Sectoral energy intensities in the Austrian Economy in 1995 and 2000 derived from physical Input-Output Analysis

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Abstract

This paper uses a physical input-output approach to analyze the energy efficiency of the Austrian economy in the years 1995 and 2000. I derived physical input-output tables in energy units, which show the amount of energy required to produce the commodities, delivered by each sector of the economy. To do so, I adapted standard methods for the calculation of energetic input-output tables, where sectoral energy balance data of (Statistik Austria, 2003) are available in "ÖNACE 2003" classification. Based on the results of the energetic PIOTs (Physical Input-Output Tables) in 1995 and 2000, the total energy dissipation requirements per unit of final demand in TJ/TJ (Proops, 1977) were calculated for 18 sectors of the Austrian economy. To get a more realistic picture of the environmental pressures, the 18 sectors´absolute energy intensities in TJ, which are also termed as "total energetic output", and the indirect and direct energy dissipation requirements of the households in TJ were also taken into account. In the case of the absolute energy intensities, the sectors "electricity" and "petrochemicals/chemicals" and for the indirect and direct energy dissipation requirements of the households, additionally, the sectors "agriculture/forestry…" , "transport…" and "services…" were most important. On the other hand, the relative energy intensities by Proops (1977) gave surprisingly huge magnitudes of the "construction" sector for both years. The results were compared to those of a different work, where the energy intensities were calculated in TJ/Million ATS. Finally, I pointed out the advantages and inalienability of PIOTs not only as an accounting framework, but also for input-output analysis in TJ/TJ. There, I wanted to make a contribution for a continuation of a methodological debate about applying input-output analysis for an accurate exploration of environmental pressures, which is necessary for decision making in environment policy.

Keywords: Energetic Input-Output Analysis, PIOTs, Energy Intensities, Energy Dissipation Requirements per Unit of Final Demand, Sectoral Energy Balance, ÖNACE 2003

Introduction

In the public discussion, the scenarios of the "*Club of Rome"* (Meadows et al., 2004) on the environmental consequences of physical economic growth seem to be forgotten or at least ignored in many cases. This can be shown by observing pressures of the physical compartments of society (Fischer-Kowalski, Haberl, et al. 1997) on the environment , which e.g. can be done by the macroeconomical use of input-output analysis in physical or mixed unit terms as already often published (Diezenbacher, 2005, Weisz and Duchin, 2005, Hubacek and Giljum, 2003). Based on recent discussions about the usefulness of physical,- extended monetary or mixed unit input-output tables for different purposes, the question about the merits of different methods or sets of methods to trace the physical compartments of society, appeared. It is the goal of this paper to contribute to this discussion.

Watching the public discussion on economic issues, we can observe that money is pervasively used als the traditional measure with which economists trace the flows of goods through the economy. This implies a big influence on the actual public discussion in practical politics - maybe even a kind of "paradigm" concerning decision making of investment activities, economic policy, environmental policy and many other different policy fields. One problem is that money flows beween the sectors in an economy might be completely different from the corresponding physical flows (Diezenbacher, 2005).

Another view on this subject area is the following: Economics can be defined (Hall et al.,1986) as the transformation of natural resources to goods and services to satisfy human needs. This aspect of the economy can be analyzed by the use of energetic input-output analysis, based on an energetic input-output table, which uses energy units instead of money, or more exactly: the energy requirements which are necessary to produce the goods and services in the economy. They illustrate the interaction between society and nature as a part of the physical compartments of society (Fischer-Kowalski, Haberl, et al. 1997). But these physical compartments of society follow different laws than money flows do. For example, the amounts of money that flows between the economic sectors i and j may be completely different from the magnitudes of physical flows, in this case energy flows (Dietzenbacher, 2004). This leads to the perception, that- in the case of focusing only on money flows and physical money related flows- the so called “Societal Metabolism” (Fischer-Kowalski, Haberl, et al. 1997), cannot be precisely determined. This leads to the perception that- against the common view of many economists arguing in Classical Economic Theory - resources are the crucial material wealth for humans and society. Based on these kinds of view, social ecologists observe these processes in economic activities to analyze economic processes and their impacts (pressures) to natural ressources and ecosystems to create approaches for sustainable developement.

In this thesis, I explain the basic assumptions of the energetic input-output model, and show how to create a static energetic input-output table from sectoral ÖNACE 2003 classification- based energy balances (Statistik Austria, 2003) as data sources. Moreover, I calculate the inter - industry energy flows in energetic input-output tables for the years 1995 and 2000. The energetic input-output model is based on the two laws of thermodynamics as conditions of consistency: The first law, the “Law of Conservation of Energy” states that energy cannot be produced or eliminated. The second law is the “Entropy Law”, which states that entropy increases in all energy transformations (Odum, 1999, Proops, 1977)**.** Based on these PIOTs I calculate the energy intensities of the Austrian economic sectors (and sector aggregations), that is “the energy dissipation requirements per unit of energy dissipated directly, to produce final demand” (Proops, 1977) in terajoules per terajoule (TJ/TJ) for these two years. In this context,

I will also calculate the indirect and direct energy dissipation requirements of the “households” sector. Features and advantages of this method by Proops (1977) are demonstrated in the discussion. There, I point out their relevance for the Austrian economy by making a contribution to understand recent states of Austrian economic activities concerning sustainable development.

