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PASHMINA – Paradigm Shifts Modelling and Innovative Approaches

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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Austrian Institute of Economic Research
Commissioned by European Commission
Report prepared for the PASHMINA project
Internal review: Kurt Kratena

Abstract

In recent years the scientific discussion on how to best measure societal progress has gained increasing attention in the political arena. The underlying question is, whether the indicators currently used, are able to provide adequate information and are appropriate for guiding political decision making with respect to societal progress and welfare as well as with respect to the concept of sustainable development.

Closely related to the concept of sustainable development a wide range of measurement approaches evolved that focus on different aspects relevant for societal wellbeing and progress. Energy plays a central role for all dimensions of sustainable development which is widely recognised in the different indicator sets. This report takes the energy indicators developed in the PASHMINA project as starting point. In order to summarise the development of the indicators for the EU total as well as EU 15 and the new member countries we calculate composite indices for sustainable energy development for the five sectors energy supply, manufacturing, services, households and transport as well as an aggregate index. A cluster analysis is performed to identify differences and similarities among countries with respect to selected energy indicators in the five sectors.

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2012/346/S/WIFO project no: 5509

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Verkaufspreis: 40,00 € • Kostenloser Download: http://www.wifo.ac.at/wwa/pubid/45904

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1 Introduction

In recent years the scientific discussion on how to best measure societal progress has gained increasing attention in the political arena. The underlying question is, whether the indicators currently used, are able to provide adequate information and are appropriate for guiding political decision making with respect to societal progress and welfare as well as with respect to the concept of sustainable development.

Closely related to the concept of sustainable development a wide range of measurement approaches evolved that focus on different aspects relevant for societal wellbeing and progress. Energy plays a central role for all dimensions of sustainable development which is widely recognised in the different indicator sets (e.g. EU, 2005a, b; UNCSD, 2001):

- First, the use of energy is crucial for economic and social development. It provides basic (energy) services such as heat, light, information or mobility and is a crucial input to all kinds of production processes.
- Second, the use of (fossil) energy generates major ecological impacts as it accounts e.g. for a large part of total anthropogenic greenhouse gas emissions that are a key driver for global warming and climate change[1].
- Third, the present energy system relies to a large extent on the use of exhaustible fossil energy sources.

For these reasons, we developed a set of sustainability indicators for the PASHMINA project (see Kettner et al., 2011) that focus on energy and are based on the EU Sustainable Development Indicators (European Commission, 2005b) as well as the IEA / IAEA Indicators for Sustainable Energy Development (IEA / IAEA, 2001).

This report takes the energy indicators developed and proposed by Kettner et al. (2011) as a starting point. One of our aims is to summarise the development of the indicators for the EU total as well as for the Old and New Member States. For this purpose we calculate composite indices for sustainable energy development for the five sectors energy supply, manufacturing, services, households and transport as well as an aggregate index building on Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009). The second objective of this report is to identify differences and similarities among countries with respect to selected energy indicators in the five sectors. For this purpose a cluster analysis is performed.

The structure of this report is as follows: We first summarise the sustainable energy indicator set developed within the PASHMINA project. In the next section we then present the methodological approach for the calculation of the composite index as well as results for the EU total and the Old and New Member States of the European Union in the period 1995 to

[1] Also, the emissions of other air pollutants are closely related to fossil energy use. From the social perspective energy is of relevance as it is not only required for the satisfaction of basic needs but also represents a significant share in household expenditures, especially in lower income percentiles.

2008. This is followed by the presentation of the cluster analysis for the five sectors. The last section concludes.

2 The PASHMINA Energy Indicator Set

For the PASHMINA project we developed and proposed a set of sustainability indicators focusing on stocks and flows (see Kettner et al., 2011). As a starting point and input for the PASHMINA approach two indicator sets were chosen: the EU Sustainability Development Indicators and the IEA/IAEA Sustainable Energy Development Indicators. The focus of the PASHMINA indicator set is put on indicators related to energy supply and use. The motivation for this focus is twofold:

- First, energy plays a central role for all dimensions of sustainable development – on the one hand it is crucial for economic and social development but on the other hand, the use of energy also entails diverse negative ecological effects.
- Second, energy is crucial when focusing on the role of stocks, flows and services relevant for well-being.

2.1 Methodological Approach

The IEA/IAEA system of Indicators for Sustainable Energy Development (ISED) provides a broad range of indicators for all levels of the energy system (IEA/IAEA, 2001). We extend this concept in several aspects:

- We focus on the role of energy services, flows and related stocks.
- We choose a sectoral structure for the representation of indicators as this structure allows for a comprehensive and detailed analysis of specific status and impacts regarding stocks, energy flows and energy services as well as underlying driving forces (disaggregated by sectors in order to identify specific conditions).

Energy services play a crucial role for the development of sustainable energy structures (see also Köppl et al., 2011). It is not the quantity of energy demanded by households and companies that is relevant for welfare and development, but the energy services consumed. These energy services, such as nutrition, housing, mobility and information, are provided by products (food, houses, fuel and media) combined with a wide range of capital stocks (as buildings, arable land, cars and the internet).

A given level of energy services can be provided by different combinations of technologies and energy flows. The range of available technologies and energy sources thus opens up a spectrum of options, which result in different amounts of energy flows and greenhouse gas emissions (GHG) for any given level of services. From a sustainability point of view energy services should hence be provided with the lowest possible input of (fossil) fuels and minimal greenhouse gas emissions.

As there is a strong connection between energy consumption and economic and social development we focus on indicators based on energy services that can be traced back through the energy system to energy consumption, taking into account the relevant technologies. We hence develop energy indicators starting from services that are related to the major components of final energy demand and which will be complemented by key indicators for electricity and heat production.

2.2 Data sources

For the indicators and subsequent analyses the following data sources are used:

Data on energy flows, energy related CO_2 emissions and energy prices are from IEA databases (IEA, 2011a; IEA, 2011b); information on households' energy demand for space heating, cooking and hot water and other purposes is taken from the Odyssee database[2].

For energy services, i.e. gross value added of the manufacturing and service sector, floor area of dwellings, transport performance[3], as well as GDP and population we use the Odyssee database.

Data on non-energy CO_2 emissions as well as on NO_x and SO_2 emissions are from the Member States' 2011 UNFCCC National Inventory Submissions[4].

For heating degree days (HDD) and household income as well as for the distance to the Member States' 2020 renewable energy targets, the Eurostat database is used[5].

2.3 Indicators

Table 1 shows the PASHMINA indicator system. In the first row, a set of meta-indicators is illustrated. These meta-indicators comprise information that is relevant for all sectors, like the countries' Gross Domestic Product (GDP) and population; data on heating degree days, the energy/environment related R&D capital stock, the oil and gas burden as well as the distance to the national targets for renewable energy use and greenhouse gas emissions.

Below this level, the indicators are arranged in a matrix system. The columns illustrate the six sectors for which the indicators are provided: energy supply, manufacturing, services, households, passenger transport and freight transport, representing the major drivers for energy use.

The rows illustrate the different levels of the energy system: The first row summarises the contextual indicators which include information on the respective relevant stocks and supplementing data (like share of energy imports, energy prices, etc.). In the second row indicators are summarised that describe or are used to approximate energy services, such as gross value added of the manufacturing and the service sector as well as the number of tonne-kilometres (tkm) and passenger-kilometres (pkm). For the household sector three

2 http://www.odyssee-indicators.org

3 If not fully available in the Odyssee database, data on vehicle kilometres is complemented by data from the International Road Federation (2009, 2007).

4 http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

5 http://epp.eurostat.ec.europa.eu

different energy service indicators are used: the floor area for space heating and lighting; the number of persons living in the household as approximation for hot water demand and the number of appliances as proxy for other energy services (e.g. cooking or ICT). Energy intensities – i.e. the amount of final energy per energy service – and energy efficiencies of electricity and heat generation are then depicted. The next indicator row gives the energy flows – transformation input and output as well as final energy consumption – that are the result of the energy services demanded and the energy efficiencies that are defined by the quality of the capital stocks. The last two rows provide information on environmental aspects (the ecological impacts of energy use and supply, such as emissions of GHG and air pollutants) and social aspects (the economic impacts of energy use for housing and passenger transport).

These indicators of course do not reflect an exhaustive list of factors relevant for well-being and sustainable development, but rather represent a selection on basis of data availability considerations.

The indicators were compiled for the EU-27 countries in the period 1995 to 2008 so far the data were available and are summarised for the EU total in the years 2000 and 2008 in Table A - 1 and Table A - 2 in the Appendix. For compiling the indicator set to an index data need to be available for a majority of the EU-27 countries and for a sufficiently long time period.

Table 1. The PASHMINA energy indicator set

Meta Indicators: GDP | Population | HDD | Energy/environment related R&D capital stock | Distance to target - RES | Distance to target - GHG | Realisation of RES potentials | Oil and gas burden

	Energy supply	Manufacturing	Services	Households	Passenger transport	Freight transport
Context	Installed capacity of RES (in MW p.c.) Share of energy imports Share of electricity imports Final energy consumption	Share of GVA in GDP Energy prices	Share of GVA in GDP Energy prices	Households Household size Stock of appliances Stock of heating systems Floor area p.c. Household income Income inequality Energy prices	Stock of vehicles by category Energy prices Public pkm Private pkm Km of road / km of rail	Stock of trucks Energy prices Tkm road Tkm rail Tkm ship Km of road / km of rail
Energy services		GVA	GVA	Space heating and lighting - proxy: floor area Hot water - proxy: number of persons Other (cooking, ICT, etc.) - proxy: number of appl.	Mobility - approx. by pkm	Mobility -approx. by tkm
Energy intensities/ efficiencies	Energy efficiency of fossil generation	Energy per GVA	Energy per GVA	Energy per service by service type	Energy per pkm	Energy per tkm
Energy use and provision	TO by energy source and installation type TI by energy source and installation type	FEC by energy source	FEC by energy source	FEC per household FEC by activity and energy source (percentage shares)	FEC by energy source and transport mode	FEC by energy source and transport mode

Table 1. The PASHMINA energy indicator set (ctd.)

Environmental aspects	Air pollutants GHG emissions Share of agricultural land used for energy production Radioactive waste	Pollutants GHG emissions	Pollutants GHG emissions	Pollutants GHG emissions	Pollutants GHG emissions	Pollutants GHG emissions
Social aspects				Share of energy costs in average household income Share of energy costs in household income of lowest 20% - proxy for energy poverty	Share of transport costs in average household income Share of transport costs in household income of lowest 20%	

Heating degree days (HDD):

Actual heating degree-days express the severity of the cold in a specific time period taking into consideration outdoor temperature and room temperature. The definition used by Eurostat for the calculation of heating degree days is (18 °C - Tm) x d if Tm is lower than or equal to 15 °C (heating threshold) and are nil if Tm is greater than 15 °C where Tm is the mean (Tmin + Tmax / 2) outdoor temperature over a period of d days. (see: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NQ-06-005/EN/KS-NQ-06-005-EN.PDF)

Environment related R&D capital stocks

Database used: Eurostat, Government appropriations or outlays for RD (GBAORD) by socio-economic objective, using the NABS (Nomenclature for the analysis and comparison of scientific programmes and budgets) classification including i.a. Environment, Transport, Energy.

Specific R&D Capital stocks can be calculated using the standard OECD perpetual inventory method with a scraping rate of eight years. This allows capturing the cumulative character of investment into research better and reducing the variation of the annual investments that may be more volatile than stocks.

Distance to target – RES

The EU Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources defines national targets for the share of energy from renewable sources in gross final consumption of energy in 2020. Based on the objectives and current shares the distance to target for the EU Member States can be calculated.

Distance to target – GHG

The greenhouse gas emission targets for 2020 from the EU Energy and Climate Package (EC, 2008) are disaggregated for Member States and compared to current emissions.

Oil and gas burden

Oil burden is defined as nominal oil expenditures (demand multiplied by the crude price) divided by nominal GDP. This is a proxy of how much any given economy spends on its oil needs in a given year. (http://www.iea.org/index_info.asp?id=1932) This calculation is also carried out for natural gas.

Income inequality – Gini coefficient

The Gini-coefficient is the most commonly used measure of inequality. The coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, all others have none).

(http://go.worldbank.org/3SLYUTVY00)

Transformation input and output

Primary energy used for electricity and heat generation is termed transformation input. Energy used as a transformation input is consumed only partly in the transformation process. The resulting transformed energy is termed transformation output. By subtracting transformation output from the inputs of the transformation sectors the transformation losses are calculated (i.e. transformation efficiency).

3 Composite Indices for Aggregate Energy Development

In addition to the indicator set, we develop a composite index for sustainable energy development. For the calculation of the index a sub-sample of indicators for each sector is selected that reflect the EU 2020 climate and energy targets; i.e. an increase of the share of renewables, a reduction of CO_2 emissions and an improvement of energy efficiency.

3.1 Methodological Approach

The procedure for the calculation of this sustainable energy index follows Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009). While the sustainable energy index by Davidsdottir et al. and Ibarrarán Viniegra et al. is based on three sub-indices – one for each dimension of sustainability – the PASHMINA composite index is based on five sub-indices, one for each of the sectors electricity generation, manufacturing, services, households and transport[6]. The sub-indices are calculated based on the following equation:

$$I_{i,t} = \sum_{j=1}^{n} w_j * \left(\frac{E_{i,j,t}}{E_{i,j,t=0}} - 1 \right)$$

where $I_{i,t}$ gives the sub index of the sustainability dimension i in year t, j is the energy indicator, n is the number of indicators, w_j is the weight for each indicator, and $E_{i,j,t}$ is the value of the energy indicator in year t. This means that each sub-index is the weighted sum of the change in the indicators compared to an assumed base year. The aggregate index in turn is calculated as the weighted sum of the sub-indices. Ibarrarán Viniegra et al. (2009) assume equal weights both for the calculation of the sub-indices and for the calculation of the aggregate index. In this report, we use equal weights for all indicators considered in the calculation of the sub-indices; in the calculation of the aggregate index on the one hand we also use equal weights but on the other hand we use the sectors' shares in total European CO_2 emissions as weights.

The main advantages of calculating the composite index and the sub-indices are that they facilitate the monitoring of different developments over time as interpreting and comparing many different indicators proves difficult when an overall conclusion about energy sustainability is aspired. The purpose of this composite index is to reduce the complexity, and to provide a useful instrument for policy monitoring and decision making. In addition, the index can serve as a communication instrument. Through summarising single indicators to composite indices information about specific details (e.g. sectoral developments), however, can be lost (e.g. OECD, 2002; OECD, 2008). We therefore also provide the single indicators that contain important information about energy sustainability in different areas.

[6] Due to data restrictions it was decided to calculate only one index for the transport sector instead of two distinct indices for passenger and freight transport.

For each sector we use the following information for the calculation of the sub-index that reflects the 2020 climate and energy targets of the European Union:

1. the sector's share of renewable energy sources,
2. the energy efficiency of the sector, and
3. the carbon efficiency of the sector[7].

The indices are calculated for 19 EU Member States (EU-19) for which data on all indicators are available for the period 1995 to 2008[8]. All variables are standardised as indices with the basis EU-19 in 1995 = 100. The variable "share of renewable energy sources" (RES) is defined as a 100% share of RES minus the sectors' actual share of renewable energy sources in a certain year[9]. For electricity and heat supply, the calculation of the share of renewables is based on transformation input, while for the other sectors it is based on final energy consumption. For the graphical representation of the indices the share of renewables is furthermore multiplied by -1 so that an increase of the indicator represents an improvement just as an increase of the other indicators. The variable "energy efficiency" (EE) is defined as transformation efficiency for sector electricity and heat supply, i.e. transformation output per transformation input, and as energy service per final energy consumption for the other sectors. The variable "carbon efficiency" (CC) is defined as the amount of final energy consumption (and – for electricity and heat supply – transformation output respectively) per unit of CO_2 emitted.

3.2 Results

In the following section the development of the sub-indices for the sectors energy supply, manufacturing, services, households and transport in the period 1995 to 2008 is described. Furthermore, the development of the aggregate index is discussed.

3.2.1 Sectoral indices for sustainable energy development

Since 1995, the performance of the sector electricity and heat supply with respect to the variables used in the calculation of the composite index has continuously improved (see Figure 1). Most notably, energy efficiency (EE) and carbon efficiency (CC) of the sector have improved; the share of renewable energy sources in transformation input (RES) shows a small increase. This points at an increasing use of fossil fuels with lower carbon content, i.e. gas, in electricity and heat supply on the one hand and at an increased diffusion of plants with higher energy efficiency.

