dendler, L., Bleda, M., 2011. Carbon labelling of grocery products: public perceptions and potential emissions reductions, Journal of Cleaner Production, Volume 19, Issue 4, March 2011, Pages 348-355. DOI: 10.1016/j.jclepro.2010.05.014

247. Urge-Vorsatz, D., Petrichenko, K., Staniec, M., Eom, J., 2013. Energy use in buildings in a long-term perspective, Current Opinion in Environmental Sustainability, Volume 5, Issue 2, June 2013, Pages 141-151. DOI: 10.1016/j.cosust.2013.05.004

248. van Oel, C. J., van den Berkhof, F. W., 2013. Consumer preferences in the design of airport passenger areas, Journal of Environmental Psychology, Volume 36, December 2013, Pages 280-290. DOI: 10.1016/j.jenvp.2013.08.005

249. Vermunt, J. K., Magidson, J., 2005. Latent GOLD 4.0 User's Guide. Belmont, Massachusetts: Statistical Innovations Inc.

250. Wackernagel. M., Rees. W. E., 1996. Our Ecological Footprint-Reducing Human Impact on the Earth. New Society Publishers. Gabriola Island. B.C.

251. Wang, Z., Zhang, B., Yin, J., Zhang, Y., 2011. Determinants and policy implications for household electricity- saving behaviour: evidence from Beijing, China. Energy Policy, 39, 3550–3557. DOI: 10.1016/j.enpol.2011.03.055

252. WCED (World Commission on Environment and Development), 1987. Our Common Future, Oxford University Press, Oxford.

253. Weisz, H., Duchin, F. 2006. Physical and monetary input–output analysis: What makes the difference?. Ecological Economics 57 (2006) 534– 541. DOI: 10.1016/j.ecolecon.2005.05.011

254. Wenke, M., 1993. Konsumstruktur, Umweltbewusstsein und Umweltpolitik. Eine makroökonomische Analyse des Zusammenhanges in ausgewählten Konsumbereichen. Berlin: Duncker & Humblot.

255. Whitmarsh, L., O'Neill, S., 2010. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. Journal of Environmental Psychology 30 (2010) 305–314. DOI: 10.1016/j.jenvp.2010.01.003

256. Whittaker, C., McManus, M. C., Smith, P., 2013. A comparison of carbon accounting tools for arable crops in the United Kingdom, Environmental Modelling & Software, Volume 46, August 2013, Pages 228-239. DOI: 10.1016/j.envsoft.2013.03.015

257. Wiedmann, T. 2009. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. Ecological Economics 69 (2009) 211–222.

258. Wind, Y., 1978. Issue and advances in segmentation research, Journal of Marketing Research, Vol. 15 pp.317-37. DOI: 10.2307/3150580

259. Wiser, R. H., 2007. Using contingent valuation to explore willingness to pay for renewable energy: A comparison of collective and voluntary payment vehicles. Ecological Economics. 62(3-4), 419-432. DOI: 10.1016/j.ecolecon.2006.07.003

260. Wolsink, M. 1987. Wind power for the electricity supply of houses. Netherlands Journal of Housing and Environmental Research, 2 (3) (1987), pp. 195–214. DOI: 10.1007/BF02497872

261. Wüstenhagen, R., Wolsink, M., Bürer, M. J., 2007. Social acceptance of renewable energyinnovation: An introduction to the concept. Energy Policy 35 (5): 2683-2691. DOI: 10.1016/j.enpol.2006.12.001

262. WWF (World Wild Fund), 2011. Planning development in a carbon constrained world. http://www.wwfblogs.org/climate/sites/default/files/WWFBinaryitem25183.pdf

263. Zacharakis, A. L., Meyer, G. D., 1998. A lack of insight: do venture capitalists really understand their own decision process? Journal of Business Venturing 13(1): 57- 76. DOI: 10.1016/S0883-9026(97)00004-9

264. Zarnikau, J., 2003. Consumer demand for 'green power' and energy efficiency. Energy Policy. 31(15), 1661-1672. DOI: 10.1016/S0301-4215(02)00232-X

265. Zhai, P., Williams, E.D., 2012. Analyzing consumer acceptance of photovoltaics (PV) using fuzzy logic model, Renewable Energy, Volume 41, May 2012, Pages 350-357. http://dx.doi.org/10.1016/j.renene.2011.11.041.

266. Zhang, L., Wu, Y., 2012. Market segmentation and willingness to pay for green electricity among urban residents in China: The case of Jiangsu Province. Energy Policy. 51(0), 514-523. DOI: 10.1016/j.enpol.2012.08.053

267. Zoric, J., Hrovatin, N., 2012. Household willingness to pay for green electricity in Slovenia. Energy Policy. 47, 180-187. DOI: 10.1016/j.enpol.2012.04.055

268. Zsóka, A., 2008. Consistency and "awareness gaps" in the environmental behaviour of Hungarian companies, Journal of Cleaner Production, Volume 16, Issue 3, February 2008, Pages 322-329, DOI: 10.1016/j.jclepro.2006.07.044