Methods

The calculation scheme is known as "Energetic Input – Output Model". This may be seen as an extension of traditional methods of input-output analysis used in economic analyses. The originally used monetary Input-Output Model, invented by Wassily Leontief (Leontief, 1936), is a well established macroeconomic method. In the last decades this framework has also been used in environmental sciences for different accounting and analysing purposes, e.g. for calculating material intensities (Katterl and Kratena, 1990, Stahmer, 2000) or estimating land appropriation of international trade (Hubacek and Giljum, 2003).

These input- output relationships can also be expressed as good streams which are usually valued by monetary prices. Here, based on the Energetic Input-Output Model, I calculated an Energetic Input-Output Table, where the good streams are expressed by the energy input which is necessary to produce these goods.

Generally, we may say that "…the Input-output approach permits us to explain the spatial distribution of output and consumption of various goods and services and of their growth or decline … " (Leontief, 1986).

Let us start to give a basic methodological explaination about the basic input-output model in energy units. This will be done by the basic illustrations of input-output relationships by Fleissner et al. (1993), Katterl and Kratena (1990) and Miller and Blair (1985):

The economy, consisting of (n) sectors can be represented by n sector-specific equations in a hierarchical order of statements (Numbers of statements n: For x=1. statement to n statement). This model leads to the basics of the Input-Output model. Generally we may say, the column in direction from bottom to the top represents the sources and magnitudes of sector i´s inputs. But in the process of production, a sector pays also for other items, like labour and capital and others. All of them together are called the (energetic) value added in sector i. Additionally, imported goods are also purchased as inputs by sector i. So these inputs – value added and imports – are often summed as purchases from the so called payments sector.

The z matrix or energy flow matrix, also denoted as the "First Quadrant", represents the purchases from the producing sector, the so called interindustry inputs- or in other words- the energetic output to entermediate demand. It is also possible that a sector uses parts of its output as an input for production. These flows are called intraindustry flows.

If we record the magnitudes of the interindustry flows table from the row point of view from the left to the right, they show each sector´s outputs. This leads to the name "Input-Output Table" and means the source of input-output analysis.

The matrix of Final Demand, also called the "Second Quadrant", usually consists of purchases (vectors) of: consumers (households), government (federal, state and local), (private) investment, purchases, and sales abroad (exports). In an algebraic notation, this means:

(Equ.0.1) $Y = C + I + G + E$. In our energetic input-output model, we have to add the energy conversion losses and a vector for energy residues to the final demand side to meet the condition of consistency based on the thermodynamic laws (Odum 1999). So, this matrix is called "Energetic Final Demand", which means the economic energetic output to final demand or the energetic use of the gross domestic product, GDP. But this proper energy statistical partition has not been explored successfully and satisfactory yet.

On the other hand, the payments sector, known as the "Third Quadrant", usually consists of the following payment component parts: labour services, denoted as L, purchases of imported inputs, M, and of all other value added items like government services (paid for in taxes), capital (interest payments), land (rental payments), entrepreneurchip (profit) etc.- these so called “other payments” are grouped together and denoted as N. So we get the sum of the payments per sector, termed as $W = L + N + M$. In our energetic input-output model, we will denote L+M as "Value Added" and M as "Transformed Imports", whereas W can be denoted as the energetic distribution of GDP.

With Z as the energy flow matrix, we get the total economic output, denoted as

(Equ.2) $X = Z + L + N + M$ for the input-side and $X = Z + C + I + G + E$ for the output-side. When we equate the two expressions for X, we get the form:

$L + N + M = C + I + G + E$ (Equ.1)

The left term of equation 1 represents Gross National Income (the total factor payments in the economy) and right the Gross National Product.

A fundamental assumption in Input-Output calculations is that the interindustry flows from i to j (e.g. in a year-period) depend exclusively on the total output of sector j for this time period. The production function shows linear curves, which reflects the assumption of constant returns to scale.

After observing the elements z_{ij} from the interindustry deleveries (“First Quadrant” of the input-output table), we can form the ratio of input to output, z_{ij}/X_j , which leads us to the so called Matrix of "Input-Output Coefficients" , (Direct) Input Coefficients or Technical Coefficients.