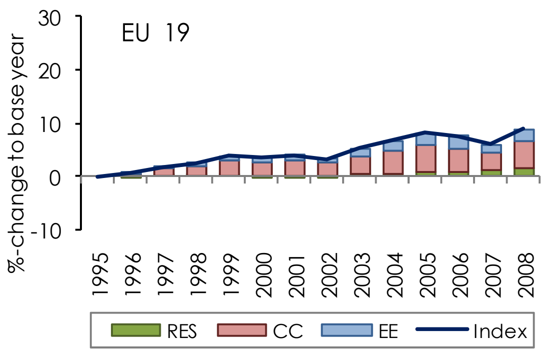
[7] In order to ensure the comparability of data among all European countries we use CO_2 efficiencies rather than absolute values.

[8] The EU-19 include twelve Old Member States (Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Spain, Sweden, UK) and seven New Member States (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Romania, Slovenia).

[9] This approach allows handling extraordinary high growth rates in case of low shares of renewable energy sources.

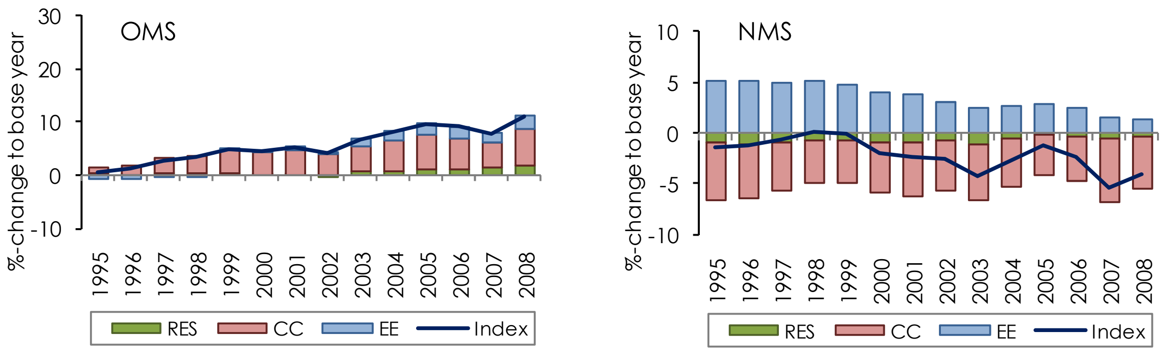
Figure 2 shows the composite indices for electricity and heat supply for the Old Member States of the European Union (OMS) as well as for the New Member States (NMS). As expected, the performance of the OMS with respect to the composite index is better than that of the NMS. This holds especially true for the carbon efficiency of electricity and heat generation, but at a smaller extent also with respect to the share of renewable energy sources in transformation input. Contrary to prevailing assumption, that transformation efficiency is higher in the OMS than in the NMS, Figure 2 shows an opposite picture: Energy efficiency of the NMS' energy supply significantly exceeds that of the OMS, particularly in the first years of the analysis. This rests on the fact that the share of district heating is higher in the NMS than in the OMS and heating plants exhibit a higher transformation efficiency than power plants.

Figure 1. Energy supply: Composite index for sustainable energy development, EU-19



Source: WIFO calculations.

Figure 2. Energy supply: Composite index for sustainable energy development, OMS vs. NMS

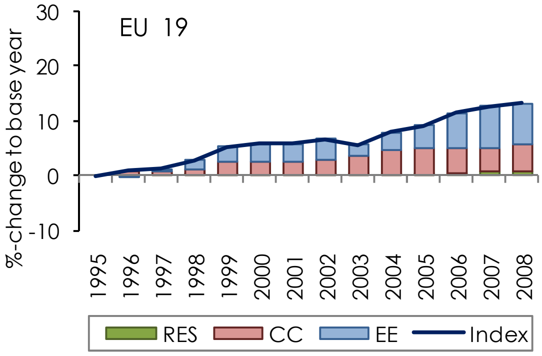


Source: WIFO calculations.

For the manufacturing sector, evidence for the EU-19 is not as clear cut as for electricity and heat supply (see Figure 3): While energy efficiency (EE; gross value added per industry final energy consumption) improves more or less continuously since 1995, the share of renewables (RES) remains largely unchanged. Carbon efficiency (CC) shows a moderate increase in the manufacturing sector in the period 1995 to 2008.

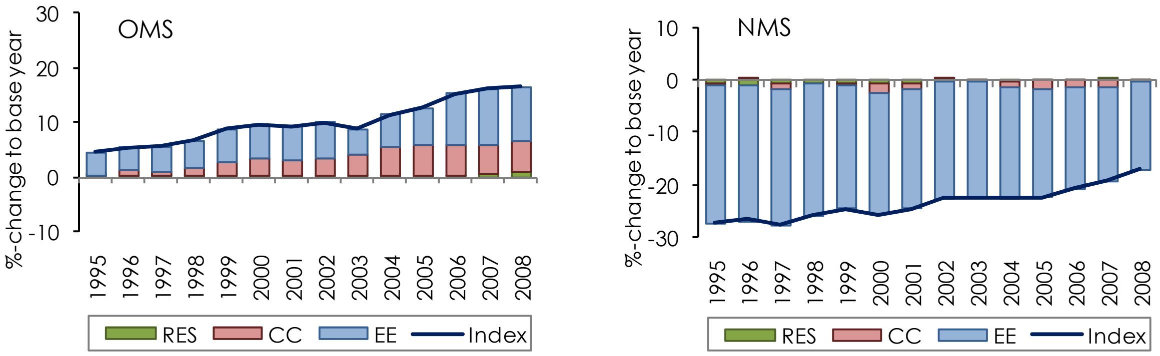
For both groups of countries, OMS and NMS, the shares of renewable energy sources are similar and have remained relatively constant since 1995 (see Figure 4). The two other indicators differ, however, considerably between the OMS and the NMS. Energy efficiency is considerably higher in the OMS than in the NMS, but improves more or less continuously for both country groups since 1995. Also with respect to carbon efficiency one can observe that the OMS exhibit a better performance than the NMS: While both country groups show a similar carbon efficiency in 1995, the OMS industries' carbon efficiency continuously improved since then, while carbon efficiency in the NMS remained relatively constant over the last 14 years.

Figure 3. Manufacturing: Composite index for sustainable energy development, EU-19



Source: WIFO calculations.

Figure 4. Manufacturing: Composite index for sustainable energy development, OMS vs. NMS

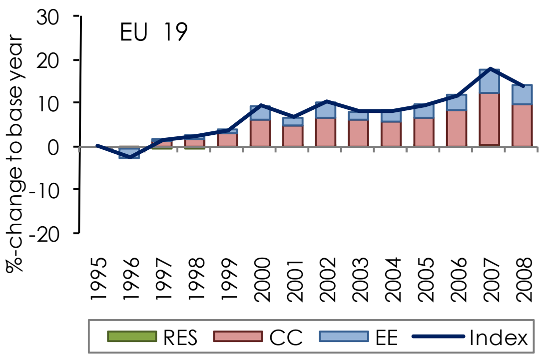


Source: WIFO calculations.

Figure 5 shows the development of the composite index for the service sector in the EU-19 in the period 1995 to 2008. Except for the year 1996, the indicators energy efficiency (EE; gross value added per final energy consumption in the service sector) and carbon efficiency (CC) have considerably increased. The share of renewable energy sources in final energy consumption (RES) in the EU-19 has, however, remained constant over the last 14 years.

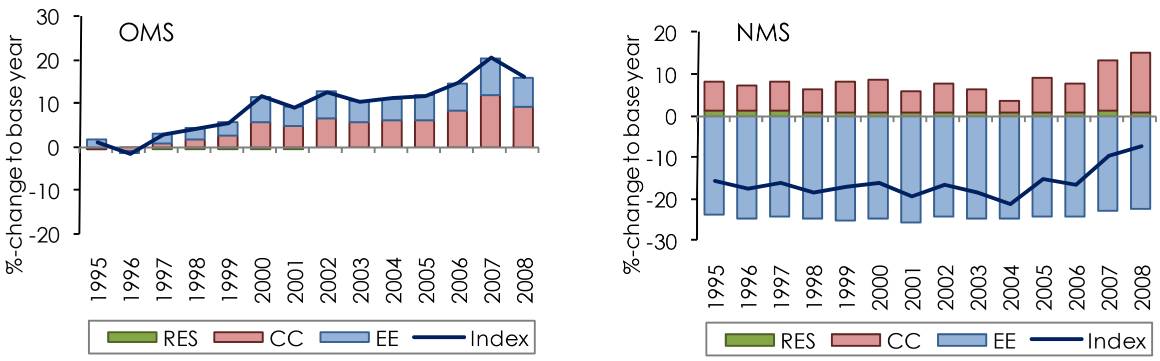
Just as for the manufacturing sector, both the OMS and the NMS on average show no significant increase with respect to the share of renewable energy sources in the service sector's final energy consumption over the period 1995 to 2008 (see Figure 6). Except for the year 1996, energy efficiency of the service sector continuously increased over the last 14 years in the OMS. In contrast, the NMS exhibit a lower energy efficiency than the OMS that has only slightly improved since 1995. With respect to carbon efficiency, one can find a different picture: In 1995 carbon efficiency was higher in the NMS than in the OMS. This points at a higher share of district heating and electricity used in the NMS as the share of renewables in the service sector is more or less the same for the OMS and NMS. In the following years, the OMS however have caught up with the NMS with respect to carbon intensity.

Figure 5. Services: Composite index for sustainable energy development, EU-19



Source: WIFO calculations.

Figure 6. Services: Composite index for sustainable energy development, OMS vs. NMS

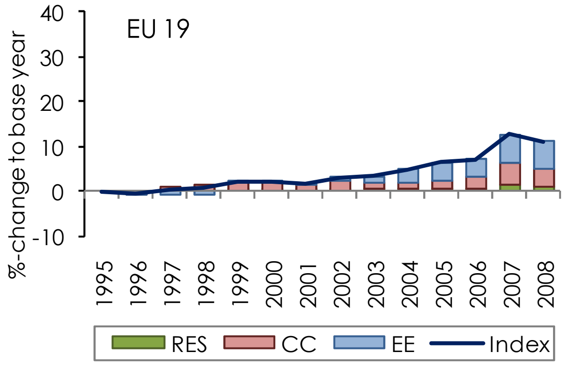


Source: WIFO calculations.

For the household, the composite index shows an upward trend in the index in the EU-19 over the 14-year period (Figure 7). While the share of renewable energy sources (RES) remained relatively constant since 1995, both energy efficiency (EE, floor area per climate corrected final energy consumption for space heating) and carbon efficiency (CC) improved continuously after 1999.

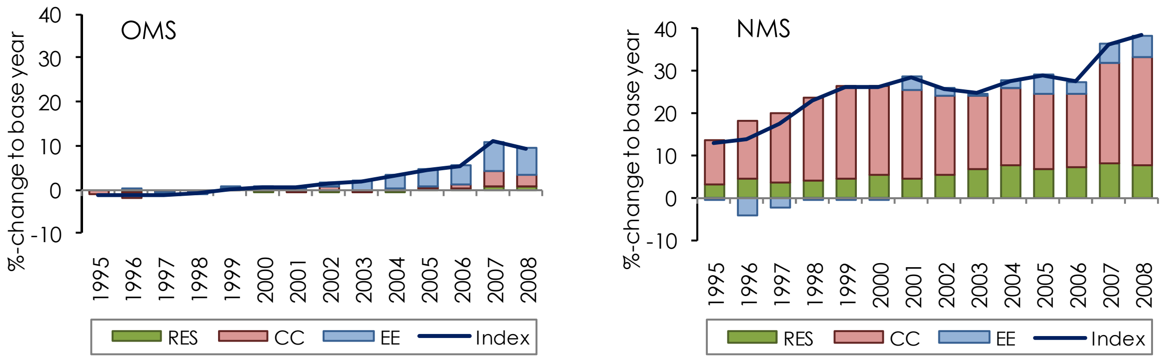
While the OMS show only moderate improvements with respect to the indicators used in the calculation of the composite index for the household sector, the opposite is true for the NMS (see Figure 8). The NMS differ significantly from the OMS with respect to the share of renewable energy sources and carbon efficiency over the whole period. Furthermore, the NMS even improved with respect to these indicators since 1995. With respect to energy efficiency, both OMS and NMS, exhibit modest improvements between 1995 and 2008.

Figure 7. Households: Composite index for sustainable energy development, EU-19



Source: WIFO calculations.

Figure 8. Households: Composite index for sustainable energy development, OMS vs. NMS

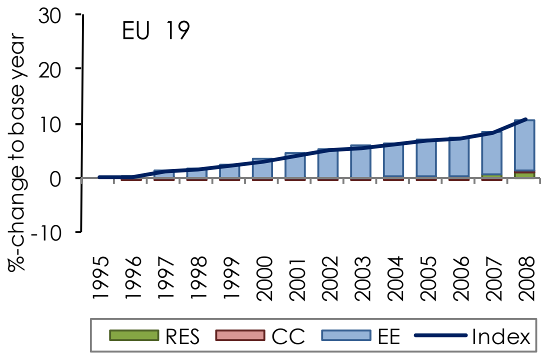


Source: WIFO calculations.

In Figure 9 and Figure 10 the developments of the composite indices for the transport sector are illustrated. For the EU-19, the index shows a continuous increase over the whole period that is almost exclusively driven by an increase in energy efficiency (EE), i.e. final energy consumption per vehicle kilometre. In contrast the share of renewable energy sources in final energy consumption of the transport sector (RES) remains unchanged. This is also reflected in the more or less constant carbon efficiency (CC) that also suggests that the share of electricity and alternative fuels used in the transport sector has not changed between 1995 and 2008.

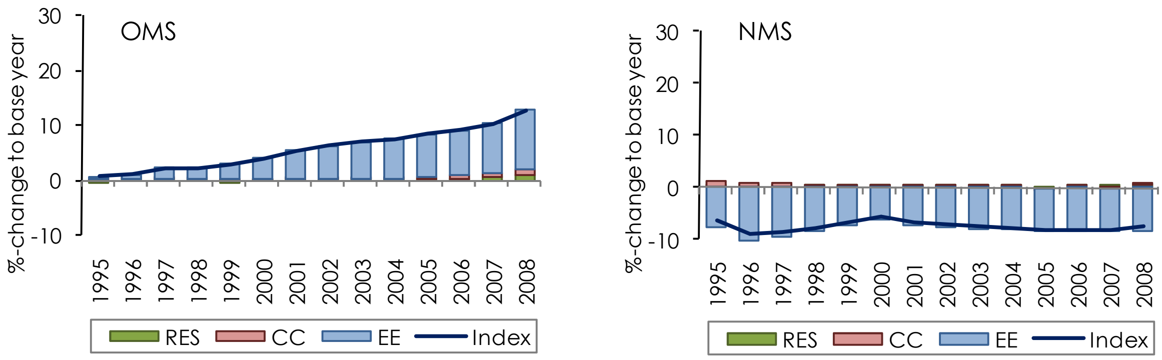
Figure 10 indicates that both groups of countries resemble with respect to the share of renewable energy sources and the carbon efficiency in the transport. The country groups differ, however, considerably with respect to energy efficiency of transport which shows a continuous upward trend in the OMS, but a low level with only little improvement in the NMS indicating that the vehicle fleet has become considerably more efficient in the OMS.

Figure 9. Transport: Composite index for sustainable energy development, EU-19



Source: WIFO calculations.

Figure 10. Transport: Composite index for sustainable energy development, OMS vs. NMS



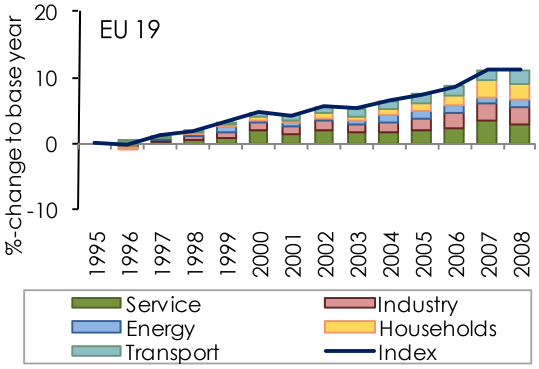
Source: WIFO calculations.

3.2.2 *An aggregate index for sustainable energy development*

The aggregate index integrates the sectoral sub-indices into one single measure of sustainable energy development. The development of the aggregate index for the EU-19 in the period 1995 to 2008 applying equal weights for the different sub-indices is presented in Figure 11. The upward trend in the composite index for the EU-19 over the whole period points at a continuous improvement towards a more sustainable energy system. The service sector contributes the most, followed by the household sector.

