Energy Intensity Indicators for Non-Energy Intensive Industries: An Analysis for Germany, the Netherlands, and the United Kingdom

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ABSTRACT

The purpose of this paper is to develop, analyze and test energy intensity indicators for non-energy intensive sectors of three European countries. A comparison is made between economic energy intensities and specific energy consumption indicators which have so far mainly been applied to energy intensive sectors. We show that a) it is feasible to develop specific energy consumption indicators, and b) the trends of the two indicators differ notably, not only in magnitude but also in direction. Since it is assumed that specific energy consumption indicators reflect the physical reality more accurately, we conclude that the use of economic energy intensities can result in false findings. Moreover, specific energy indicators allow us to analyze the effect of change in product mix overtime. Hence, our findings point out the need to use physical indicators for monitoring the trends of energy intensity among non-energy energy industries, especially when conclusions are to be derived for policy making.

Introduction

In the last decades, indicators[1] have played an important role in monitoring trends and policies. Indicators, as a tool for formulation and evaluation of policymaking, began to appear first in the field of economics in the 1930's (i.e. growth, employment and inflation), but the term itself became widespread only in the 1960s (Godin, 2002). In the field of energy, indicators are important because they allow us to know how much energy is used, whether energy consumption has declined or not and how much is the potential for future savings. Energy intensity, defined as energy per unit of output, is the most commonly used indicator for assessing trends and developments in energy efficiency, especially at the sectoral and national level.[2] The simplest energy intensity indicators are based on monetary values, that is, energy demand per unit of sectoral value added or GDP. These indicators are called economic indicators. Besides these, there are other energy intensity indicators that have become widely used, although mainly for the analysis of energy intensive sectors. These are physical indicators which relate energy use (expressed in energetic units like Joule) to the amount of output expressed in physical units (such as ton or m^3 of product). In this paper we will use the term Economic Energy Intensity (ECI) when referring to energy used by unit of *economic* output and Specific Energy Consumption (SEC) when dealing with energy used by unit of *physical* output.

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[1] An indicator can be defined as a variable theoretically linked to the variable of interest which itself cannot be directly observed.
[2] Since energy efficiency is generally defined as the ratio of the amount of energy services provided by the amount of energy consumed, energy intensity and energy efficiency are considered to be inversely related.

Economic energy intensity indicators (ECI) are the most popular indicators used in international comparisons. The fact that economic data is generally more readily available than physical production data has been one of the main reasons for their popularity. Nevertheless, with ECI indicators it often remains unclear what the values and changes in the indicator really indicate. Take, as an example, a decrease of energy per value added in the industrial sector. This decrease may be caused by (a) price changes which have an influence on the level of the value added or (b) a shift from energy intensive activities to less energy intensive activities (structural change) and not by real improvements in energy efficiency, that is, by a reduction of energy use for accomplishing the same functional unit.

On the other hand, specific energy consumption (SEC) is often mentioned as the most reliable indicator to provide estimates of changes in energy efficiency (Farla 2000; Farla & Blok 2000; Freeman et al. 1997; Hyman & Reed 1994; Kim & Worrell 2002; Nanduri 1998; Phylipsen et al. 1998, Schipper & Meyers 1992). Moreover, SECs are also the preferred measure to track changes in energy use in energy efficiency policies in some countries[3] (Kim & Worrell 2002). However, SECs have mainly been used in energy intensive sectors such as the paper and pulp industry and the iron and steel industry, where we encounter the following situation: a) due to their high-energy intensity, disaggregate information on energy consumption by fuel is available, b) the diversity of key products in these industries is fairly limited (at least, a meaningful analysis can be prepared without going into too much details) and, c) the number of the main production processes is limited and fairly well known. While, these characteristics allow analyses using SECs, they are often named as the main restrictions to apply this kind of indicator to low energy industries.

Against this background the main purpose of this research is to develop, analyze and test SECs for non-energy intensive sectors (NES) in three European countries: Germany, the Netherlands and the United Kingdom. The main questions to be answered are: a) does data availability and data reliability allow development SEC values that accurately reflect developments of energy efficiency for the NES? and b) do SECs lead to a different conclusion about energy efficiency than ECIs?