$a_{ij} = z_{ij}/X_j$ (Eq.2)

For the Leontieff Model, we can replace each z_{ij} by aij Xj (for each sector) and put them on the left term as shown for the first row in the next equation:
$X = (I – A)^{-1} Y$ (Eq.3)

Creating an Energetic Input-Output Table from Sectoral Energy Balance Data

Here we use the method described by Fleissner et al. (1993): The Austrian sectoral Energy Balance consists of 11 indicators, 4 on the make side and 5 on the use side which are shown in *Figure 6* in the Appendix. These Indicators are illustrated disaggregated by energy sources in terajoules (TJ) and denoted by numbers in square brackets.
Here, there are two possibilities calculating the Gross Energy Consumption [10] in the Austrian Economy. On the one hand, we may define it by the make side, on the other hand, by the use side. Equating the two terms for indicator [10], the Input at Ultimate Consumers [11] can be calculated :
:
[11]= [10]-[5]-[6]-[7] +[8]-[9] (Eq.4)

The first step towards an Input-output table is to create an energy balance in the form of the make-use scheme. There are two possibilities für calculating the Gross Energy Requirement q: on the one hand from the make side as the sum of the energy balance indicators [1], [2], [3], –[6] and [8], and on the other hand from the use side as the sum of –[4], [5], [7], [9] and [11].

In the next step we can construct the Make Matrix V as the sum of the indicators with column numbers [1] and [8]. The sum of the transposed vectors of the indicators with the column numbers [7] and [11] gives the Use Matrix U. One fact is that the gross energy requirement q, including raw- and derived energy requirement, therefore contains double counts. Here, we get the energy balance in the Make- Use scheme.

<u>Figure 1 :</u> Energy Balance in the Make- Use Scheme (Modified from Fleissner et al., 1993)

	Use Matrix: **U** = $[7]^T+[11]^T$	**c**	**Final Demand** **f= -** [4]+[5]+[9]	**Gross Energy Requirement** **q**
Make Matrix : **V** = [1]+[8]				**Output X**
$\mathbf{V_c^T}$				$\mathbf{X_c}$
r^T= [2]+[3]-[6]				
	$\mathbf{w^T}$	$\mathbf{w_c}$		
qT	$\mathbf{X^T}$	$\mathbf{X_c}$		

This table shows the version of the make-use scheme with an explicitly constituted Private Consumers Sector c, which is called an "Open Model" and is the usual form of input-ouput tables. To get this form, we have to partition the matrices U and V. This means that we have to add the last row of the matrix V to the vector r^T and the last column of the matrix U to the final demand matrix f. Indeed we denominate the new make- and use matrices also as V and U. The other variables mean f as "Final Demand", w as "Value Added", X as the "Total (Energy) Output" and r as a residue.

Here, the gross energy requirement q can be calculated as the sum of f and the product of U and the 1-column vector "1". The transformed Gross Output Vector X^T can be calculated as the sum of 1^T U and w^T or in the other way X results from the product of matrix V and 1.

The Input-Output Table

To get an Input- Output Table, first we have to multiply the matrix V by the matrix $<q>^{-1}$ (the inverse of the diagonal matrix which has the vector q on its diagonal and zeros elsewhere) which gives the so called "Market-Share Matrix" (Fleissner et al., 1993) D. The matrix B can be constructed as the product of U and $<X>^{-1}$. By the multiplication of D and B we get the Energetic Input-Output Coefficient Matrix A_{aa}: This leads us to the first row of the input-output table, shown in Equation 5, whereas we can see the complete tables in Table 3 and Table 4 in the Appendix.

$$A_{aa} <X> + D\ c + D\ f = X \tag{5}$$

Figure 2: Input- Output Energy Balance based on (Fleissner et al., 1993):

A <X>	**D c**	**D f**	**X**
Transformed Imports etc. $V_c^T <q>^{-1} U$ + $r^T <q>^{-1} U$			
Value Added : w^T			
X^T			

Advantages of this Model

A feature of the physical input output model as an accounting framework to measure environmental pressures is its ability to follow all inputs and outputs along the full supply chain (Duchin, 2004). There is also a direct physical counterpart to the monetary models´ "value added" which accumulates all factors of production like labor and capital, also including physical items. For this model it means exactly that energy is also a factor of production (Duchin, 2004).

Calculation of the Austrian Economic Sectors´ Energy Intesities

The calculation of the “Energy dissipation requirements per unit of energy dissipated directly, to produce final demand” **e** (Proops 1977) in TJ/TJ can be done as shown in Equation 6 by multiplying the 1 column vector by the Leontief Inverse:

$$e = 1\ (I - A)^{-1} \tag{6}$$

This term relates the vector of total energetic output in the economy to the vector of energetic final demand. The equation means in other words: Which total energy dissipation requirements (TJ) are necessary to produce 1 TJ of energetic final demand? These total energy dissipation requirements quantify the total amount of energy dissipated in the economy to produce the goods of this particular sector. As we can see in Equation 6, these energy intensities in TJ/TJ are the column sums of the Leontief Inverse, which reflect the input direction and the rasing side of the input-output table and therefore the term “energy dissipation reqirements”.