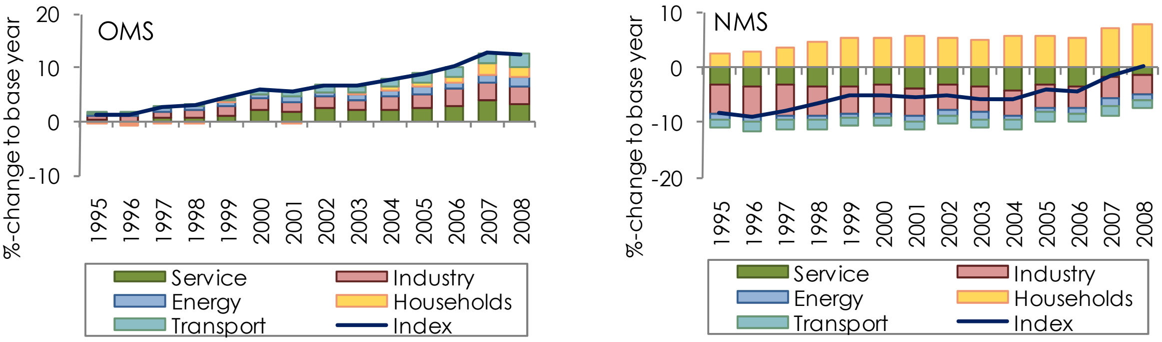
Figure 12 splits the equal weighted aggregate index of sustainable energy development into the two country groups, OMS and NMS. The OMS improve continuously with respect to all sectors in the period 1995 to 2008. The trend for the NMS is not as straightforward. Overall, the figure shows the index values of the NMS are below the EU-19 averages in 1995 and the following years for all sectors except the household sector. Most sectors, however, also exhibit a positive development over the 14-year period. Most notably these improvements show for the service sector.

Figure 11. Aggregate index for sustainable energy development, EU-19 (equal weights)



Source: WIFO calculations.

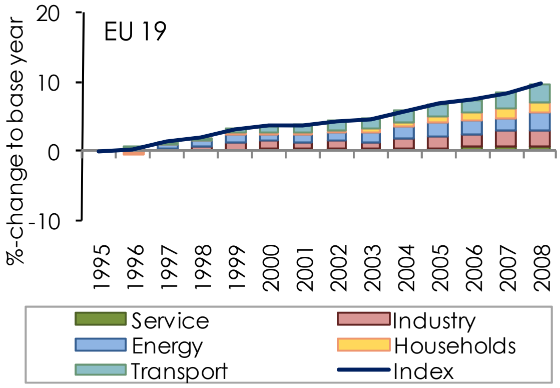
Figure 12. Aggregate index for sustainable energy development, OMS vs. NMS (equal weights)



Source: WIFO calculations.

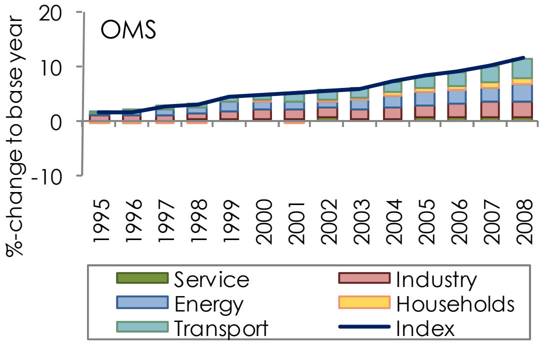
Figure 13 and Figure 14 show the aggregate indices weighting the sub-indices according to the sectors' shares in European CO_2 emissions for each year. The new weighting has only a moderate impact on the level of the aggregate index – which is now 1 percentage point higher than in the case of equal weights – but has considerable effects on the sectors' contribution to the aggregate index. While the importance of the sectors households and services, which on average account for only 13% and 5% of EU CO_2 emissions respectively, decreases, the development of the other sub-indices is mirrored stronger in the aggregate index. This is most notably true for the sectors electricity and heat supply and transport which on average account for 38% and 26% of total CO_2 emissions.

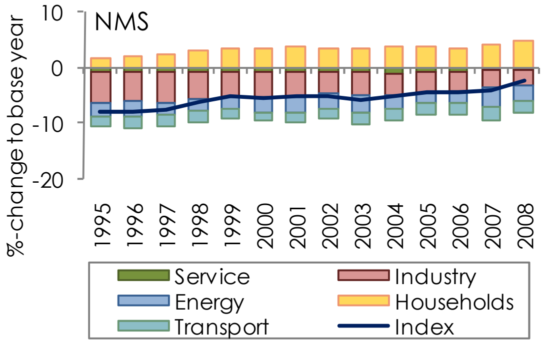
Figure 13. Aggregate index for sustainable energy development, EU-19 (weighted by CO_2)



Source: WIFO calculations.

Figure 14. Aggregate index for sustainable energy development, OMS vs. NMS (weighted by CO_2)





Source: WIFO calculations.

4 Cluster Analysis

In order to identify countries that score similar with respect to the energy indicators in the sectors energy supply, manufacturing, services, households and transport a cluster analysis is carried out. The chapter starts out with a description of the methodological approach; that is followed by a description of the results of the sectoral cluster analysis for the years 1995 and 2008.

4.1 Methodological Approach

Cluster analysis can be defined as "the art of finding groups in data" (Kaufmann and Rousseuw, 1990). Objects within one group identified by the cluster analysis on the one hand show a high degree of similarity ("internal cohesion") and on the other hand differ significantly from objects in other groups ("external isolation") at least with respect to some characteristics (Everitt et al., 2001). The groups of similar objects identified by the cluster analysis are called clusters; the group assignment is called clustering. Cluster analysis techniques are widely used exploratory data-analysis techniques. In contrast to other statistical approaches they are, however, "intended largely for generating rather than testing hypotheses" (Everitt, 1993).

One can differentiate between several cluster techniques; the most common procedures are, however, hierarchical and partitioning methods (see e.g. Everitt et al., 2001; Backhaus et al., 2006; Gore, 2000). Partitioning methods, most notably *kmean* and *kmedian* procedures, split the objects into a predefined number of *k* groups in an iterative procedure. The *kmean* and *kmedian* procedures begin with the predefined number of *k* initial group centres. The objects are assigned to the group with the closest centre. The mean or median of each group is computed, and the procedure is repeated until no object changes the group anymore. Hierarchical procedures either successively fusion the individual objects into larger and larger groups (agglomerative methods) or successively split the total observations into smaller and smaller groups (divisive methods). Clusters that have been identified once in a hierarchical cluster procedure will remain unchanged throughout the whole clustering procedure.

Each cluster technique has both advantages and disadvantages (see e.g. Everitt et al., 2001; Backhaus et al., 2006): For partitioning methods, for example, the results depend on the initially chosen group centres. Furthermore, while intra-cluster variance is minimised, it is not guaranteed that the results represent a global optimum. Hierarchical clustering approaches, in contrast, are sensitive with respect to the chosen linkage method.

As we are focusing on a small number of objects, we opt for an agglomerative hierarchical cluster technique using the average linkage method[10]. In addition we have to select a distance or similarity measure among the large number of available measures (see e.g.

[10] The average linkage method is based on the average distance between a pair of objects from two different clusters and represents a relatively robust linkage method (see Everitt et al., 2001).

Everitt et al., 2001). We use a distance measure as we are interested in differences in the magnitude of the indicators and select the city block distance; this distance measure is not sensitive with respect to outliers[11].

The cluster analysis is limited to the same 19 countries (EU-19) as in the calculation of the composite index due to data restrictions (see above). In order to give equal weights to all indicators used in the cluster analysis all variables are standardised as indices with the basis EU-19 in 1995 = 100.

In order to confirm the statistical validity of the country groups identified by the cluster analysis an ANOVA regression is performed. The regression analysis allows verifying which indicators discriminate between the different country clusters as well as the extent of cross country variation for each indicator that is explained by the groups.

4.2 Results

4.2.1 Energy supply

The analysis of similarities of countries with respect to electricity and heat supply is based on three variables that reflect the indicators already chosen for the calculation of the composite index:

- Share of renewable energy sources in electricity and heat generation (E RES)
- Efficiency of electricity and heat supply (E EI)
- Carbon intensity of electricity and heat supply (E CI)

The variable "Share of renewable energy sources in electricity and heat generation" (E RES) is defined as a 100% share of RES minus the country's actual share of renewable energy sources in electricity and heat generation in a certain year. The variable "Efficiency of electricity and heat supply" (E EI) is defined as the energy input required for producing one unit of electricity and heat, i.e. transformation input per transformation output. The variable "Carbon intensity of electricity and heat supply" (E CI) is defined as the amount of CO_2 per unit of transformation output. The influence of the correlation of the variables is discussed in the next section.

Correlation between variables

In order to make sure that the chosen variables do not cover identical but provide different information a correlation analysis was carried out. The scatter plots and the correlation coefficients (Figure A - 1 and Figure A - 2 in the Appendix) indicate a high correlation between the share of renewable energy sources and the carbon intensity of electricity and heat generation. This seems obvious at first sight as a stronger role of renewables in electricity

[11] The city block distance (also: Manhattan distance, L1 distance, taxicab distance, rectilinear distance) measures distances on a rectilinear basis. It describes the distance between two observations as the sum of the absolute differences of their coordinates. It is similar to the Euclidean distance measure but puts less weight on outliers as the distances are not squared (see e.g. Peneder, 2007).

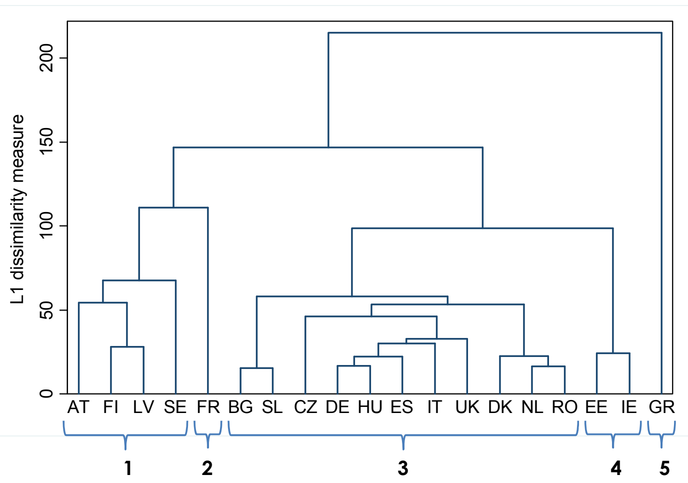
and heat generation reduces the average carbon content. Besides this apparent link, however, the carbon content is determined by two other factors: the share and mix of fossil fuels and the share of nuclear energy. Not only renewable but also nuclear energy is considered completely carbon free for GHG accounting.

The correlation analysis also confirms a link between the share of renewable energy sources and energy efficiency. This is the result of a statistical convention: In the energy balances transformation input generally equals transformation output for renewable energy sources (with the notable exception of biomass), i.e. transformation efficiency is assumed to be 100%, for other energy sources efficiency is well below 100%. As a consequence a higher share of renewables (low values of "E RES") implies higher energy efficiency (low values of "E EI") and vice versa.

Identified country groups and summary statistics

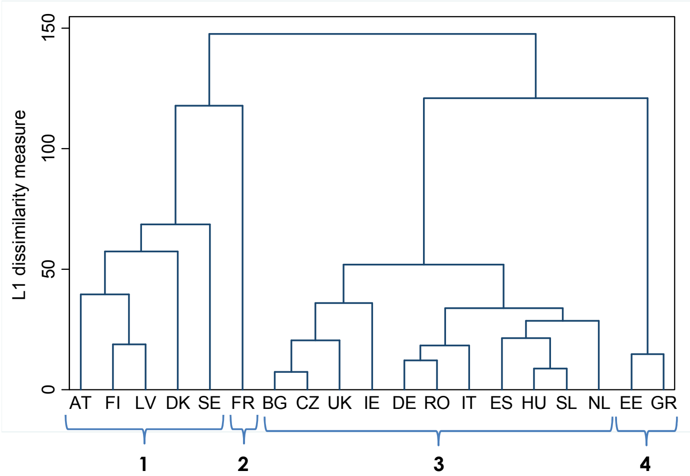
For the first year of the analysis, 1995, the cluster analysis identifies five country groups with respect to electricity and heat supply as indicated in Figure 15 (see also Table A - 3 in the Appendix). The groups differ significantly in size: Groups 2 and 5 for example include only one country, France and Greece respectively, while Group 3 consists of eleven countries. For 2008, four groups of countries are differentiated (see Figure 16 and Table A - 4 in the Appendix). The country groups to a large extent resemble those of 1995: France still represents an outlier that is not integrated in a group of countries; the groups still differ significantly in size. Some movements between country groups can, however, be observed. Denmark, which used to belong to the largest group in 1995, now is part of Group 1 consisting of Austria, Finland, Latvia and Sweden. Greece, which represented an outlier in 1995, now forms a group together with Estonia, while Ireland has moved to the largest country group, Group 3.

Figure 15. Energy supply: Cluster dendrogram, 1995



Source: WIFO calculations.

Figure 16. Energy supply: Cluster dendrogram, 2008



Source: WIFO calculations.

From Table 2 one can get a sense why the cluster analysis identifies five different country groups for the year 1995. The countries in Group 1 exhibit a high share of renewables as well as high energy and high carbon efficiency. France, the only country included in Group 2, differs from Group 1 with respect to energy efficiency and the share of renewable energy sources, but also shows a higher carbon efficiency. This rests on the fact that energy supply in France relies mainly on nuclear power, while the Group 1 countries, Austria, Finland, Latvia and Sweden, employ a high share of renewable energy sources. Countries in Group 1 profit from 100% energy efficiency for renewables assumed according to statistical conventions, while for nuclear energy a transformation efficiency of 33% applies. The remaining three groups resemble France with respect to the share of renewables, but show a carbon intensity of electricity and heat supply that clearly exceeds those of Groups 1 and 2. These results suggest that fossil energy sources dominate in electricity and heat generation in these countries.

For 2008, the country clusters differ in similar respects as in 1995 (Table 8). Compared to 1995, Group 1 has further increased the share of renewables and improved energy and carbon intensity. Groups 3 and 4 are again similar to France with respect to the share of renewable energy sources and energy intensity. They differ, however, with respect to carbon intensity which substantially exceeds those of Groups 1 and 2 and has even increased compared to 1995. One notable exception in this respect is Greece whose carbon intensity decreased by 60 index points between 1995 and 2008 due to changes in the fossil fuel mix (gas is increasingly used instead of coal) and an increasing share of renewable energy sources.

Table 2. *Energy supply: Mean values of energy indicators by country group, 1995*

Group	E RES	E EI	E CI
1	76.54	64.22	44.83
2	100.52	118.89	12.53
3	101.78	94.38	121.91
4	105.28	91.86	203.26
5	104.05	127.75	275.14

Source: WIFO calculations.

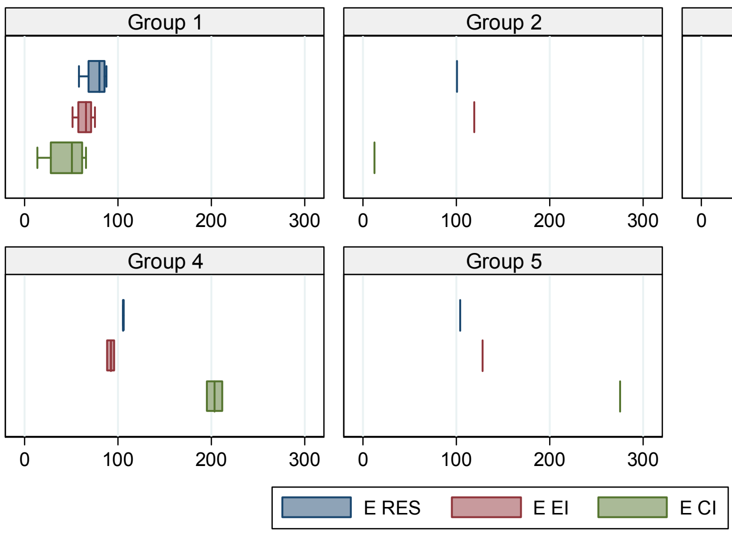
Table 3. *Energy supply: Mean values of energy indicators by country group, 2008*

Group	E RES	E EI	E CI
1	68.82	60.55	44.65
2	101.20	115.62	16.75
3	98.28	92.76	114.22
4	103.46	104.69	216.50

Source: WIFO calculations.