The sectors were selected based on three main criteria: a) in terms of ECI, they are below the average of the total manufacturing sector, b) energy costs account for less than 3% of total costs[4], and c) availability of data. This paper shows the first results for three industrial sectors: production, processing and preserving of meat and meat products (NACE 151), processing and preserving of fruits and vegetables (NACE 1532-3) and manufacture of dairy products (NACE 155)[5]. Three other sectors are currently being studied: Printing and services related to printing (NACE 222), manufacture of plastic products (NACE 252) and the manufacture of automobiles (NACE 34).

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[3] In the Netherlands the progress of the long- term agreements with industry are tracked using Energy Efficiency Indexes (EEI) based on physical indicators. The EEI has been defined as the energy consumption in the year in question to produce the total output in that year, divided by the energy consumption that would have resulted had the same production been made or if the same amounts hade been produced with the energy efficiency in the year of reference (1989) (Nuijen, 1998).

[4] Total costs include labour costs, purchases of raw materials and packaging, consumption of energy and other operating costs such as rent and maintenance of buildings, machinery, automation costs and R&D.

[5] NACE is the statistical classification of economic activities used within the European community.

Data & Methodology

Data

One of the critical points, as well as the most time consuming, when constructing indicators is data gathering. This section details an overview of the data sources used in this paper. Note that we rely primarily on sources from the individual countries and use international data sources mainly for closing data gaps and for cross-checks. The time period covered in this study was determined by the availability of energy data. Hence, for the Netherlands the analysis covers the period 1986-2000 while for Germany and the United Kingdom are restricted to 1990-2000. Data for earlier years would have been available for Germany but have been proven to be unreliable and inconsistent due to different reporting systems and economic systems prior to reunification.

Energy. The following data sources were used[6]:

- *Germany*: Produzierendes Gewerbe. Reihe 4.1.1 (production data, serie 4.1.1), published by Statistisches Bundesamt.
- *The Netherlands*: The Nederlandse energiehuishouding jaarcijfers (the Dutch energy statistics yearbook), published by the Centraal Bureau voor de statistiek (CBS).
- *The United Kingdom*: Energy consumption in the UK published by the UK National Statistic Office.

All energy data in this paper refer to primary energy. To this end the following efficiencies for electricity generation were used: 40% for the Netherlands and the UK, 38% for Germany.[7]

Physical production. This kind of data was more difficult to gather than energy or economic data. We found data published at the national and international level can differ significantly, as it can be between sources at the national level (statistical offices and industrial associations). Changes in product classifications, breaks in time series due to changes in statistical classifications, contradictory data according to different sources were the main problems identified. Since we had to go into the details of how data was gathered and analyzed in each source (so differences could be explained) obtaining reliable figures of production proved to be a time intensive task. The following data sources were used:

- *Germany*: For all sectors, Produzierendes Gewerbe. Reihe 3.1 (production data, Serie 3.1), published by Statistisches Bundesamt, Wiesbaden, yearly publication.
- *The Netherlands*: For all sectors: production data provided by the CBS. For NACE 151: data from the Product Boards for Livestock, Meat and Eggs. For NACE 1532-2: Data provided by the Dutch Association of Vegetables and Fruit Processing Industry (VIGEF). For NACE 155: Data from the Dutch Dairy Board (Productschap Zuivel).

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[6] Please note that in 1995 in Germany and in 1993 in the Netherlands, the Statistics offices adopted the NACE classification and therefore data before and after the change is not completely compatible.

[7] These values were calculated using the Annual energy balances published by the International Energy Agency (2000).

- *The United Kingdom*: For all sectors, Prodcom data provided by the UK National Statistics. For the NACE sectors 151 and 155, data from the Monthly digest of statistics from the UK National Statistics Office.

Additionally, for all sectors and all countries we used data from the United Nations industry commodity production statistics database. For all countries and for the sectors NACE 151 and NACE 155, we used data from the FAO database and from the Foreign Agricultural Service's Production, Supply and Distribution (PS&D) online database. For all countries and the sector NACE 155 we used data provided by the Association of European Fruit & Vegetables Processing Industry.

Economic production. Data for value added, production value and producer price indexes were also gathered. The following sources were used:

- *Germany*: Produzierendes Gewerbe. Reihe 4.3.1 (production data, Serie 4.3.1), published by Statistisches Bundesamt, Wiesbaden, yearly publication.
- *The Netherlands*: Samenvattend overzich van de industrie (summarizing overview of the industry), published by the CBS, yearly publication.
- *The United Kingdom*: United Kingdom input-output analysis published by the UK National Statistics Office.