To get more information about the environmental pressures, we also calculate the magnitudes of the total energetic output, which can be interpreted as the absolute energy intensities in TJ in a year (see Figure 4). Moreover, we calculate the indirect and direct energy dissipation requirements “e_c” of the “households” sector in 1995 and 2000 by multiplying the vector “e” of energy intensities (Proops, 1977) by the diagonalized matrix of the “households” vector “<D c>” as we can see in Equation 7.

$$e_c = e \langle D\ c \rangle \qquad (7)$$

In the next section we analyze the energy dissipation requirements to produce a unit of final demand for the years 1995 and 2000 in TJ/TJ as shown in Figure 3. The classification of the economic sectors is explained in Table 5 in the Appendix.

Material and Methodology

Data sources and data preparation

For calculating the energetic input-output table we used the sectoral energy balance data 1995 and 2000 by Statistik Austria (2003) and the energy conversion data (Statistik Austria, 2003), which are based on the “ÖNACE, 2003” classification (Statistik Austria, 2003). These data vere abailable in partially aggregated and disaggregated form in 24 sector-aggragates. For correctly calculating the input-output table, I had to avoid zero values in the energy requirement- and output vectors. Therefore I had to create a data set, consisting of 18 sector-aggregates and 32 energy sources. So, I merged the sectors “rail traffic”, “other land transport”, “inland water transport”, “air transport” and “pipeline transport” to the sector “transport…”. I also aggregated the fuels “bitumen”, “lubricants”, and “other oil products” to the fuel “other oil products”, as well as the fuels “blast furnace gas” and “generator gas” to “blast furnace gas”. The calculated energetic input-output tables for the years 1995 and 2000 and the table of the classification of the economic sectors (Statistik Austria, 2003) is explained in the Appendix.

For the year 2000, a problem was that no data were available for the energy- balance-indicator “stock changes of consumers” [4] because of sparse data availability due to energy market liberalisation (Statistik Austria, 2005). This indicator is necessary for calculating the final demand vector, which consists of “non-energetic use” [9] plus “exports” [5] minus “stock changes of consumers” [4]. Here, the the data of the indicator [4] was not separate available for the year 2000, only combined with the data of the indicator “Stock Changes of Producers and Importers” [3]. In order to close this data gap, I used the latest separate available data of this indicator of the year 1997. This was the only possibility to calculate the input-output table for 2000.

Therefore the energetic input-output table 2000 is not consistent in its input direction along the columns. That means that “Value added” and “Imports” do not have the correct magnitudes. Along the rows (output direction) the table is consistent. There we should interpret the results of the year 2000 carefully. For calculation of the “other final demand” in 1995 the applicable data of the indicator “stock changes of consumers” [4] only was available in the “Statistische Nachrichten 2/1998” (Statistik Austria, 1998).

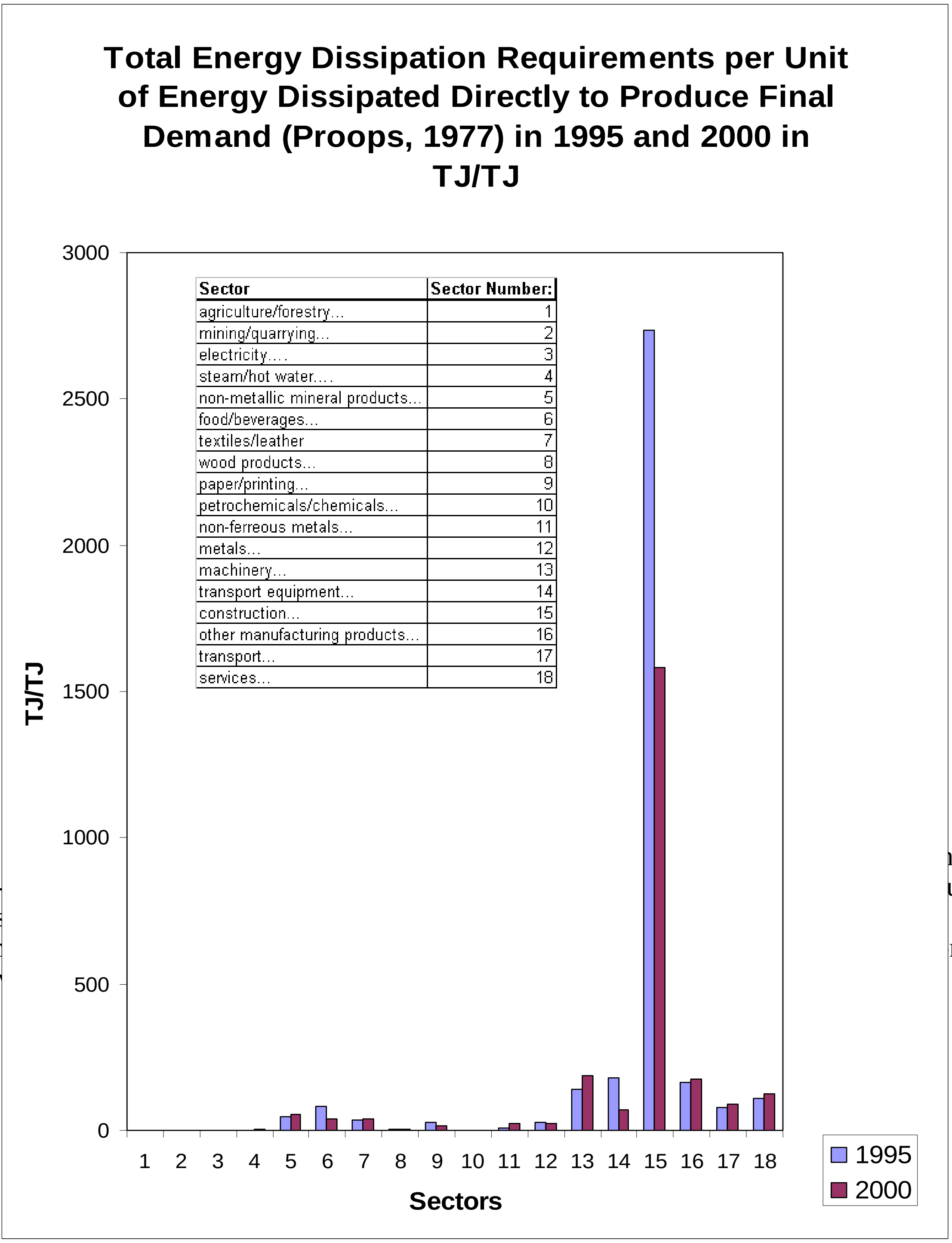
Generally we have to denote, that it is also important to pay attention to some