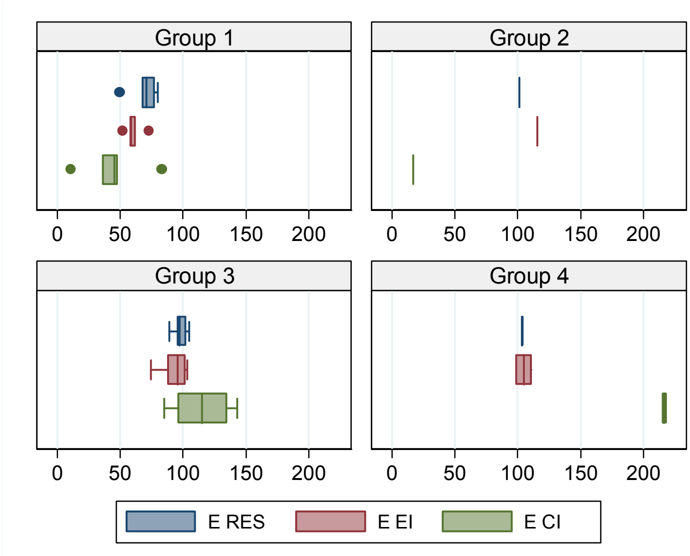
Figure 17 and Figure 18 show box-plots for the three variables by country group for the years 1995 and 2008 respectively. The figures illustrate the spread of values and show that the groups identified by the cluster analysis do not only differ in the respective mean values as indicated in Table 2 and Table 3 above, but in the whole range of values. For 1995, one can generally observe a lower spread of values compared to 2008. This indicates that since 1995 countries diverged in the sector electricity and heat supply regarding the share of renewables as well as with respect to energy and carbon intensity.

Figure 17. *Energy supply: Box plots of energy indicators by country group, 1995*



Source: WIFO calculations.

Figure 18. Energy supply: Box plots of energy indicators by country group, 2008



Source: WIFO calculations.

Econometric validation of country classification

The ANOVA regression results for 1995 are summarised in Table 4. Groups 2 to 5 differ significantly from the first group with respect to the share of renewable energy sources and energy efficiency in the sector electricity and heat supply. Furthermore, Groups 3 to 5 differ from Group 1 with respect to carbon intensity with a very high level of significance. The clusters explain between 63% and 93% of the total variation of the indicators (as indicated by the R^2 statistics) and are significant to explain the variation across countries for the indicators (as explained by the F statistics).

The regression results for 2008 (Table 5) confirm the observations made above for the changed country groups. Group 2 differs from the first country group with respect to the share of renewable energy sources as well as with respect to the energy intensity with a very high level of significance. Groups 3 and 4 significantly differ from Group 1 regarding all indicators. Between 81% and 89% of the total variation of the indicators are explained by the country grouping.

Table 4. Energy supply: Validation of country classification with ANOVA regression, 1995

	E RES	E EI	E CI
Group 2	23.97**	54.67**	-32.30
	(0.009564)	(0.004638)	(0.172438)
Group 3	25.24***	30.16**	77.09***
	(0.000030)	(0.003185)	(0.000012)
Group 4	28.73***	27.64*	158.4***
	(0.000382)	(0.045498)	(0.000000)
Group 5	27.51**	63.53**	230.3***
	(0.003975)	(0.001575)	(0.000000)
Constant	76.54***	64.22***	44.83***
	(0.000000)	(0.000000)	(0.000536)
Observations	19	19	19
R-squared	0.748	0.634	0.927
F-Test	10.39	6.060	44.54

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

Table 5. Energy supply: Validation of country classification with ANOVA regression, 2008

	E RES	E EI	E CI
Group 2	32.38**	55.07***	-27.90
	(0.0010)	(0.0001)	(0.2397)
Group 3	29.47***	32.21***	69.57***
	(0.0000)	(0.0000)	(0.0000)
Group 4	34.64***	44.14***	171.9***
	(0.0000)	(0.0000)	(0.0000)
Constant	68.82***	60.55***	44.65***
	(0.0000)	(0.0000)	(0.0002)
Observations	19	19	19
R-squared	0.813	0.808	0.888
F	21.76	21.06	39.72

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

4.2.2 Manufacturing

The cluster analysis for the manufacturing sector is based on three variables reflecting the indicators used in the calculation of the composite index:

- Share of renewable energy sources in manufacturing (M RES)
- Energy intensity of manufacturing (M EI)
- Carbon intensity of manufacturing (M CI)

The variable "Share of renewable energy sources in manufacturing" (M RES) is defined as 100% share of renewable energy minus a country's actual share of renewables in manufacturing in a certain year. The variable "Energy intensity of manufacturing" (M EI) denotes final energy consumption per energy service, i.e. final energy consumption by industry gross value added. The variable "Carbon intensity of manufacturing" (M CI) gives the CO_2 content of final energy consumption in the manufacturing sector.

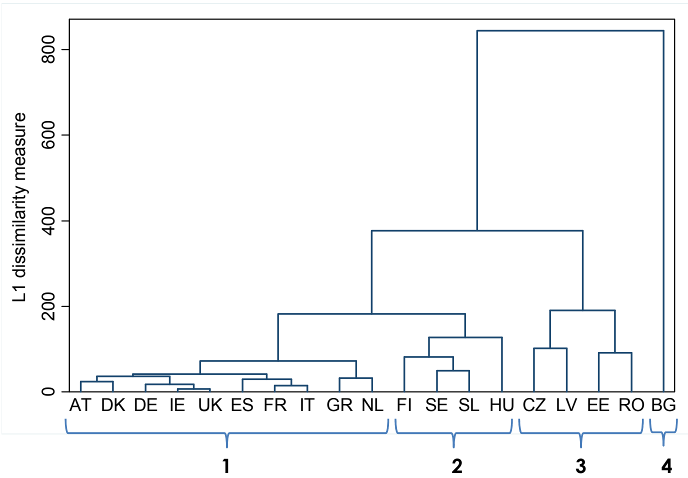
Correlation between variables

The correlogram and the correlation coefficients (Figure A - 3 and Figure A - 4 in the Appendix) confirm again the correlation between the share of renewable energy sources and carbon intensity. This correlation seems obvious as a higher share of renewables reduces the average carbon content. Besides this apparent link, however, the carbon content is determined by the share and mix of fossil fuels and the share of electricity and district heating used in the manufacturing sector. CO_2 intensity and the share of renewable energy sources are uncorrelated with energy efficiency.

Identified country groups and summary statistics

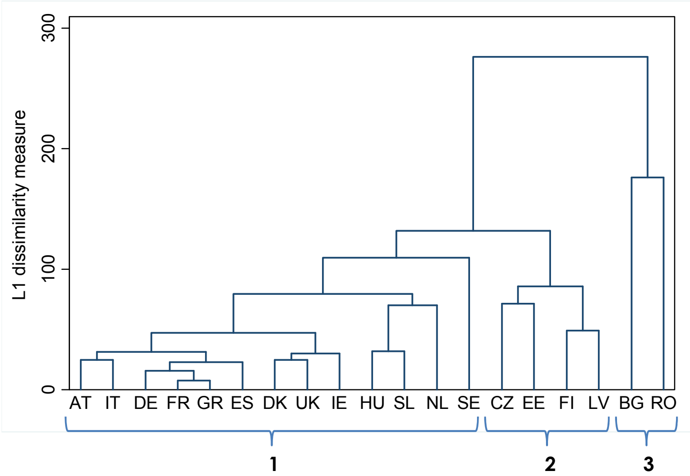
As illustrated in Figure 19, the hierarchical cluster procedure identifies four country groups for the manufacturing sector in 1995 (see also Table A - 5 in the Appendix). Group 1 comprises ten EU Old Member States (OMS). Group 2 consists of four countries, the Scandinavian countries Sweden and Finland and two New Member States (NMS), Slovenia and Hungary. In Groups 3 and 4 the remaining NMS are included with Group 4 consisting of only one country, Bulgaria. For 2008, three groups of countries are distinguished (see Figure 20 and Table A - 6 in the Appendix). Compared to 1995, Groups 1 and 2 are now combined in one single group. This first country group includes eleven OMS as well as Hungary and Slovenia.

Figure 19. Manufacturing: Cluster dendrogram, 1995



Source: WIFO calculations.

Figure 20. Manufacturing: Cluster dendrogram, 2008



Source: WIFO calculations.

Table 6 gives an indication why the cluster analysis differentiates between the four country groups for the year 1995. Group 1 shows the highest energy efficiency in the manufacturing sector, but also the highest carbon intensity. This high carbon intensity is partly explained by a below-average share of renewable energy sources in Group 1, but also points at a use of fossil fuels with higher carbon content. Group 2 – Finland, Sweden, Hungary and Slovenia – on average exhibit a higher share of renewables as well as a lower carbon intensity than Group 1. The energy intensity in this country group is, however, twice as high as in the first group. Groups 3 and 4, the remaining NMS, significantly differ from the first two groups with respect to energy efficiency of the manufacturing sector but also among each other.

As indicated in Table 7, the differences between the new clusters for 2008 are similar as in 1995. Overall, while there is little movement regarding the share of renewables and carbon intensity, energy efficiency has considerably increased in the EU manufacturing sector between 1995 and 2008, particularly in the NMS.

Table 6. Manufacturing: Mean values of energy indicators by country group, 1995

Group	M RES	M EI	M CI
1	101.50	91.04	102.16
2	87.24	220.76	75.43
3	99.44	479.19	100.26
4	105.02	1018.97	77.07

Source: WIFO calculations.

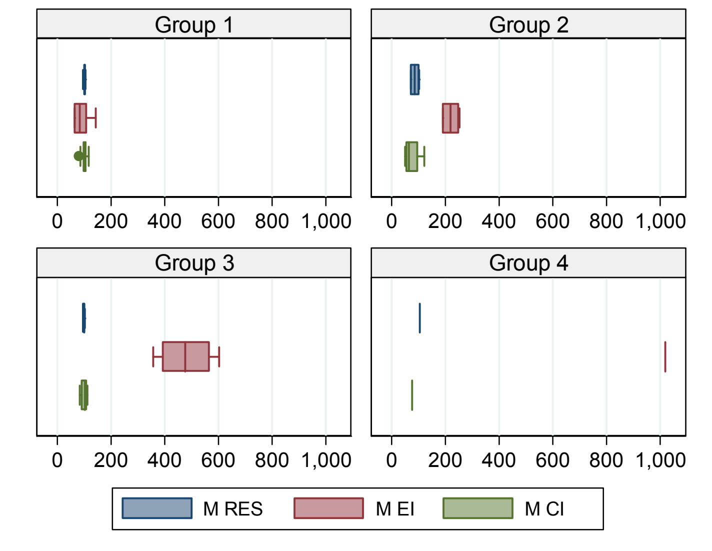
Table 7. Manufacturing: Mean values of energy indicators by country group, 2008

Group	M RES	M EI	M CI
1	97.45	83.75	85.25
2	87.18	174.87	75.03
3	101.91	350.60	100.83

Source: WIFO calculations.

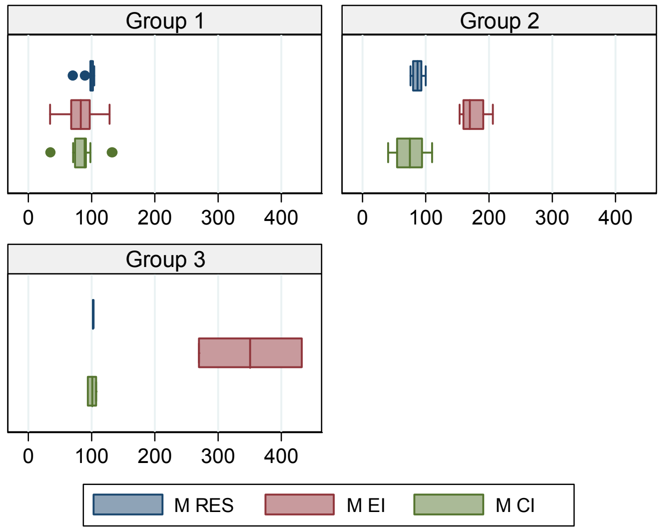
In Figure 21 and Figure 22 box-plots for the three variables by country group are depicted for the years 1995 and 2008 respectively. The box-plots indicate the range of the data within the country groups for each variable and confirm that the country groups differ in the whole range of values and not only in the mean values of the groups as shown by the tables above. In addition, it is illustrated that the country groups in both years differ particularly with respect to energy intensity in the manufacturing sector. Furthermore, the spread of values has decreased between 1995 and 2008.

Figure 21. Manufacturing: Box plots of energy indicators by country group, 1995



Source: WIFO calculations.

Figure 22. Manufacturing: Box plots of energy indicators by country group, 2008



Source: WIFO calculations.

Econometric validation of country classification

The ANOVA regression results for 1995 are summarised in Table 8. Group 2 significantly differs from Group 1 regarding all three indicators. Groups 3 and 4 in contrast differ with a very high significance level from the first country group only with respect to energy intensity in manufacturing. With respect to energy efficiency, the classification explains 96% of the total variation (as indicated by the R^2 statistics) and is significant to explain the variation across countries (as explained by the F statistics).

The ANOVA regression results for 2008 are similar (see Table 9). Groups 2 and 3 differ from the first country group with respect to energy intensity in manufacturing with a very high significance level. 85% of the total variation of the indicator is explained by the country clustering. The classification is significant to explain the variation across countries. For the others two indicators, the variables are not statistically different between the three groups.

Table 8. Manufacturing: Validation of country classification with ANOVA regression, 1995

	M RES	M EI	M CI
Group 2	-14.26**	129.7**	-26.73*
	(0.00870)	(0.00125)	(0.02100)
Group 3	-2.051	388.2***	-1.894
	(0.67059)	(0.00000)	(0.85748)
Group 4	3.524	927.9***	-25.09
	(0.68011)	(0.00000)	(0.19249)
Constant	101.5***	91.04***	102.2***
	(0.00000)	(0.00011)	(0.00000)
Observations	19	19	19
R-squared	0.401	0.958	0.350
F-Test	3.350	115.1	2.687

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

Table 9. Manufacturing: Validation of country classification with ANOVA regression, 2008

	M RES	M EI	M CI
Group 2	-10.28	91.12***	-10.22
	(0.0603)	(0.0008)	(0.4387)
Group 3	4.455	266.8***	15.58
	(0.5190)	(0.0000)	(0.3758)
Constant	97.45***	83.75***	85.25***
	(0.0000)	(0.0000)	(0.0000)
Observations	19	19	19
R-squared	0.244	0.847	0.0997
F	2.577	44.27	0.886

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

4.2.3 Services

As for the other sectors the analysis of similarities of countries in the service sector is also based on three variables reflecting the indicators chosen for the calculation of the composite index:

- Share of renewable energy sources in the service sector (S RES)
- Energy intensity of services(S EI)
- Carbon intensity of services (S CI)

The variable "Share of renewable energy sources in the service sector" (S RES) is defined as 100% share of renewables minus the actual share of RES in the service sector of a country in a certain year. The variable "Energy intensity of services" (S EI) denotes final energy consumption per energy service, i.e. final energy consumption by gross value added in the service sector. The variable "Carbon intensity of services" (S CI) gives the CO_2 content of final energy consumption in the service sector.

Correlation between variables

Again a correlation analysis was conducted in order to ensure that the variables chosen for the service sector provide different information. As indicated in the correlograms and by the correlation coefficients (Figure A - 5 and Figure A - 6), the variables energy intensity and carbon intensity do not correlate. The share of renewable energy sources and carbon intensity show a positive, but moderate correlation. This points at a higher influence of the mix of fossil fuels on carbon intensity than in the sectors analysed before. Furthermore, one can find a negative correlation between the share of renewable energy sources and energy intensity that decreases between 1995 and 2008. An explanation for this negative correlation is not straightforward and could reflect the use of inefficient biomass systems in some countries.

Identified country groups and summary statistics

In the service sector, the cluster analysis identifies three country groups for 1995 (see Figure 23 and Table A - 7). The first group comprises the OMS and Bulgaria; Groups 2 and 3 cover the remaining NMS. While the dendrogram indicates a high degree of homogeneity among the OMS, it suggests considerable differences between Hungary and Latvia and the remaining NMS. For the year 2008, two groups of countries are found (Figure 24 and Table A - 8). Group 1 contains the OMS and Slovenia; Group 2 includes the remaining NMS. The dendrogram indicates that between 1995 and 2008 the differences have decreased among the NMS. Bulgaria, that used to form a group together with the OMS in 1995, is now attributed to this larger group of NMS. The opposite is true for Slovenia, which is now included in Group 1.