Methodology

Specific energy consumption (SEC). Following the methodology developed by Phylipsen et al. (1998) and Farla et al. (2000), we express the aggregate index of specific energy consumption ISEC of a sector as:

$$ISEC_j = \frac{\sum E_{i,j}}{\sum m_{i,j} \times SEC_{ref_{i,j}}} \qquad \text{(Eq.1)}$$

In which:
ISEC = index of specific energy consumption for sector j (dimensionless)
$E_{i,j}$ = primary energy consumption of product i in sector j (e.g., in Petajoule)
$m_{i,j}$ = physical production of product i in sector j (e.g., in tonnes)
SEC_{refi} = a reference value for the specific energy consumption of product i (e.g., in Gigajoules primary energy per tonne).

The idea behind equation 1 is to correct for differences in product mix in various countries and years. This is done in equation 1 by dividing the energy consumption of an industrial sector published in statistics (numerator) by a weighted production. This way differences on energy requirements *between* products to be taken into account. As weighting values, we use reference values for the specific energy consumption of the key products (SEC_{ref}). There are several possibilities for choosing the SEC_{ref}. For example, it is possible to choose the SEC of best available technologies, best practice, the best existing plant or an average of the current technologies[8]. Due to the large number of processes and products and

[8] Best plant observed is defined as the production plant with the lowest SEC that is already in full operation. Best practice is understood as the production plant with the lowest SEC that can be realized using proven

the limited availability of reference values for the different processes we are working with, we use SEC_{ref} values which reflect average technologies in use. Note that SEC_{ref} are kept constant through the time series analysed [9]. The SEC_{ref} value should be then obtained for all key products which are important from an energy point of view) in each sector. The identification of these key products is a fundamental and not always a trivial task. For instance, for the meat sector (NACE 151), an international product classification such as Prodcom identifies 60 different product categories. Out of these we identified as key products: beef/veal meat, lamb/sheep meat, poultry meat, pork meat and processed products[10]. The product selection takes into account both differences in energy consumption and data availability as well as developments in production in the last 20 years. Once products are identified, a literature survey is conducted in order to gather SEC values from various sources. As an example, Table 1 shows values gathered for the meat sector. Similar tables were obtained for the fruits and vegetable and dairy sectors. We selected suitable reference values after examining the reliability of the sources, the methodological choices (i.e. primary vs. final energy, process mix, degree of disaggregation) the year of study (we decided that our SEC_{ref} should reflect average technologies for the late 90's), the developments in the sector and the plausibility in view of other published values. We then use final energy data for electricity and direct fuel use to calculate reference values in primary terms. Table 2 shows the SEC_{ref} used in all sectors. Once SEC_{ref} are defined and production and energy data have been gathered, equation 1 is used to generate trends on ISEC.

Economic energy intensity indicators (ECI). We defined this indicator as the primary energy use per unit of economic output. As measure of economic output we have taken two measures: value added and production value. All economic values are converted to 1990 prices using producer price indexes for the individual countries. It was not possible to gather disaggregated figures of production value and value added for the vegetable and fruit processing sector (NACE 1532-3) in the United Kingdom (in publicly available statistics this sector is combined with the fish processing sector).

Results & Analysis

Figures 1 to 6 show the trends obtained using ISEC and ECI indicators[11]. All figures have been indexed to the year 2000. An important first finding is that the time series for ISEC and ECI can lead to significantly different conclusions. For instance, the ECIs for the Netherlands indicate an increase in energy intensity for all three sectors, while the ISEC only shows it for one case, the meat sector. At the same time, ECI trends for Germany and the United King-

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technology at reasonable costs and best available techniques is the production plant with the lowest SEC that can be realized using proven technology (Phylipsen et al, 1998).

[9] Although one could think on use a SEC_{ref} for every year of study, the fact is that to gather data of SEC for all years of analysis and for each product is in fact a daunting task, which low possibilities of success. This speaks for keeping the SEC_{ref} constant for all years, with the additional advantage of representing a frozen intensity development, which allows identifying the contribution of energy efficiency versus structural changes.