aspects like shadow economy and data blurring (Statistik Austria, 2005), which should be taken into account while interpreting the results of both years.

Results

The results of calculation of the energy dissipation requirements per unit of energy dissipated directly to produce final demand by Poops (1977) are demonstrated in Figure 3:

Figure 3: Austrian Economy´s Energy Intensities in (TJ/TJ) in 1995 and 2000



Sector	Sector Number:
agriculture/forestry...	1
mining/quarrying...	2
electricity....	3
steam/hot water....	4
non-metallic mineral products...	5
food/beverages...	6
textiles/leather	7
wood products...	8
paper/printing...	9
petrochemicals/chemicals...	10
non-ferreous metals...	11
metals...	12
machinery...	13
transport equipment...	14
construction...	15
other manufacturing products...	16
transport...	17
services...	18

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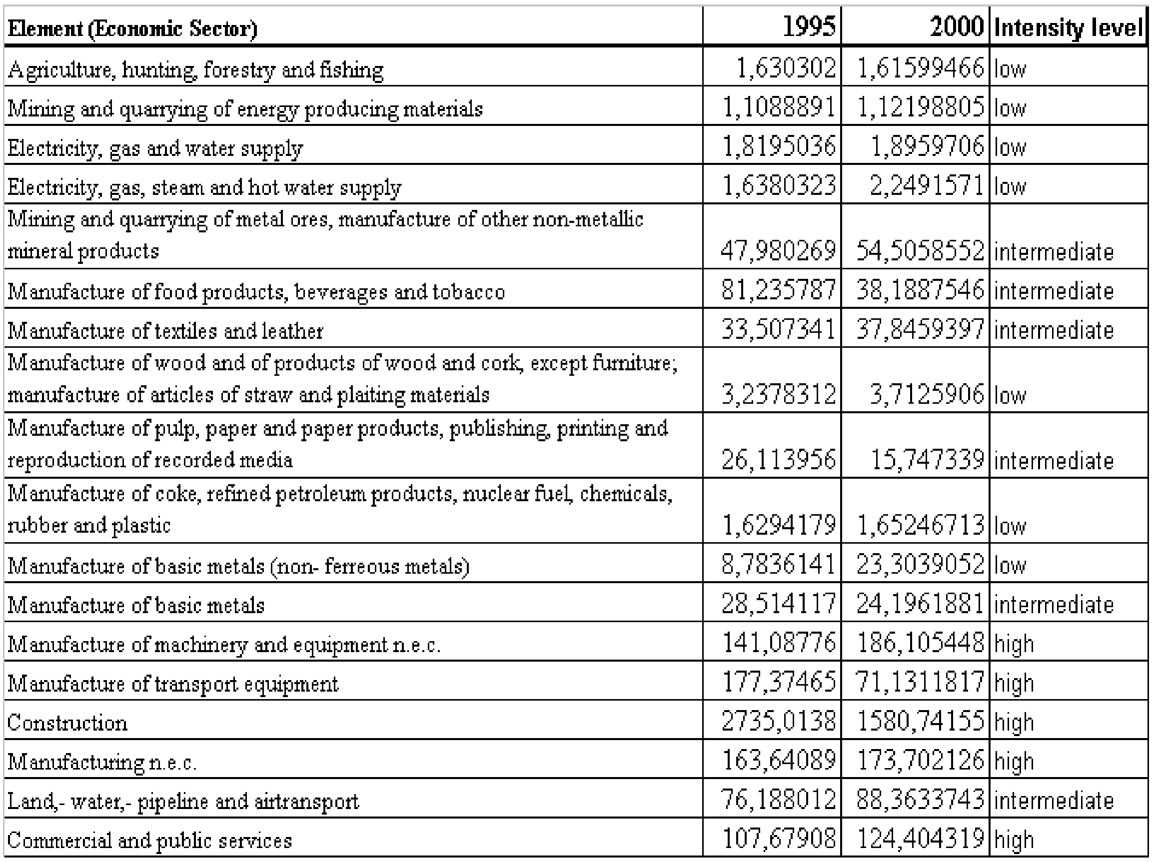
<u>Table 1:</u> Austrian Economies´ Energy Intensities in TJ/TJ divided into low,- intermediate,- and high Magnitudes of Energy Intensities.