Figure 23. Services: Cluster dendrogram, 1995

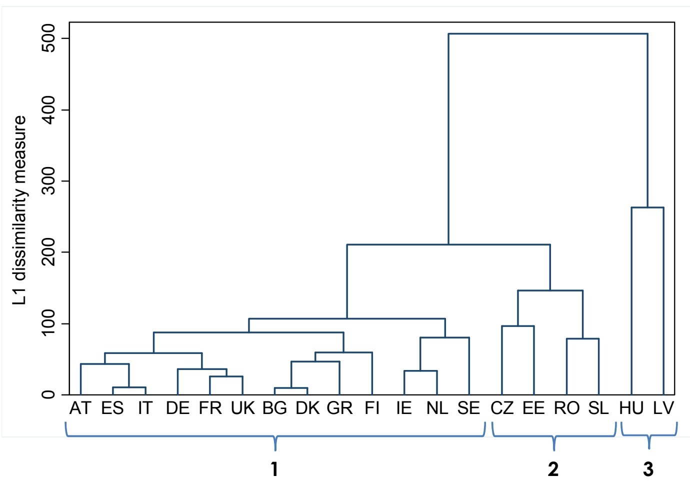
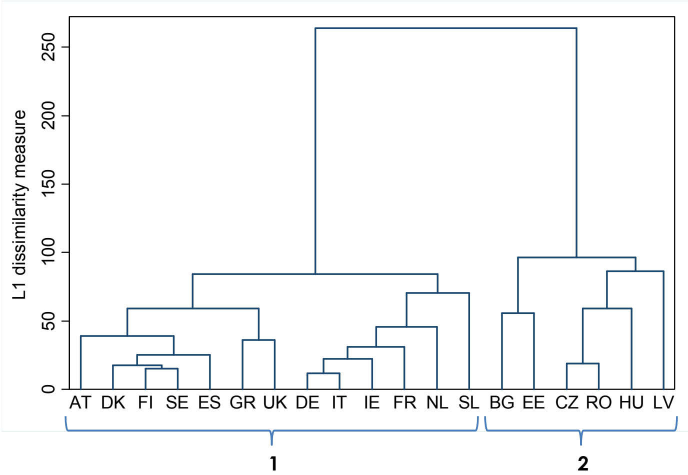


Figure 24. Services: Cluster dendrogram, 2008



Source: WIFO calculations.

Table 10 provides a first indication why the hierarchical cluster analysis finds three country groups for the service sector in 1995. The three groups differ most notably with respect to the sector's energy intensity which is lowest in the OMS (Group 1). The first group on average shows the lowest share of renewable energies in line with a high carbon intensity. Groups 2 and 3 differ regarding the share of renewable energy sources but exhibit a similar carbon intensity. This suggests that Group 2 countries have a larger share of electricity in the sector's final energy consumption or fossil fuels with a comparably low carbon content that offsets the lower share of renewables.

Differences in the mean values of the variables for the two country groups identified for the year 2008 are summarised in Table 11. Again the clusters differ only to a minor extent with respect to the share of renewable energy sources and carbon intensity, but show considerable differences with respect to energy intensity.

Table 10. Services: Mean values of energy indicators by country group, 1995

Group	S RES	S EI	S CI
1	100.21	101.88	77.09
2	97.25	270.27	69.55
3	89.76	604.57	70.72

Source: WIFO calculations.

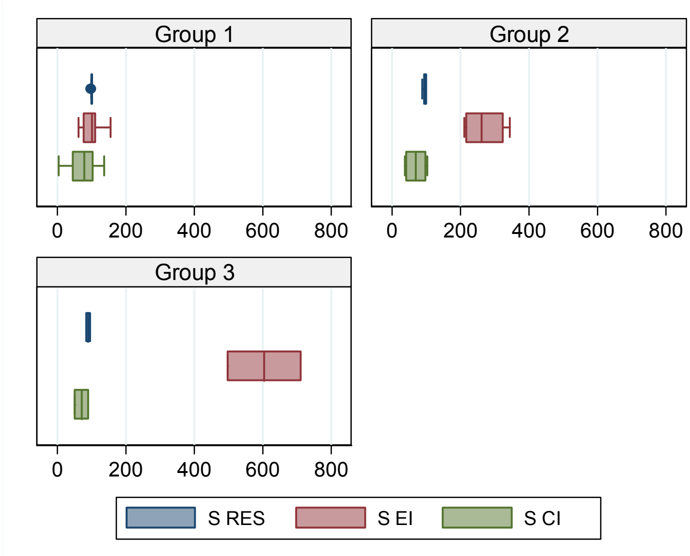
Table 11. Services: Mean values of energy indicators by country group, 2008

Group	S RES	S EI	S CI
1	99.59	95.05	65.63
2	95.59	324.20	57.98

Source: WIFO calculations.

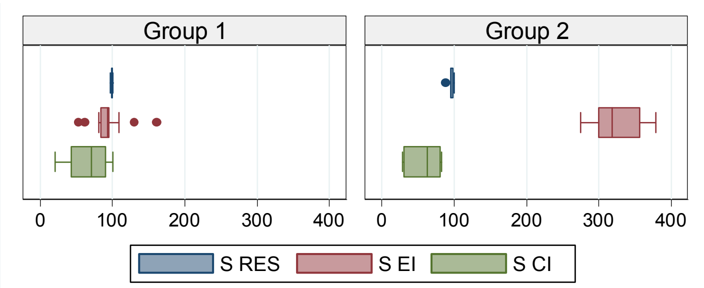
Box-plots that illustrate the range of the data within the country groups for each variable are shown in Figure 25 and Figure 26 for the years 1995 and 2008 respectively. The figures confirm the observations made above showing that the two groups are most distinct with respect to energy intensity. Energy intensity is characterised by a quite large range in 1995 that decreases considerably in 2008.

Figure 25. Services: Box Plots of energy indicators by country group, 1995



Source: WIFO calculations.

Figure 26. Services: Box Plots of energy indicators by country group, 2008



Source: WIFO calculations.

Econometric validation of country classification

The results of the ANOVA regression for 1995 (Table 12) are in line with the observations made above. The three country groups for the service sector differ strongly from each other with respect to energy intensity. Furthermore, Group 3 differs significantly from Group 1 with respect to the share of renewable energy sources. For the shares of renewable energy sources as well as for energy efficiency, the classification explains between 50% and 91% of the total variation (as indicated by the R^2 statistics) and is significant to explain the variation across countries (as explained by the F statistics).

For 2008, the ANOVA regression results (Table 13) show a statistically significant differentiation of the two groups with respect to the share of renewable energy sources and energy intensity. For carbon intensity, the variables are – as in 1995 - not statistically different between the two groups.

Table 12. Services: Validation of country classification with ANOVA regression, 1995

	S RES	S EI	S CI
Group 2	-2.962	168.4***	-7.545
	(0.1582)	(0.0001)	(0.7276)
Group 3	-10.45**	502.7***	-6.367
	(0.0012)	(0.0000)	(0.8247)
Constant	100.2***	101.9***	77.09***
	(0.0000)	(0.0000)	(0.0000)
Observations	19	19	19
R-squared	0.502	0.910	0.00946
F-Test	8.050	81.24	0.0764

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

Table 13. Services: Validation of country classification with ANOVA regression, 2008

	S RES	S EI	S CI
Group 2	-3.996**	229.1***	-7.646
	(0.0059)	(0.0000)	(0.5893)
Constant	99.59***	95.05***	65.63***
	(0.0000)	(0.0000)	(0.0000)
Observations	19	19	19
R-squared	0.368	0.930	0.0175
F	9.904	224.9	0.303

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

4.2.4 Households

For the household sector four variables are used for the cluster analysis:

- Share of district heating in the household sector (H DH)
- Share of renewable energy sources in the household sector (H RES)
- Energy intensity of space heating (H EI)
- Carbon intensity in the household sector (H CI)

The indicators reflect the variables chosen for the calculation of the composite index for this sector, complemented by the indicator "Share of district heating in the household sector" that indicates to which extent emissions for space heating and the share of renewable energy sources are attributed to the sector energy supply instead of the household sector.

The variable "Share of district heating in the household sector" (H DH) is defined as 100% district heating minus the actual share of district heating in the household sector in a certain year. The variable "Share of renewable energy sources in the household sector" (H RES) is defined as 100% share of renewable energy minus the actual share of renewables in the household sector in a given year. The variable "Energy intensity of space heating" (H EI) denotes final energy consumption for space heating per energy service, i.e. climate corrected final energy consumption by the floor area of dwellings. The variable "Carbon intensity in the household sector (H CI) gives the CO_2 content of final energy consumption in the household sector.

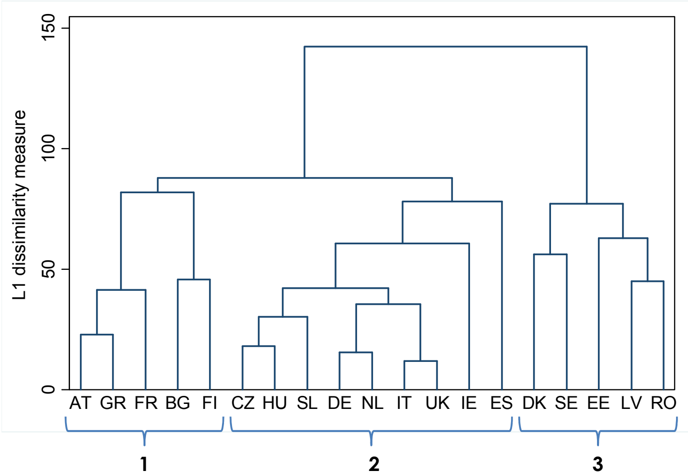
Correlation between variables

The correlation between the four variables chosen as basis for the definition of country groups in the household sector is illustrated in Figure A - 7 and Figure A - 8 in the Appendix for 1995 and 2008 respectively. As indicated in the correlograms and by the correlation coefficients, the shares of renewable energy sources and district heating are each correlated with carbon. This rests on the fact that according to the system of energy balances renewable energy sources are considered completely carbon free for GHG accounting and emissions from district heating are accounted for in the energy supply sector. The energy intensity of space heating is uncorrelated with the other three variables.

Identified country groups and summary statistics

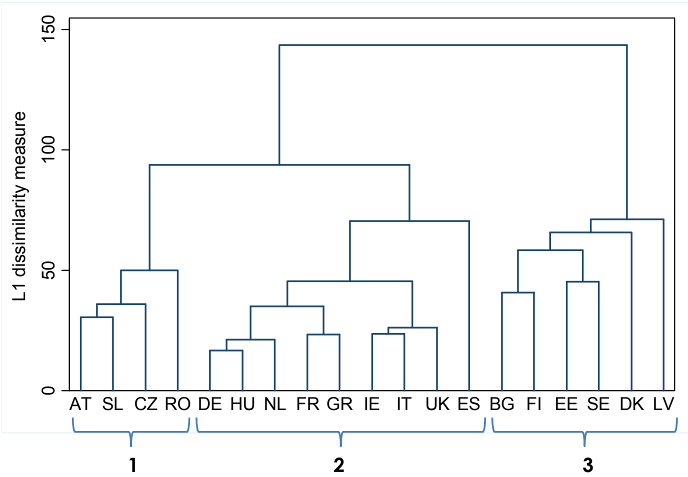
As indicated in Figure 27, the hierarchical cluster analysis identifies three country groups with respect to the household sector in the year 1995 (see also Table A - 9 in the Appendix). The size distribution of the three groups is relatively balanced. Each country group consists of both Old and New EU Member States. For 2008, again three groups of countries are identified for the household sector (see Figure 28 and Table A - 10 in the Appendix). Compared to the sectors analysed above, the household sector shows the same number of clusters in 1995 and 2008, but a stronger variation of group members can be observed, despite a relatively constant group size for both years.

Figure 27. Households: Cluster dendrogram, 1995



Source: WIFO calculations.

Figure 28. Households: Cluster dendrogram, 2008



Source: WIFO calculations.

Table 14 indicates why the cluster analysis identifies three different groups for the household sector in 1995. Group 1 exhibits above-average scores for all indicators: low energy and carbon intensity as well as a high share of district heating and renewables. Group 2 differs from Group 1 with respect to the energy mix (and hence also regarding the carbon intensity of space heating), but shows a similar energy efficiency. The opposite is true for the third country group: Countries in this cluster exhibit a high share of renewables and district heating and hence a low carbon intensity, but differ substantially from the first two groups with respect to energy intensity. Group differences in 2008 are similar to 1995 despite differing group members (Table 15).

Table 14. Households: Mean values of energy indicators by country group, 1995

Group	H DH	H RES	H EI	H CI
1	96.98	86.77	94.80	83.98
2	102.26	102.46	93.73	120.07
3	67.02	82.30	102.83	36.53

Source: WIFO calculations.

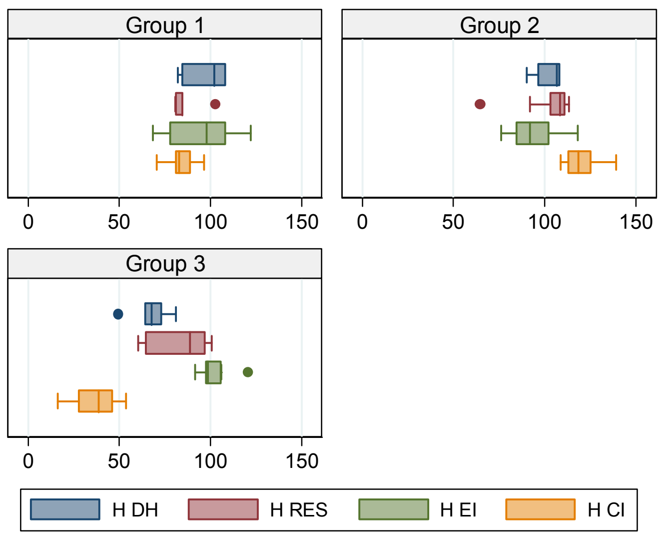
Table 15. Households: Mean values of energy indicators by country group, 2008

Group	H DH	H RES	H EI	H CI
1	94.32	73.07	91.71	69.96
2	105.87	99.94	92.39	110.23
3	76.05	70.33	102.15	21.57

Source: WIFO calculations.

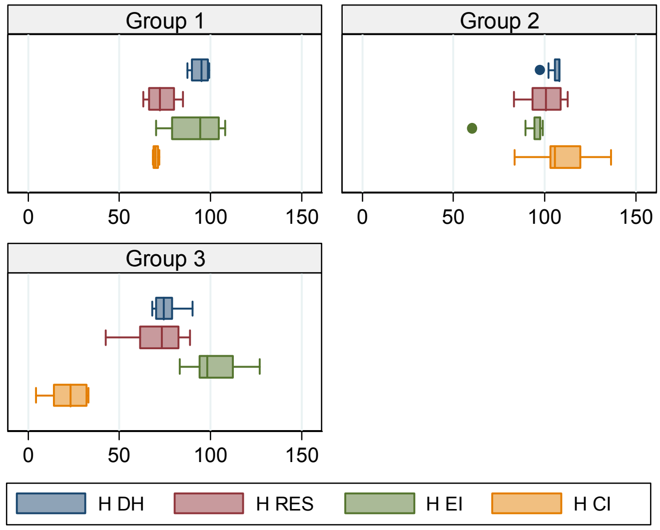
In Figure 29 and Figure 30 box-plots for the four variables are presented by country group for 1995 and 2008. The box-plots indicate the range of the data within the country groups for each variable. The figures highlight significant differences between the country groups with respect to all indicators and especially for the carbon intensity of household final energy consumption for both years of the analysis.

Figure 29. Households: Box plots of energy indicators by country group, 1995



Source: WIFO calculations.

Figure 30. Households: Box plots of energy indicators by country group, 2008



Source: WIFO calculations.

Econometric validation of country classification

Table 16 summarises the regression results for the first year for which the cluster analysis is performed, 1995. In general the results are in line with the observations made above. The ANOVA regression shows that Groups 2 and 3 differ from Group 1 with respect to carbon intensity with a very high significance level. Furthermore, Group 3 differs from the first country group with respect to the share of district heating in final energy consumption. For the share of district heating and for the carbon efficiency, the classification explains 72% and 92% of the total variation respectively (as indicated by the R^2 statistics) and is significant to explain the variation across countries (as explained by the F statistics).

The ANOVA regression results for 2008 are presented in Table 17. Group 2 now differs from the first country group not only with respect to the carbon intensity of household final energy consumption, but also with respect to the shares of district heating and renewables. Group 3 again differs from Group 1 regarding the share of district heating and carbon intensity with a very high level of significance. For the shares of district heating and renewables as well as for the carbon efficiency, the clustering explains between 60% and 91% of the total variation.