[10] Within the processed products, we include the following products: Bellies and cuts of swine salted, in brine, dried or smoked; pig meat slated, in brine, dried or smoked (including bacon); sausages; prepared pork meat (including mixtures); preparations of beef and veal, and tallow and lard.

[11] ECIs plotted in Figures 1 to 6 correspond to energy per unit of value added.

Table 1. Overview of SEC Figures Published for the Meat Sector

Source	Country/ company	Specific energy consumption (measured in terms of final consumption)			
		Cattle & lamb	Pig	Poultry	Processing
COWI, 2001	Australia	Range: 1200-4800 MJ/ton HSCW[a] Best practice: 1700 MJ/ton HSCW[a]			
	Denmark	Average: 1080 MJ / head[b] Best practice: 252 MJ / head[b]	Average: 450 MJ / head[c] Best practice : 108 MJ / head[c]		
	Canada	252-900 MJ/ton DW[d] [electricity] 200-500 MJ/DW[d] [thermal]	252-1080 MJ/ ton DW[d] [electricity] 500-900 MJ/ton DW [thermal]		
Danish crown, 2000	Danish crown		86.4 MJ/animal		
European Commission, 2000	Netherlands		2500 MJ/ton	600 MJ/ton [electricity abattoir]	
European Commission, 2002	EU	324-3938 MJ/ton	396-2746 MJ/ton	547-3085 MJ/ton	
FEI, 2000	Finland	1244-1584 MJ/ ton	2052-3564 MJ/ton	3564 MJ/ton	
Kolbech,2000	Denmark			5842 MJ/ton	
LCA,2001	Sweden	7.6 MJ/kg[i]			
Nieuwland, 2002	Netherlands		1750 MJ/ton[g]		Average: 7000 MJ/ton[g,h]
Nutreco,2001	Nutreco		677 MJ/ton[e] [total abattoir]	1470 MJ/tone [total abattoir]	
Pagan, 2002	Australia	1600 MJ/ton HCSW (heat) 800 MJ/ton HCSW (electricity)			
Pontoppidan, 2000	Denmark			Average: 2.12 MJ/ bird Range: 1.6-3.16 MJ/bird	
Suijkerbuijk, 1995	Netherlands	235 MJ/ton	505 MJ/ton	820 MJ/ton	5120 MJ/ ton [all meat]
Swedishmeats, 2000	Swedishmeats	54 MJ/kg[f]	32 MJ/kg[f]		
Wijlhuizen, 1982	Netherlands	Average: 2500 MJ/ton	3000 MJ/ton		Average: 5500 MJ/ton [all pork meat products] Average: 2155 MJ/ton [sausages]
Zuidema,1993	Netherlands		65,8 MJ/animal		

a: HSCW: Hot standard carcass weight b: Animal with an average weight of 250 Kg c: Animal with an average weight of 90 kg d: DW: Dressed weight e: Ton produced is the sum of all slaughter, deboning/cutting and production of processed meat f: kilogram of boneless meat g: Ton of slaughtered meat, which is considered equal to ton of ready meat h: further processing of pork meat

Table 2. Chosen Reference Specific Energy Consumption Values (SEC_{ref}) by Sector (Average Technologies for Late 90's)

Sector NACE	SEC_{ref} (in primary energy)
151	Beef &lamb: 2.8 MJ/kg of carcass weight equivalent Pork:3.6 MJ/kg carcass weight equivalent Poultry:4.9 MJ/kg carcass weight equivalent Processed meat products: 8.8 MJ/kg output
1532-3	Canned fruit and vegetables: 2.4 MJ/kg output Frozen fruit and vegetables: 7.6 MJ/kg output Dried fruit and vegetables: 14.9 MJ/kg output Fruit juices: 2.4 MJ/kg output
155	Liquid milk: 1.1 MJ/kg output Cheese: 4.3 MJ/kg output Butter: 2.2 MJ/kg output Milk powder: 11.2 MJ/kg output Condensate milk: 2.5 MJ/kg output Whey powder: 8.9 MJ/kg output Other whey products: 1.8 MJ/kg output Ice cream: 2.1 MJ/kg output

dom tend to show a more pessimistic picture than the time series for ISEC. Although the comparison between the results obtained by economic and physical indicators is not straightforward -they do measure different things-, the fact that the trends can be completely opposite in direction (i.e. Figure 3 & 4) is quite a striking and important one, since for non-energy intensive sectors mostly ECI indicators are being used.