to produce a unit of final demand: show "Agriculture, hunting, forestry and fishing",



Element (Economic Sector)	**1995**	**2000**	**Intensity level**
Agriculture, hunting, forestry and fishing	1,630302	1,61599466	low
Mining and quarrying of energy producing materials	1,1088891	1,12198805	low
Electricity, gas and water supply	1,8195036	1,8959706	low
Electricity, gas, steam and hot water supply	1,6380323	2,2491571	low
Mining and quarrying of metal ores, manufacture of other non-metallic mineral products	47,980269	54,5058552	intermediate
Manufacture of food products, beverages and tobacco	81,235787	38,1887546	intermediate
Manufacture of textiles and leather	33,507341	37,8459397	intermediate
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	3,2378312	3,7125906	low
Manufacture of pulp, paper and paper products, publishing, printing and reproduction of recorded media	26,113956	15,747339	intermediate
Manufacture of coke, refined petroleum products, nuclear fuel, chemicals, rubber and plastic	1,6294179	1,65246713	low
Manufacture of basic metals (non- ferreous metals)	8,7836141	23,3039052	low
Manufacture of basic metals	28,514117	24,1961881	intermediate
Manufacture of machinery and equipment n.e.c.	141,08776	186,105448	high
Manufacture of transport equipment	177,37465	71,1311817	high
Construction	2735,0138	1580,74155	high
Manufacturing n.e.c.	163,64089	173,702126	high
Land,- water,- pipeline and airtransport	76,188012	88,3633743	intermediate
Commercial and public services	107,67908	124,404319	high

The following sectors assembled in Table 1 have low energy dissipation requirements:

"Mining and quarrying of energy producing minerals", "Electricity-, gas- and water supply" and "Manufacture of coke, refined petroleum products, nuclear fuel and chemicals", which also show almost similar magnitudes in 1995 and 2000. The sectors "Electricity-, gas-, steam and hot water supply" and "Manufacture of wood and of products of wood, except furniture..." show slightly increasing magnitudes, whereas the sector "Manufacture of basic matals (non-iron metals)" shows an increase of 165%.

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The following examples illustrate intermediate magnitudes of energy dissipation requirements per unit of final demand. Following sectors have slightly increasing intensities from the year 1995 to 2000: "Mining and quarrying of metal ores, ...", "Manufacture of textiles and leather" and "Land,- water,- pipeline- and airtransport". Decreasing energy intensities couldbe observed in the following cases: The energy intensitiy of the sector "Manufacture of food products, beverages and tobacco" by 53%, that of "Manufacture of pulp, paper and paper products,.." by 40% and that of "Manufacture of basic metals" by 15%.

The highest energy intensity of all sectors was found to be that of the "Construcion" sector (Figure 3). This value surpasses that of the next highest magnitude ("Manufacture of transport equipment") by a factor of 15,4 in 1995. In 2000 the energy intensity of this sector was 8,5 times higher than that of "Manufacture of machinery and equipment n.e.c."