Table 16. Households: Validation of country classification with ANOVA regression, 1995

	H DH	H RES	H EI	H CI
Group 2	5.275	15.69	-1.071	36.08***
	(0.358)	(0.082)	(0.902)	(0.000)
Group 3	-29.96***	-4.472	8.024	-47.45***
	(0.000)	(0.648)	(0.420)	(0.000)
Constant	96.98***	86.77***	94.80***	83.98***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	19	19	19	19
R-squared	0.724	0.299	0.0702	0.918
F-Test	20.97	3.409	0.604	89.46

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

Table 17. Households: Validation of country classification with ANOVA regression, 2008

	H DH	H RES	H EI	H CI
Group 2	11.55**	26.87**	0.686	40.27***
	(0.00)	(0.00)	(0.94)	(0.00)
Group 3	-18.27***	-2.743	10.44	-48.38***
	(0.00)	(0.74)	(0.27)	(0.00)
Constant	94.32***	73.07***	91.71***	69.95***
	(0.00)	(0.00)	(0.00)	(0.00)
Observations	19	19	19	19
R-squared	0.855	0.608	0.112	0.914
F	47.30	12.39	1.012	85.49

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

4.2.5 Transport

For the analysis of country groups in the transport sector five variables are used:

- Share of public passenger transport (TP PUB)
- Share of public freight transport (TF PUB)
- Energy intensity of passenger transport (TP EI)
- Energy intensity of freight transport (TF EI)
- Carbon intensity of transport (T CI)

The five indicators reflect the variables chosen for the calculation of the composite index for the transport sector, complemented by indicators that report the shares of public transport in passenger and freight transport. Indicators on the shares of renewable energy sources in the transport sector were omitted. Due to limited data availability (especially with respect to data on passenger transport) this analysis is limited to 16 countries; Bulgaria, the Czech Republic and Estonia had to be dropped.

The variable "Share of public passenger transport" (TP PUB) is defined as the share of passenger kilometres travelled by bus and rail in total passenger kilometres. The variable

"Share of public freight transport" (TP PUB) denotes the share of tonne kilometres hauled by rail in total tonne kilometres. The variable "Energy intensity of passenger transport" (TP EI) is defined as final energy consumption per passenger kilometre; analogue the variable "Energy intensity of freight transport" (TF EI) is defined as final energy consumption per tonne kilometre. "Carbon intensity of transport" (H CI) gives the CO_2 content of final energy consumption in the transport sector.

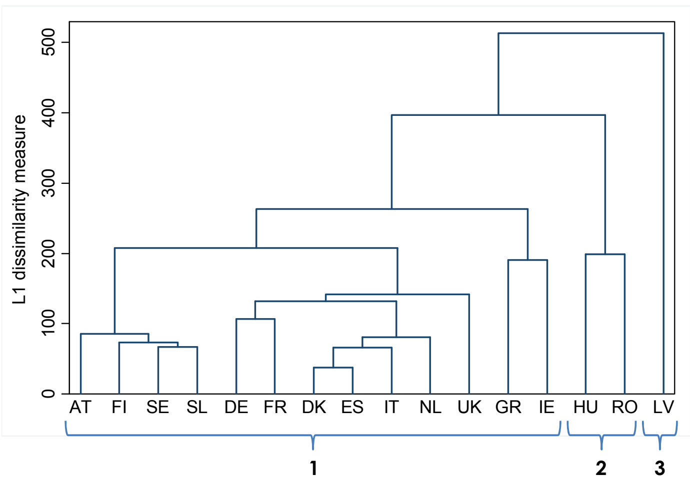
Correlation between variables

As expected and indicated in correlation analysis (Figure A - 9 and Figure A - 10 in the Appendix), one can observe a negative relationship between the share of public (passenger and freight) transport and carbon intensity. This relationship is straightforward as the share of electricity used in public transport is higher than in individual road transportation. Furthermore we can confirm a negative correlation between the share of public freight transport and energy intensity of freight transport. A higher share of goods shipped by train instead of trucks obviously decreases intensity.

Identified country groups and summary statistics

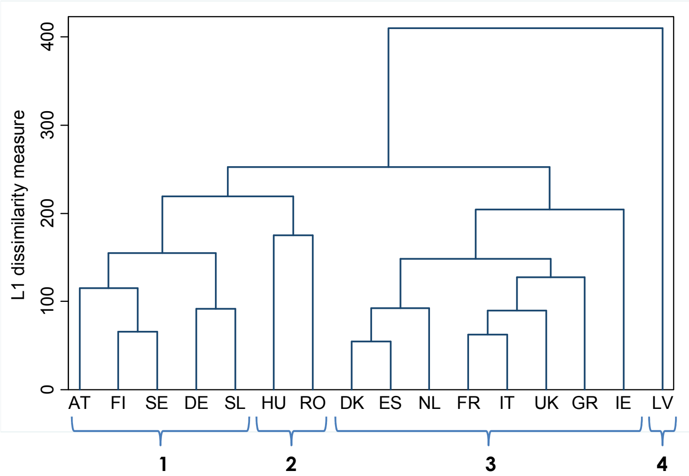
For the transport sector, the hierarchical cluster analysis identifies three groups of countries for the year 1995 as shown in Figure 31 and summarised in Table A - 11 in the Appendix. Group 1 comprises the OMS and Slovenia; Groups 2 and 3 comprise the remaining three NMS. For the year 2008, four country clusters are defined (see Figure 32 and Table A - 12 in the Appendix). The OMS and Slovenia are now clustered in two different groups (Groups 1 and 3), while the grouping of Hungary, Romania and Latvia remained the same. This suggests that the OMS diverge from each other with respect to the indicators for the transport sector.

Figure 31. Transport: Cluster dendrogram, 1995



Source: WIFO calculations.

Figure 32. Transport: Cluster dendrogram, 2008



Source: WIFO calculations.

In Table 18 a first indication for the identification of three country groups for the transport sector in 1995 is given. The first group, the OMS and Slovenia, has the lowest share of public transport. This is also reflected in the high energy intensity of passenger and freight transport in these countries. In Group 2, Hungary and Romania, the share of public passenger and freight transport is more than twice as high as in Group 1. For freight transport, this high share of public transport is reflected in high energy efficiency. The higher share of public transport does, however, not translate into a higher energy efficiency for passenger transport due to a particularly low energy efficiency of motorised individual transport in this group. Furthermore Group 2 exhibits the lowest carbon intensity which points at a comparably high share of electricity in the transport sector in these countries. Latvia, the only country in Group 3, differs from the other two groups particularly with respect to the high share of public freight transport. Energy efficiency of freight transport is also higher in Latvia than in the other country groups due to the high share of goods hauled by train. With respect to carbon intensity, Latvia scores, however, worst indicating that the share of electricity and renewable energy sources used in the transport sector is comparably low.

For 2008 the cluster analysis defines four clusters (Table 19), i.e. in 2008 two distinct groups of OMS are identified. Group 3 significantly differs from Group 1 regarding freight transport: Countries in this group exhibit on average a lower share of public transport and hence a higher energy intensity of freight transport. The carbon intensity in the first country group is also lower than in Group 3 due to a comparably high share of electricity and biofuels in the transport sector.

Table 18. Transport: Mean values of energy indicators by country group, 1995

Group	TP PUB	TF PUB	TP EI	TF EI	T CI
1	114.45	104.11	111.77	104.32	100.17
2	295.05	253.20	109.17	49.40	96.94
3	173.00	538.78	103.74	53.71	100.32

Source: WIFO calculations.

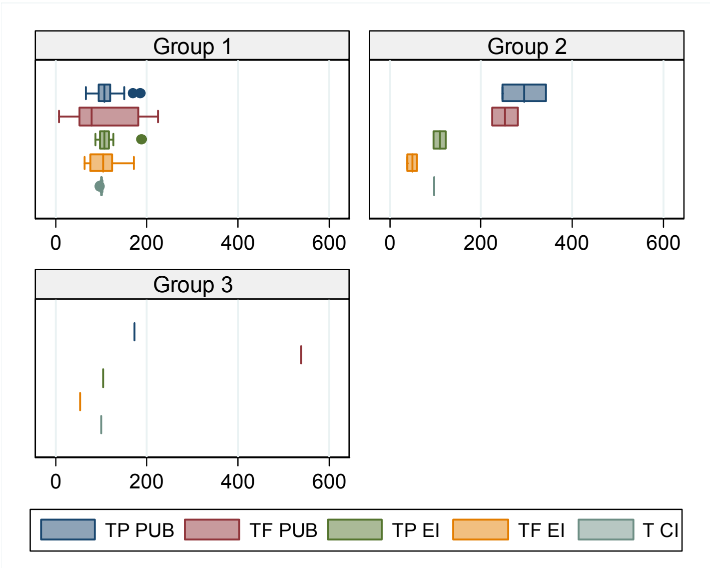
Table 19. Transport: Mean values of energy indicators by country group, 2008

Group	TP PUB	TF PUB	TP EI	TF EI	T CI
1	95.90	163.66	104.11	67.84	97.16
2	209.45	126.74	117.49	62.40	97.99
3	109.50	47.17	100.06	129.00	99.88
4	89.31	392.57	90.00	30.99	102.80

Source: WIFO calculations.

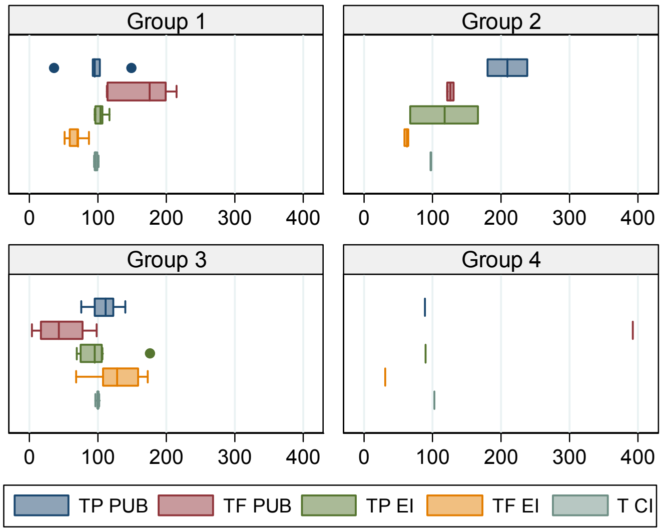
Figure 33 and Figure 34 present box-plots for the five variables considered for the transport sector by country group for the years 1995 and 2008. The box-plots indicate the range of the data within the country groups for each variable. The figures show that for both years the country groups differ predominantly with respect to the share of public freight transport.

Figure 33. Transport: Box Plots of energy indicators by country group, 1995



Source: WIFO calculations.

Figure 34. Transport: Box Plots of energy indicators by country group, 2008



Source: WIFO calculations.

Econometric validation of country classification

Table 20 and Table 21 summarise the ANOVA regression results for the 1995 and 2008 clustering respectively. The results for 1995 show that Groups 1 and 2 differ statistically significant for four of the five indicators considered – with respect to the share of public passenger and freight transport, energy intensity of freight transport as well as carbon intensity. Latvia differs from Group 1 only regarding the indicator TF PUB with a very high level of significance. For the indicator energy intensity of passenger transport, the variables are not statistically different between the three country groups. For the other indicators, the classification explains between 34% and 75% of the total variation of the indicators (as indicated by the R^2 statistics).

For the 2008 classification, Group 2 differs from the first country group only with respect to the share of public passenger transport with a very high level of significance. As already indicated above, Group 3 differs from Group 1 regarding the share of public freight transport and the energy intensity of freight transport with a high level of significance. Group 4 and Group 1 differ statistically significant with respect to the share of public freight transport and the carbon intensity of transport. For energy intensity of passenger transport, the variables are again not statistically different between the four country groups. For the other indicators, between 39% and 88% of the total variation of the indicators are explained by the classification. For the indicators TP PUB, TF PUB and TF EI the classification is significant to explain the variation across countries in the year 2008.

Table 20. Transport: Validation of country classification with ANOVA regression, 1995

	TP PUB	TF PUB	TP EI	TF EI	T CI
Group 2	180.6***	149.1*	-2.602	-54.92*	-3.231*
	(0.0000)	(0.0211)	(0.8958)	(0.0417)	(0.0169)
Group 3	58.55	434.7***	-8.027	-50.61	0.149
	(0.1630)	(0.0001)	(0.7677)	(0.1515)	(0.9276)
Constant	114.5***	104.1***	111.8***	104.3***	100.2***
	(0.0000)	(0.0002)	(0.0000)	(0.0000)	(0.0000)
Observations	16	16	16	16	16
R-squared	0.753	0.733	0.00778	0.344	0.370
F-Test	19.81	17.84	0.0510	3.411	3.818

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

Table 21. Transport: Validation of country classification with ANOVA regression, 2008

	TP PUB	TF PUB	TP EI	TF EI	T CI
Group 2	113.5***	-36.92	13.38	-5.443	0.827
	(0.0008)	(0.2678)	(0.6433)	(0.8189)	(0.6711)
Group 3	13.60	-116.5***	-4.046	61.17**	2.721
	(0.4496)	(0.0002)	(0.8365)	(0.0023)	(0.0574)
Group 4	-6.588	228.9***	-14.11	-36.85	5.642*
	(0.8471)	(0.0001)	(0.7087)	(0.2496)	(0.0426)
Constant	95.90***	163.7***	104.1***	67.84***	97.16***
	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
Observations	16	16	16	16	16
R-squared	0.647	0.879	0.0465	0.674	0.390
F	7.344	29.11	0.195	8.263	2.561

p-values in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Source: WIFO calculations.

5 Summary and conclusions

In this report we built on the indicators for sustainable energy development set out by Kettner et al. (2011) that focus on energy services and integrate them into composite indices. The composite indices address sustainable energy development in five different sectors – energy supply, manufacturing, services, households and transport – on the one hand and sustainability of the overall energy system on the other hand.

For the calculation of the aggregate index, two different weighting procedures are followed: First we apply equal weights for all sectors included in the index; then we weight the sectors according to their shares in total energy related CO_2 emissions.

The results of the former approach show an overall upward trend for the countries covered by the index over the whole period 1995 to 2008. This points at a continuous improvement towards a more sustainable energy system. Weighting the sectors by their shares in CO_2 emissions does not considerably change the aggregate results. However, the importance of the sectors households and services which contributed significantly to the overall improvement of the index decreases, as they account for a comparably small share in emissions, while the development of the other sub-indices is mirrored stronger in the aggregate index. This is most notably true for the sectors electricity and heat supply and transport which on average emit 38% and 26% of total CO_2.

To gain more insight into similarities and differences of countries with respect to the energy indicators a cluster analysis was performed for the years 1995 and 2008. The results show that the clustering of countries for the sectors analysed is more or less stable over time but differs between sectors. While the cluster analysis clearly differentiates between Old and New Member States for the sectors manufacturing, services and transport, country groups identified in the sectors energy supply and households consist of both OMS and NMS. For the sectors manufacturing, services and transport the spread of values is considerably higher both between OMS and NMS and within the respective clusters than in the other sectors.

Furthermore, it has to be stressed that only 19 EU member states could be covered due to data availability. One also has to mention that the concept of energy services needs to rely on proxy measures as traditional data bases typically illustrate energy flows. For the indicators developed here we had to combine official data bases with other data sources. For a continuous monitoring of energy sustainability a expansion of official statistics mirroring the service aspect as well as the interaction between flows and stocks is desirable.