The differences between ISEC and ECI indicators originate partially in the fact that the latter does not correct for structural differences which the ISEC does[12]. Studies for mainly energy intensive sectors have shown a trend towards lower energy intensities over time which is generally caused by a combination of higher (physical) energy efficiencies for the processes involved and a trend toward higher value products (higher ratio of price to mass or energy input). Although the production mix in the sectors we studied has indeed shifted towards products with higher value added, this has not meant lower energy intensities. The reason is that, in the food industry, higher value-added products are at the same time more energy intensive to produce (see Table 2). Hence, an increase or a decrease in the production of high value added products strongly influences the energy consumption in this sector. For instance, the steep decrease showed by the ISEC of the British vegetable and fruit sector can be partly explained by the strong decline in frozen products (Figure 7)[13] while the increase on ISECs shown by the meat industry is related to the increasing amount of fast food and ready to eat products in the sector. Moreover, production mix can be particularly sensitive to market forces. For the dairy sector market forces are especially significant in the European Union where the total amount of cow milk produced by country is regulated and

[12] If we want to sort out the effect of structural changes from our ECI, we should use for instance a decomposition methodology, which has as main goal to estimate the energy impact of structural change in production. However, in order to apply this kind of methodology we require more disaggregate data (decomposition at the 2 digit level requires data at the 3 digit level). In this study we are using data at the 3 and 4 digit level, which implies that we need energy and economic data at the 4-5 digit level. For the sectors we studied such data is not published.

[13] The role of a more energy intensive product such as dried fruits and vegetables in the British fruit and vegetable sector is minor: it keep a constant proportion of about 2,5% of the total physical production of the British vegetable and fruit sector between 1990-2000.

hence its distribution within diaries responds to demand (internal and external) and market prices. How much this influences the sectoral energy consumption is still not clear. For instance, the production of energy intensive products such as whey and milk powders is strongly dependent on cheese production: an increase on cheese means an increase on the amounts of whey produced but at the same a decrease on the production of milk powders and butter (there is less liquid milk available for them). Cheese production in turn is determined by market prices and demand.

Figure 1. ISEC Developments for the Meat Sector (NACE 151)

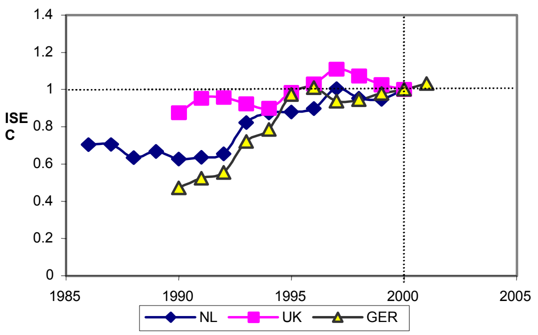


Figure 2. ECI Developments in the Meat Sector (NACE 151)

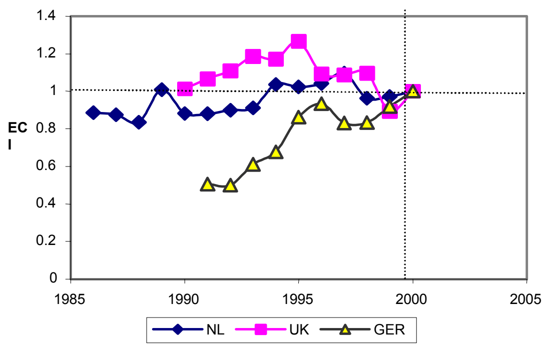


Figure 3. ISEC Developments for the Fruit and Vegetable Processing Industry (NACE 1532-3)

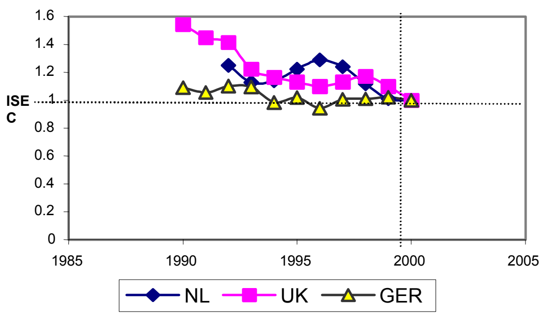


Figure 4. ECI Developments for the Fruit and Vegetable Processing Sector (NACE 1532-3)