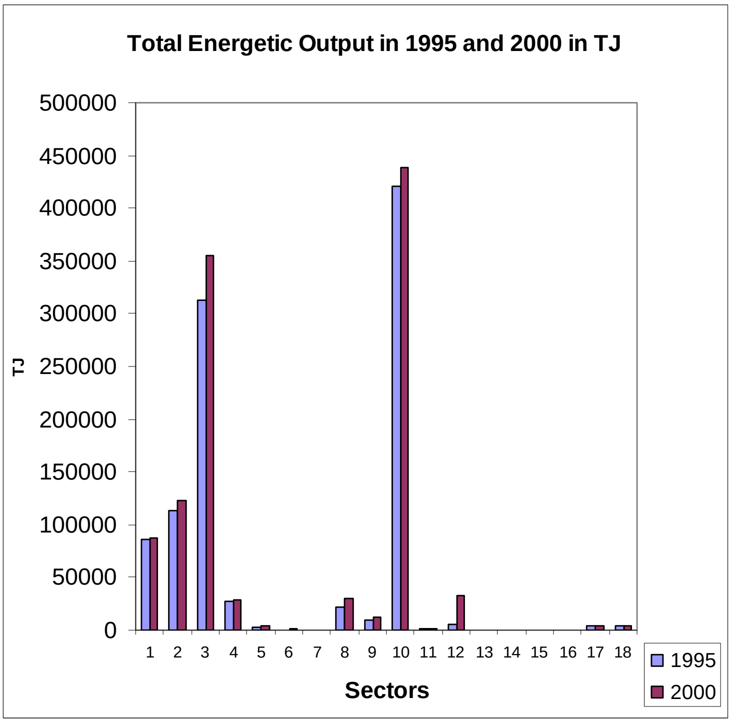
These exceedingly high energy intensities of this sector are maybe not entirely correct as calculated here, because of possible accounting problems which should be solved in future research. The huge value of 2735,01 TJ/TJ in 1995 decreases to 1850,74 TJ/TJ in 2000 (minus 42%). While these values could to some extent be due to data accounting problems, I beleave it to be highly unlikely that theese inconsistencies fundamentally distort my results.

The next smaller value in the year 1995 can be found to be that of the sector “Manufacture of transport equipment” (177,37 TJ/TJ) a value that decreases by 60% in 2000. The energy intensity of “Manufacture of machinery and equipment n.e.c.” increases from 1995 to 2000 by 32%. The energy intensity of the sector “Manufacturing n.e.c.” increases by 6%, whereas the amount of the sector “Commercial and public services” increases by 16%.

Only the sectors “Agriculture, hunting, forestry and fishing”, “Manufacture of food products, beverages and tobacco”, “Manufacture of pulp, paper and paper products,..”, “Manufacture of basic metals”, “Manufacture of transport equipment” and “Construction” experienced a decrease of total energy dissipation requirements to produce one TJ of final demand.

To get more information about the pressures to the environment, we also have to consider other aspects like the total energetic output as shown in Table 3, Table 4 and Figure 4.

Figure 4:

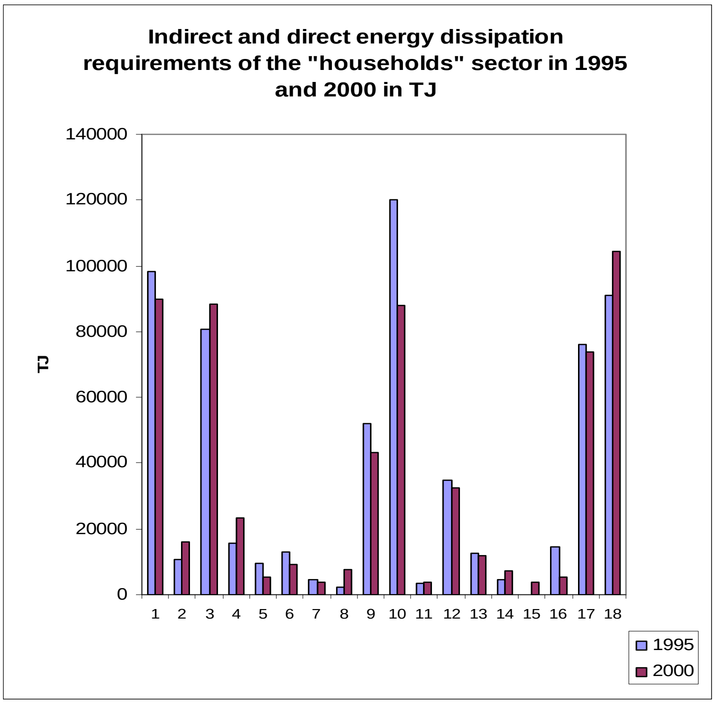


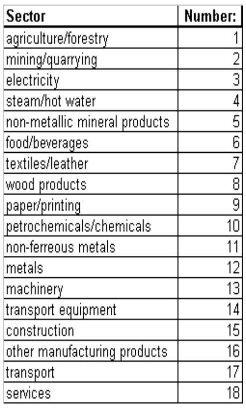
Sector	Sector Number:
agriculture/forestry...	1
mining/quarrying...	2
electricity....	3
steam/hot water....	4
non-metallic mineral products...	5
food/beverages...	6
textiles/leather	7
wood products...	8
paper/printing...	9
petrochemicals/chemicals...	10
non-ferreous metals...	11
metals...	12
machinery...	13
transport equipment...	14
construction...	15
other manufacturing products...	16
transport...	17
services...	18

Here, we can group the results into low, intermediate and high magnitudes of total energetic output. The sectors: “non-metallic mineral products”, “food/beverages”, “textiles/leather”, “non-ferreous metals”, “machinery”, “transport equipment”, “construction”, “other manufacturing products”, “transport” and “services” have low values. Intermediate magnitudes can be observed with the sectors: “agriculture/forestry”, “mining/quarrying”, “steam/hot water”, “wood products”, “paper/printing” and “metals”. The highest total energetic output could be found with the sectors “electricity” with 312506,264 TJ in 1995 and 354640,342 TJ in 2000 and “petrochemicals/chemicals” with 421126,099 TJ and 438378,668 TJ for both years.