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Appendix

Appendix 1

Table A - 1. The PASHINA energy indicator set, EU-27 in 2000

EU, 2000

Energy supply

EU, 2000	Name	Unit	Data
Contextual indicators	Energy dependency	%	47.7
	Installed RES capacities	GW	152.4
	Total final consumption	PJ	46,898
	Net Electricity imports	%	0.7
Intensitities	Energy efficiency coal	%	43.71
	Energy efficiency oil	%	48
	Energy efficiency gas	%	59.17
Energy use and provision	Transformation output	PJ	12,921
	T. input oil	PJ	1,742
	T. input coal	PJ	9,777
	T. input gas	PJ	4,185
Environmental aspects	CO_2 emissions	Mt	1,493
	NOx emissions	Gt	2,228
	SO_2 emissions	Gt	5,861
	Radiocative waste	t	3,108

Manufacturing

EU, 2000	Name	Unit	Data
Contextual indicators	Share of GVA in GDP	%	24.84
	Energy price gas	€/TJ	4,012
	Energy price fuel oil	€/TJ	10,202
	Energy price diesel	€/TJ	17,655
	Energy price electricity	€/TJ	14,316
Energy service	Gross Value Added	bn €	2,292
Intensitities	Energy per GVA	TJ/M€	6.2
Energy use and provision	Coal consumption	PJ	1,573
	Oil consumption	PJ	2,056
	Gas consumption	PJ	4,248
	RES consumption	PJ	679
	Electricity consumption	PJ	3,808
	Heat consumption	PJ	388
Environmental aspects	CO_2 emissions	Mt	950
	NOx emissions	Gt	1,785
	SO_2 emissions	Gt	1,385

Services

EU, 2000	Name	Unit	Data
Contextual indicators	Share of GVA in GDP	%	62
	Energy price gas	€/TJ	4,012
	Energy price fuel oil	€/TJ	10,202
	Energy price electricity	€/TJ	14,316
Energy service	Gross Value Added	bn €	5,721
Intensitities	Energy per GVA	TJ/M€	0.9
Energy use and provision	Coal consumption	PJ	65
	Oil consumption	PJ	942
	Gas consumption	PJ	1,456
	RES consumption	PJ	46
	Electricity consumption	PJ	2,242
	Heat consumption	PJ	265
Environmental aspects	CO_2 emissions	Mt	173
	NOx emissions	Gt	190
	SO_2 emissions	Gt	145

Households

EU, 2000	Name	Unit	Data
Contextual indicators	Number of households	Mio	189.4
	Household size	c/HH	2.5
	Heating systems	per HH	0.97
	Floor area per capita	m^2	31.2
	Household income	€	28,669
	Income inequantity	GINI	30.6
	Energy price gas	€/TJ	8,184
	Energy price fuel oil	€/TJ	13,288
	Energy price electricity	€/TJ	26,743
Energy service	Heated floor area	Mm^2	15,017
	Population (hot water)	Mio.	482
	Households (other)	Mio.	189
Intensitities	Heated floor area	MJ/m^2	545
	Hot water/capita	MJ/cap	3,673
	Other/household	GJ/HH	12
Energy use and provision	Energy per household	GJ/HH	60.5
	Coal consumption	%	3.8
	Oil consumption	%	20.5
	Gas consumption	%	36.8
	RES consumption	%	10.1
	Electricity consumption	%	21.2
	Heat consumption	%	7.6
Environmental aspects	CO_2 emissions	Mt	468
	NOx emissions	Gt	412
	SO_2 emissions	Gt	454
Social aspects	Energy expenditures	%	3.1
	Energy expenditures lowest quintil**	%	5.0

Passenger Transport

EU, 2000	Name	Unit	Data
Contextual indicators	Cars	Mio.	194.3
	Busses	Mio.	0.728
	Motorcycles	Mio.	24.67
	Energy price diesel	€/TJ	21,226
	Energy price gasoline	€/TJ	27,885
	Public transport	Gpkm	921
	Private transport	Gpkm	4,290
	Share of rail/road	%	9
	Pkm per vkm	km	13,492
Energy service	Mobility	Mpkm	5,235
Intensitities	Energy per Road	MJ/pkm	1,643
	Energy per Rail	MJ/pkm	365
Energy use and provision	Oil consumption cars	PJ	7,264
	RES consumption cars	PJ	19
	Oil consumption busses	PJ	356
	RES cons. busses	PJ	1
	Oil cons. motorbike	PJ	141
	RES consumption bike	PJ	0
	El. consumption rail	PJ	91
	Oil consumption rail	PJ	69.8
Environmental aspects	CO_2 emissions	Mt	611
	NOx emissions	Gt	1,148
	SO_2 emissions	Gt	109
Social aspects	Transport expenditures	%	12.8
	Transport expenditures lowest quintil**	%	10.0

Freight Transport

EU, 2000	Name	Unit	Data
Contextual indicators	Trucks	Mio.	27
	Energy price diesel	€/TJ	21,226
	Freight transport road	Gtkm	1,679
	Freight transport rail	Gtkm	397
	Freight transport ship	Gtkm	176
	Share of rail/road	%	24
	Tkm per vkm	km	1,926
Energy service	Mobility	Mtkm	2,251
Intensitities	Energy per Road	MJ/tkm	2,331
	Energy per Rail	MJ/tkm	445
	Energy per Ship	MJ/tkm	1,193
Energy use and provision	Oil consumption trucks	PJ	3,903
	RES cons. trucks	PJ	10
	Oil cons. rail	PJ	76
	El. consumption rail	PJ	100
	Oil consumption ships	PJ	248
Environmental aspects	CO_2 emissions	Mt	330
	NOx emissions	Gt	5,005
	SO_2 emissions	Gt	196

*** Year 2005**
**** Year 1999**

Table A - 2. The PASHINA energy indicator set, EU-27 in 2008

EU, 2008

Contextual indicators

Sector	Name	Unit	Data
Energy supply	Energy dependency	%	55.5
Energy supply	Installed RES capacities	GW	240
Energy supply	Total final consumption	PJ	49,205
Energy supply	Net Electricity imports	%	0.5
Manufacturing	Share of GVA in GDP	%	23.5
Manufacturing	Energy price gas	€/TJ	9,616
Manufacturing	Energy price fuel oil	€/TJ	21,273
Manufacturing	Energy price diesel	€/TJ	28,919
Manufacturing	Energy price electricity	€/TJ	27,524
Services	Share of GVA in GDP	%	63.9
Services	Energy price gas	€/TJ	9,616
Services	Energy price fuel oil	€/TJ	21,273
Services	Energy price electricity	€/TJ	27,524
Households	Number of households	Mio	206
Households	Household size	c/HH	2.4
Households	Heating systems	per HH	0.98
Households	Floor area per capita	m^2	34.6
Households	Household income	€	35,309
Households	Income inequantity*	GINI	30.7
Households	Energy price gas	€/TJ	16,281
Households	Energy price fuel oil	€/TJ	25,113
Households	Energy price electricity	€/TJ	42,216
Passenger Transport	Cars	Mio.	230
Passenger Transport	Busses	Mio.	0.8
Passenger Transport	Motorcycles	Mio.	31
Passenger Transport	Energy price diesel	€/TJ	34,756
Passenger Transport	Energy price gasoline	€/TJ	38,112
Passenger Transport	Public transport	Gpkm	1,033
Passenger Transport	Private transport	Gpkm	4,650
Passenger Transport	Share of rail/road	%	10
Passenger Transport	Pkm per vkm	km	14,541
Freight Transport	Trucks	Mio.	34
Freight Transport	Energy price diesel	€/TJ	34,756
Freight Transport	Freight transport road	Gtkm	2,095
Freight Transport	Freight transport rail	Gtkm	426
Freight Transport	Freight transport ship	Gtkm	193
Freight Transport	Share of rail/road	%	20
Freight Transport	Tkm per vkm	km	2,690

Energy service

Sector	Name	Unit	Data
Manufacturing	Gross Value Added	bn €	2,548
Services	Gross Value Added	bn €	6,920
Households	Heated floor area	Mm^2	17,224
Households	Population (hot water)	Mio.	497
Households	Households (other)	Mio.	206
Passenger Transport	Mobility	Mpkm	5,557
Freight Transport	Mobility	Mtkm	2,714

Intensitities

Sector	Name	Unit	Data
Energy supply	Energy efficiency coal	%	43
Energy supply	Energy efficiency oil	%	45
Energy supply	Energy efficiency gas	%	62
Manufacturing	Energy per GVA	TJ/M€	5.6
Services	Energy per GVA	TJ/M€	0.9
Households	Heated floor area	MJ/m^2	467
Households	Hot water/capita	MJ/cap	3,697
Households	Other/household	GJ/HH	14
Passenger Transport	Energy per Road	MJ/pkm	1,542
Passenger Transport	Energy per Rail	MJ/pkm	331
Freight Transport	Energy per Road	MJ/tkm	2,225
Freight Transport	Energy per Rail	MJ/tkm	380
Freight Transport	Energy per Ship	MJ/tkm	1,086

Energy use and provision

Sector	Name	Unit	Data
Energy supply	Transformation output	PJ	14,475
Energy supply	T. input oil	PJ	1,174
Energy supply	T. input coal	PJ	9,529
Energy supply	T. input gas	PJ	6,253
Manufacturing	Coal consumption	PJ	1,254
Manufacturing	Oil consumption	PJ	1,728
Manufacturing	Gas consumption	PJ	3,675
Manufacturing	RES consumption	PJ	873
Manufacturing	Electricity consumption	PJ	4,085
Manufacturing	Heat consumption	PJ	654
Services	Coal consumption	PJ	61
Services	Oil consumption	PJ	906
Services	Gas consumption	PJ	1,766
Services	RES consumption	PJ	65
Services	Electricity consumption	PJ	2,763
Services	Heat consumption	PJ	393
Households	Energy per household	GJ/HH	55.8
Households	Coal consumption	%	3.3
Households	Oil consumption	%	16.8
Households	Gas consumption	%	37.9
Households	Renewable consumption	%	11.2
Households	Electricity consumption	%	23.9
Households	Heat consumption	%	7.0
Passenger Transport	Oil consumption cars	PJ	7,260
Passenger Transport	RES consumption cars	PJ	235
Passenger Transport	Oil consumption busses	PJ	332
Passenger Transport	RES cons. busses	PJ	15
Passenger Transport	Oil consumption bike	PJ	163
Passenger Transport	RES consumption bike	PJ	1
Passenger Transport	El. consumption rail	PJ	96
Passenger Transport	Oil consumption rail	PJ	66.7
Freight Transport	Oil consumption trucks	PJ	4,514
Freight Transport	RES cons. trucks	PJ	146
Freight Transport	Oil consumption rail	PJ	66
Freight Transport	El. consumption rail	PJ	96
Freight Transport	Oil consumption ships	PJ	278

Environmental aspects

Sector	Name	Unit	Data
Energy supply	CO_2 emissions	Mt	1,519
Energy supply	NOx emissions	Gt	2,187
Energy supply	SO_2 emissions	Gt	4,041
Energy supply	Radiocative waste*	t	2,573
Manufacturing	CO_2 emissions	Mt	889
Manufacturing	NOx emissions	Gt	1,631
Manufacturing	SO_2 emissions	Gt	1,020
Services	CO_2 emissions	Mt	178
Services	NOx emissions	Gt	203
Services	SO_2 emissions	Gt	94
Households	CO_2 emissions	Mt	444
Households	NOx emissions	Gt	433
Households	SO_2 emissions	Gt	456
Passenger Transport	CO_2 emissions	Mt	610
Passenger Transport	NOx emissions	Gt	913
Passenger Transport	SO_2 emissions	Gt	73
Freight Transport	CO_2 emissions	Mt	379
Freight Transport	NOx emissions	Gt	3,983
Freight Transport	SO_2 emissions	Gt	131

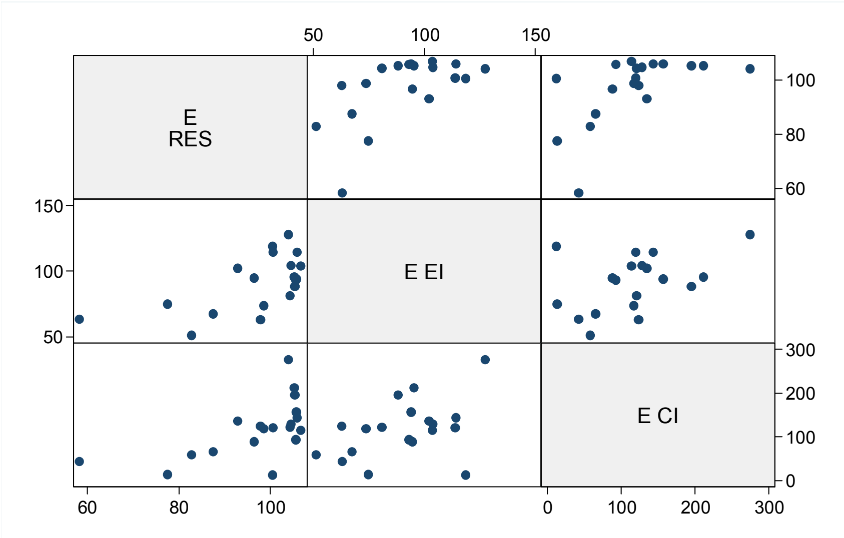
Social aspects

Sector	Name	Unit	Data
Households	Energy expenditures	%	4.0
Households	Energy expenditures lowest quintil*	%	7.1
Passenger Transport	Transport expenditures	%	12.4
Passenger Transport	Transport expenditures lowest quintil*	%	8.1

*** Year 2005**

Appendix 2

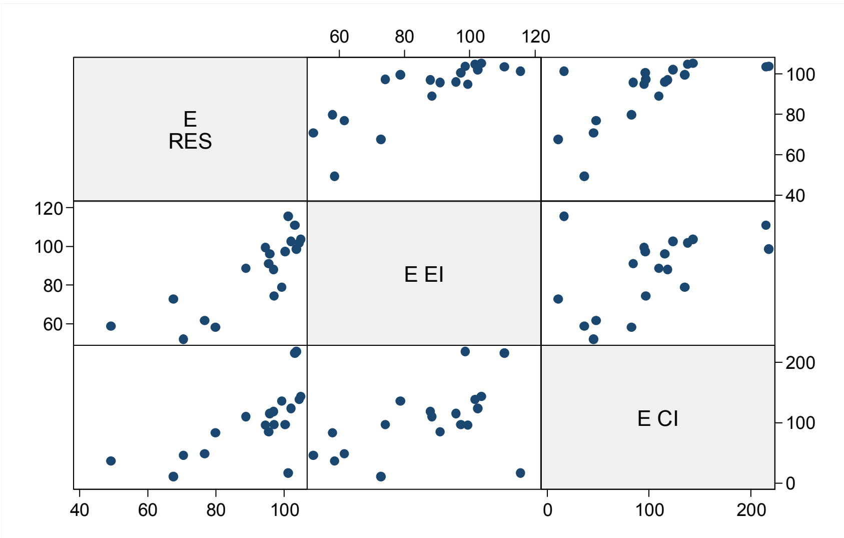
Figure A - 1. Energy supply: Correlation between variables, 1995



Correlation Coefficients	
E RES - E EI	0.61
E RES - E CI	0.59
E EI - E CI	0.45

Source: WIFO calculations.

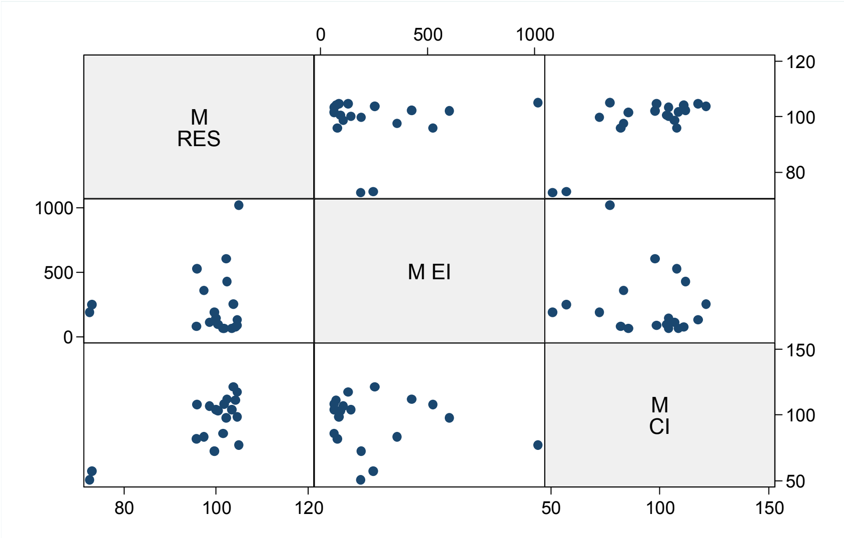
Figure A - 2. Energy supply: Correlation between variables, 2008



Correlation Coefficients	
E RES - E EI	0.82
E RES - E CI	0.67
E EI - E CI	0.51

Source: WIFO calculations.

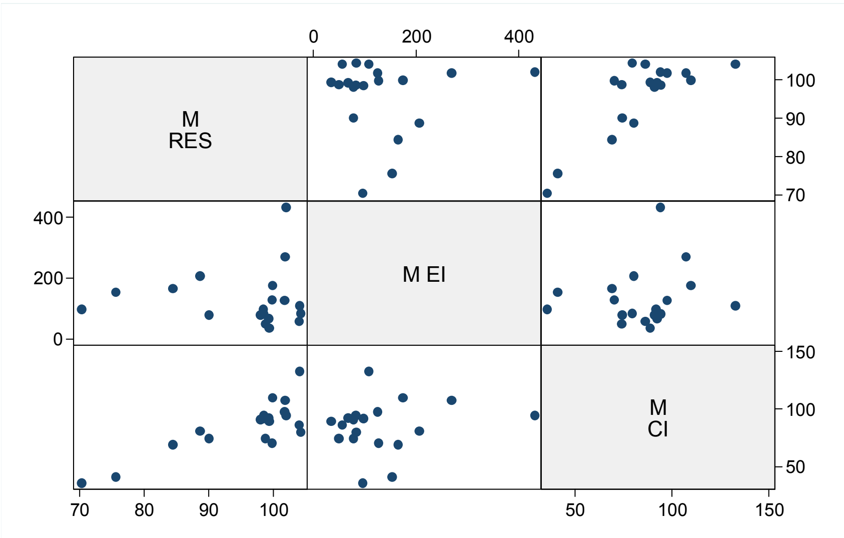
Figure A - 3. Manufacturing: Correlation between variables, 1995



Correlation Coefficients	
M RES - M EI	0.07
M RES - M CI	0.76
M EI - M CI	-0.15

Source: WIFO calculations.