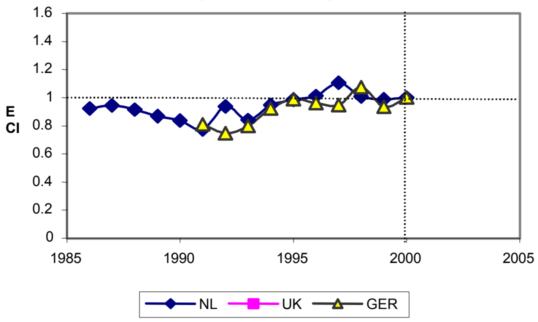


Figure 5. ISEC Developments for the Dairy Sector (NACE 155)

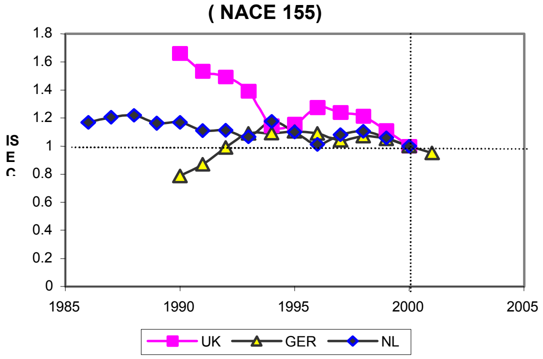
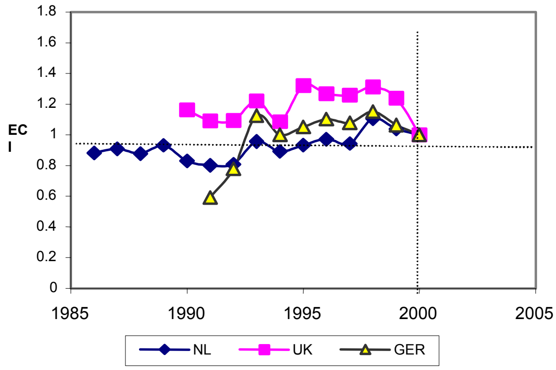
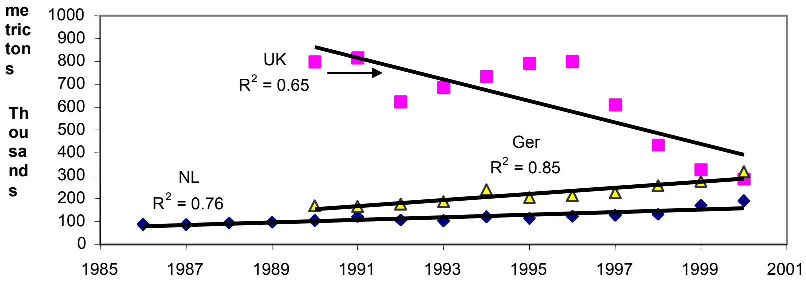


Figure 6. ECI Developements in the Dairy Sector (NACE 155)



Note: ECI plotted are in terms of primery energy per value added.

Figure 7. Production of Frozen Fruits & Vegetables (linear regresion)



Note: the linear equations used in these trends are: 1) for UK: y = -46989x + 9E+07; 2) for Germany: y = 13325x - 3E+0 and 3) for the Netherlands y = 5681.4x - 1E+07

Apart from the increase in frozen and ready to eat products, the increasing demand for food security is another driver for higher energy use in the food industry, especially in the meat sector. Consequences of the meat scandals of the last decade[14] have been shorter batch runs, double heat treatments and increased temperatures for cleaning and sterilization which all contribute to higher specific energy requirements per ton of meat product compared with 10 or 15 years ago. Hence, a combination of increasing production of more energy consuming products and stringent legislation can explain the increasing ISECs found for the meat sector in the last decade.

Instead of depicting primary energy as done in Figure 1-6, it is possible to plot the trends separately for electricity and for direct fuel use. As an example Figures 8 & 9 show the electricity and fuel developments for the dairy industry. It shows an increase in electricity and a decrease in fuel specific energy consumption. One reason for the very pronounced decline in the ISEC trend for fuel consumption in the British dairy sector, compared with the other two countries, is the shift from coal to natural gas which is accompanied by energy efficiency gains[15](in UK, the share of coal of the total final energy consumption decreased from 11% in 1990 to 0.5% by the year 2000[16]). On the other hand, the increase in electricity consumption may be related to automation of industrial production and the introduction of membrane technology in the sector.

Finally, one way of analyzing the robustness of the results is to look at their volatility. While lower volatility is not a guarantee for higher data reliability it makes higher data reliability more likely. An indicator for volatility is the coefficient of variation (ratio of the standard deviation to the mean). Results are shown in Table 3. In general, ISEC indicators tend to be less volatile than ECI indicators

Since the trends showed by ECIs and ISECs can diverge not only in magnitude but also in direction the choice of the indicator is crucial. We can summarize that the following arguments speak for the use of ISECs instead of ECIs for energy analysis: Firstly, it is

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[14] Just to name a few: E.coli in beef trimmings, the use of hormones in cattle, the Bovine Spongiform Encephalopathy (BSE) crisis together with the Creutzfeld-Jakob disease (vCjd) crisis in the UK, the mouth and foot disease, the swine fever in pigs and dioxins in poultry.

[15] The use of a more efficient energy source means less energy input is required to produce the same amount of output.

[16] The shares of coal for the meat and the British fruit and vegetable sector, and for all the Dutch and German sectors studied have been negligible.

obvious that there is a stronger relation between changes in energy efficiency and physical production than with economic values (this is true also for energy intensive sectors); secondly, the effect of production mix is easier to be analysed with ISECs than with ECIs, and thirdly SEC values tend to be less volatile.

Figure 8. SEC for Electricity Consumption in the Dairy Industry

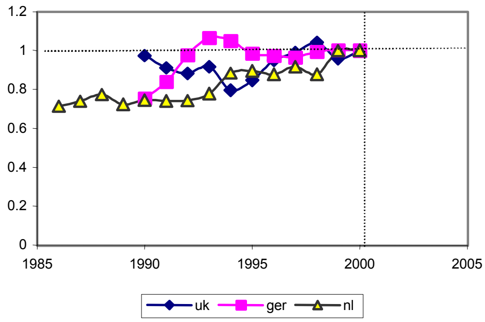

Figure 9. SEC for Fuel Consumption in the Dairy Industry

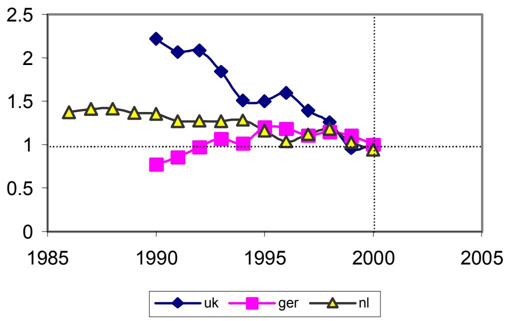

Table 3. Coefficient of Variation on the Energy Intensity Indicators (in %).

Sector	Germany			Netherlands			United Kingdom		
	ISEC	ECI		SEC	ECI		SEC	ECI	
		VA	PV		VA	PV		VA	PV
151	25	25	26	7	8	16	6	9	6
1531-3	4	11	7	9	9	9	16	n.a.	n.a.
155	10	17	12	6	9	7	7	9	9

VA: value added; PV: production value

Conclusion

In this paper the authors presented an overview of energy intensity trends using both physical and economic indicators for three sectors of the food industry. We show that a) although it is a time intensive task, it is feasible to obtain reliable data which allow the development of ISEC trends, and b) differences between trends obtained using ISEC and ECI are important (not only in magnitude but also in direction). While data needed to calculate ECI is easier to gather and calculate, the use of ECI can indeed result in misleading conclusions. Furthermore, ISEC indicators not only make comparability between countries easier, but also allow an easier analysis of intra-industrial structural changes.

It should be added that the literature search for SEC_{ref} showed that there are large differences in the figures published even when they come from the same source (i.e in the dairy sector figures for the same product could differ for a factor of up to 100). This point is especially significant since it indicates that there are interesting energy saving possibilities within the sectors. However, the influence of new regulation in process conditions in the food industry need to be studied in detail in order to fully understand the developments and achieve more detail conclusions about energy efficiency and its implications for future energy savings.

Concluding, our findings indicate the need to focus on the development of SEC indicators for sector specific studies not only for energy intensive sectors but for low energy consumers as well, especially when conclusions are to be derived for policymaking.

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