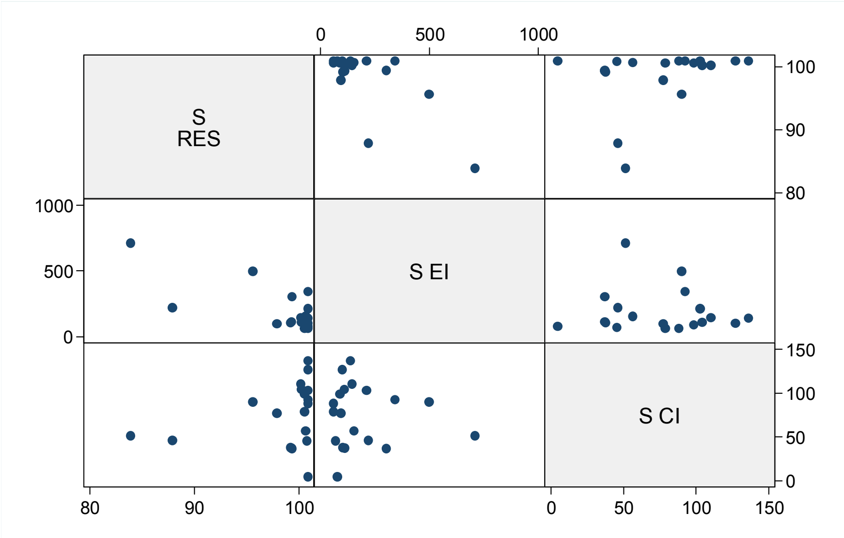
Figure A - 4. Manufacturing: Correlation between variables, 2008



Correlation Coefficients	
M RES - M EI	0.02
M RES - M CI	0.81
M EI - M CI	0.15

Source: WIFO calculations.

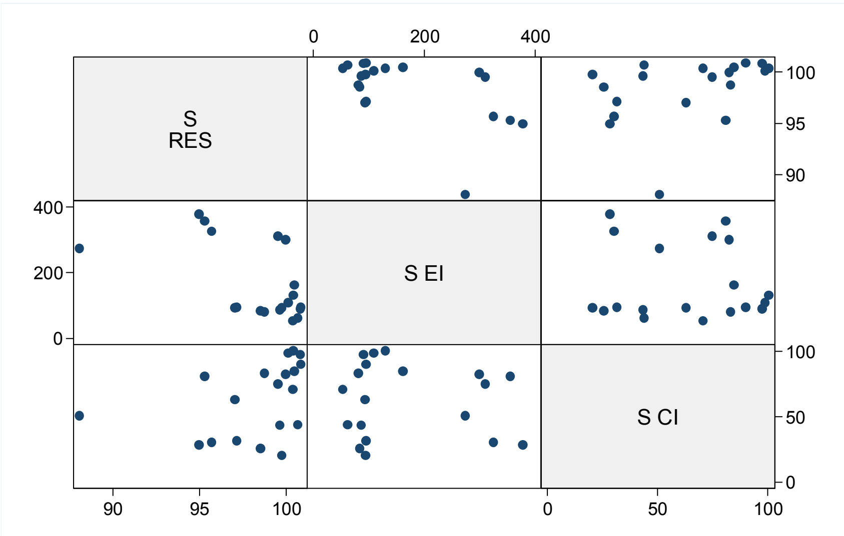
Figure A - 5. Services: Correlation between variables, 1995



Correlation Coefficients	
S RES - S EI	-0.72
S RES - S CI	0.27
S EI - S CI	-0.07

Source: WIFO calculations.

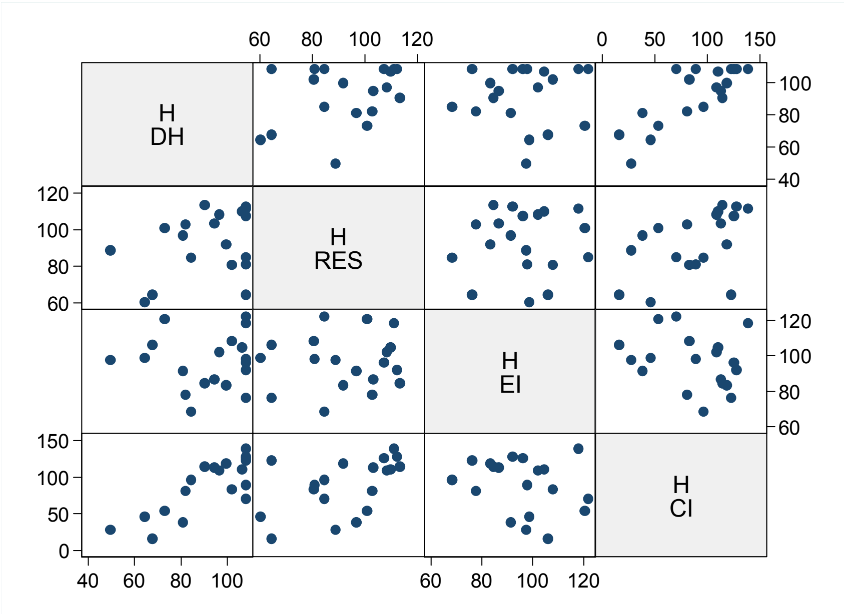
Figure A - 6. Services: Correlation between variables, 2008



Correlation Coefficients	
S RES - S EI	-0.55
S RES - S CI	0.37
S EI - S CI	-0.08

Source: WIFO calculations.

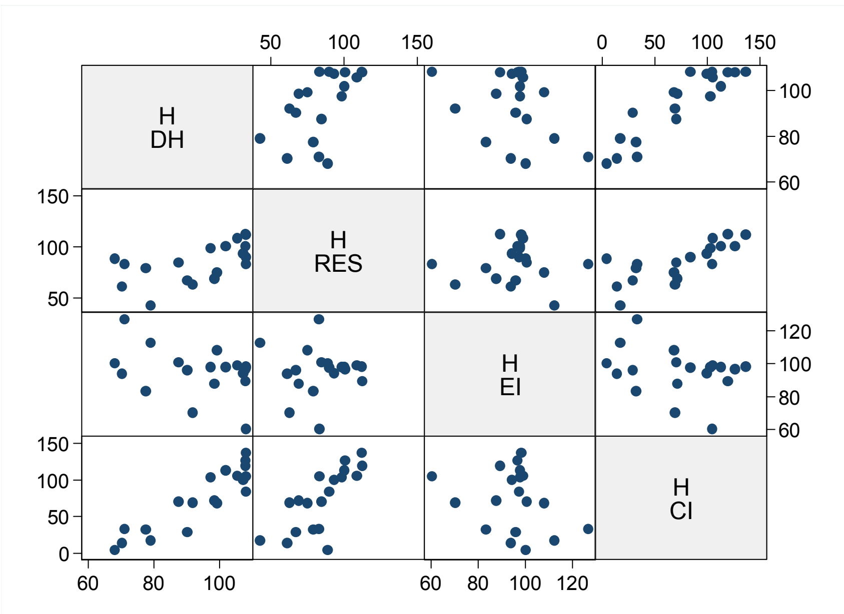
Figure A - 7. Households: Correlation between variables, 1995



Correlation Coefficients	
H DH - H RES	0.32
H DH - H EI	0.04
H DH - H CI	0.81
H RES - H EI	0.06
H RES - H CI	0.52
H EI - H CI	-0.25

Source: WIFO calculations.

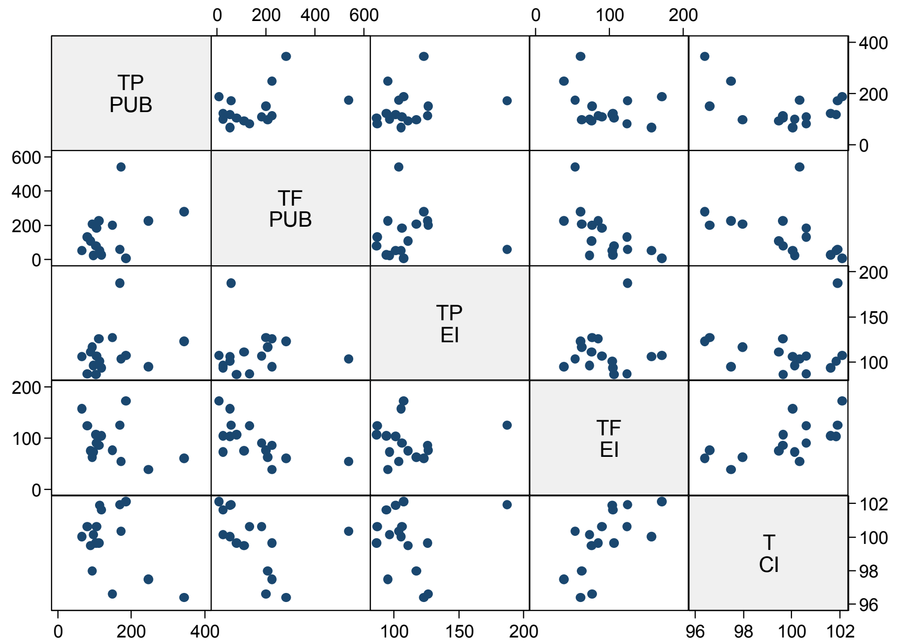
Figure A - 8. Households: Correlation between variables, 2008



Correlation Coefficients	
H DH - H RES	0.58
H DH - H EI	-0.34
H DH - H CI	0.91
H RES - H EI	0.01
H RES - H CI	0.76
H EI - H CI	-0.27

Source: WIFO calculations.

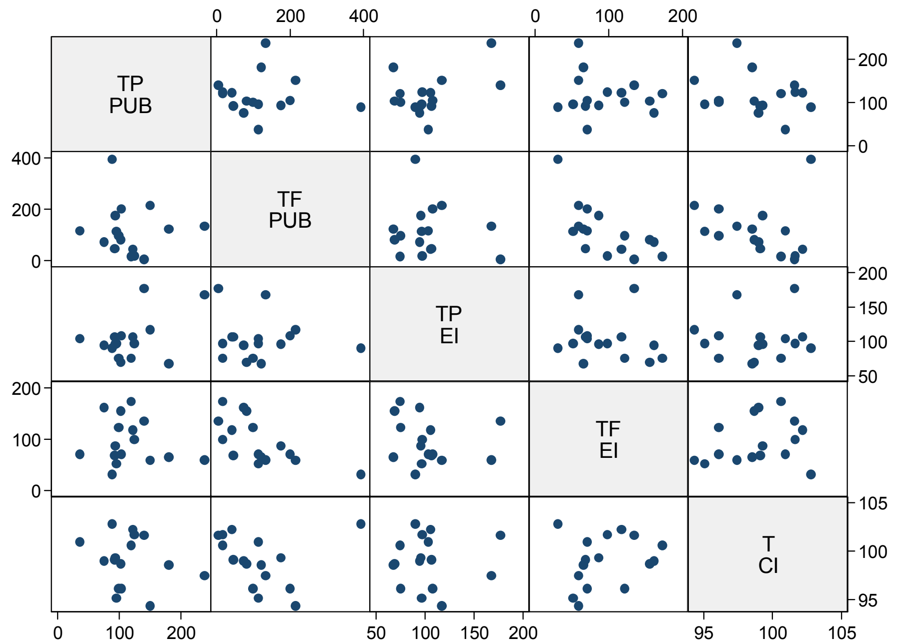
Figure A - 9. Transport: Correlation between variables, 1995



Correlation Coefficients	
TP PUB - TF PUB	0,39
TP PUB - TP EI	0,24
TP PUB - TF EI	-0,35
TP PUB - T CI	-0,45
TF PUB - TP EI	0,01
TF PUB - TF EI	-0,65
TF PUB - T CI	-0,45
TP EI - TF EI	0,07
TP EI - T CI	0,00
TF EI - T CI	0,65

Source: WIFO calculations.

Figure A - 10. Transport: Correlation between variables, 2008



Correlation Coefficients	
TP PUB - TF PUB	0.06
TP PUB - TP EI	0.44
TP PUB - TF EI	-0.15
TP PUB - T CI	-0.20
TF PUB - TP EI	-0.11
TF PUB - TF EI	-0.66
TF PUB - T CI	-0.15
TP EI - TF EI	-0.17
TP EI - T CI	0.04
TF EI - T CI	0.23

Source: WIFO calculations.

Appendix 3

Table A - 3. Energy supply: Country groups identified from the cluster analysis, 1995

Group 1	Group 2	Group 3	Group 4	Group 5
Austria Finland Latvia Sweden	France	Bulgaria Czech Republic Germany Denmark Spain Hungary Ireland Netherlands Romania Slovenia UK	Estonia Ireland	Greece

Source: WIFO calculations.

Table A - 4. Energy supply: Country groups identified from the cluster analysis, 2008

Group 1	Group 2	Group 3	Group 4
Austria Denmark Finland Latvia Sweden	France	Bulgaria Czech Republic Germany Spain Hungary Ireland Italy Netherlands Romania Slovenia UK	Estonia Greece

Source: WIFO calculations.

Table A - 5. Manufacturing: Country groups identified from the cluster analysis, 1995

Group 1	Group 2	Group 3	Group 4
Austria Germany Denmark Spain France Greece Ireland Italy Netherlands UK	Finland Hungary Sweden Slovenia	Czech Republic Estonia Latvia Romania	Bulgaria

Source: WIFO calculations.

Table A - 6. Manufacturing: Country groups identified from the cluster analysis, 2008

Group 1	Group 2	Group 3
Austria	Czech Republic	Bulgaria
Germany	Estonia	Romania
Denmark	Finland	
Spain	Latvia	
France		
Greece		
Hungary		
Ireland		
Italy		
Netherlands		
Sweden		
Slovenia		
UK		

Source: WIFO calculations.

Table A - 7. Services: Country groups identified from the cluster analysis, 1995

Group 1	Group 2	Group 3
Austria	Czech Republic	Hungary
Bulgaria	Estonia	Latvia
Germany	Romania	
Denmark	Slovenia	
Spain		
Finland		
France		
Greece		
Ireland		
Italy		
Netherlands		
Sweden		
UK		

Source: WIFO calculations.

Table A - 8. Services: Country groups identified from the cluster analysis, 2008

Group 1	Group 2
Austria	Bulgaria
Germany	Czech Republic
Denmark	Estonia
Spain	Hungary
Finland	Latvia
France	Romania
Greece	
Ireland	
Italy	
Netherlands	
Sweden	
Slovenia	
UK	

Source: WIFO calculations.

Table A - 9. Households: Country groups identified from the cluster analysis, 1995

Group 1	Group 2	Group 3
Austria	Czech Republic	Denmark
Bulgaria	Germany	Estonia
Finland	Spain	Latvia
France	Hungary	Romania
Greece	Ireland	Sweden
	Italy	
	Netherlands	
	Slovenia	
	UK	

Source: WIFO calculations.

Table A - 10. Households: Country groups identified from the cluster analysis, 2008

Group 1	Group 2	Group 3
Austria	Germany	Bulgaria
Czech Republic	Spain	Denmark
Romania	France	Estonia
Slovenia	Greece	Finland
	Hungary	Latvia
	Ireland	Sweden
	Italy	
	Netherlands	
	UK	

Source: WIFO calculations.

Table A - 11. Transport: Country groups identified from the cluster analysis, 1995

Group 1	Group 2	Group 3
Austria Germany Denmark Spain Finland France Greece Ireland Italy Netherlands Sweden Slovenia UK	Hungary Romania	Latvia

Source: WIFO calculations.

Table A - 12. Transport: Country groups identified from the cluster analysis, 2008

Group 1	Group 2	Group 3	Group 4
Austria Germany Finland Sweden Slovenia	Hungary Romania	Denmark Spain France Greece Ireland Italy Netherlands UK	Latvia

Source: WIFO calculations.