For the inderect and direct energy dissipation requirements of the “households”, see Figure 5 and Table 2 in the Appendix.

Figure 5:





Sector	Number:
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petrochemicals/chemicals	10
non-ferreous metals	11
metals	12
machinery	13
transport equipment	14
construction	15
other manufacturing products	16
transport	17
services	18

Here (Fig.5) following sectors have the lowest values: “mining/quarrying”, “steam/hot water”, “non- metallic mineral products”, “food/beverages”, “textiles/leather”, “wood products”, “non- ferreous metals”, “machinery”, “transport equipment”, “construction” and “other manufacturing products”. Intermediate values could be found the sectors “paper/printing” and “metals”. The highest magnitudes of the indirect and direct energy dissipation requirements can be observed with the sectors “agriculture/forestry” with 98146,64 TJ in 1995 and 89944,3 TJ in 2000, “electricity” (80844,25 TJ and 88377,99 TJ), “petrochemicals/chemicals” (120224,48 TJ and 87831,03 TJ), “transport” (76151,48 TJ and 73852,66 TJ) and “services” (91042,95 TJ and 104590,53 TJ).

Discussion and Conclusions

First, specific aspects of the calculation of the energetic input-output tables are to be discussed, as it turned out that the colum sums of the “households” sector in the input-output tables are different compared to the corresponcing results in the use matrices.

Another aspect is the structure of “Value added” in the energetic input-output tables. They have negative values in some producing- and some service sectors, which does not seem to be realistic. This means, that “Value Added” cannot be interpreted as “domestic extraction”or “direct energy input” of the so called energy flow accounting (Schandl et al, 2002). Another aspect is that the energetic make- and use matrices, input-output tables and the following calculations in this paper include double counts, which could be avoided by assigning the primary energetic inputs to the energetic final demand. Theese problems cannot be solved in this paper and will be an issue for future research.

The following discussion of the results should be generally seen under the aspect of the energy efficiency of the Austrian economy. As mentioned in the “Results” section, only 6 economic sectors had a decreasing energy intensity by Proops (1977) in the period from 1995 to 2000. This implies that the remaining 12 of 18 ecomomic sectors had increasing relative and absolute energy intensities. If we may interpret this as a kind of “trend”, comparing the results of the two years, it is difficult to find a consistent tendency towards the aim of energy efficiency and sustainable development often voiced in the Austrian public political discussion.

The energy intensities by Proops (1977) of the “construction” sector, with 2735,01 TJ in 1995 and 1850,74 TJ in 2000 to produce 1 TJ of energetic final demand, was extremely high, compared to the other sectors. Physical input-output analysis reveals the direct and indirect resource requirements of producing the goods in a specific sector. This means, that the system boundaries are the same for all sectors. Apart from the possible, but probably not decisive data problems, these results are many times higher than the next highest magnitudes and need to be explained. The energy used in the construction sector mainly consists of primary- and derived fossil fuels. This can be seen in the Use Matrices of both years in Tables 7 and 9 in the Appendix, where the fuels used by the sectors are apparent.

In this context, we have to note the lowest absolute energy intensities, referred to as total energetic output with 9,95 TJ and 21,94 TJ for both years. In Tables 3 and 4 in the Appendix we can also observe the lowest magnitudes for the sales to final demand. Here, the fact that the energy intensities by Proops (1977) relate the total energy dissipation requirements in the economy to the output to final demand explains its´low absolute but high relative energy intensities by Proops (1977).

Other possible and also likely reasons for the results of the construction sector can be found in the calculations of Kratena and Wüger (2005): they find an annual increase of final demand´s energetic “Input at Ultimate Consumers” [11] at the construction sector of 10,5% for the time period 1990 until 2003. As we have seen above, this indicator of the Austrian Energy Balance is relevant for calculating the matrix of technical coefficients A – and as a consequence – for these handled energy intensities. This could explain the relatively high amounts of the construction sector´s total energy dissipation requirements to produce one unit of final demand for the years 1995 and 2000.

The “construction” sector probably has a long “supply chain” of energy dissipation requirements and it does not produce energy, which could also explain these high magnitudes. Generally this sector includes different construction activities, for example the construcion of buildings and road construction. This analysis suggests, that the Austrian policy should undertake efforts in energy saving activities as a main part of economic policy. For example, in the case of construcion, suitable measures have been proposed by Redle and Baccini (1998). It is also likely that the huge amounts of the "construction" sector are also caused by road construction activities due to Austrians transport policy as generally agreed in the public discussion.

Because of the high amount of fossil fuels in the construction sector (as demonstrated in the make- and use tables of both years- see Tables 6, 7, 8 and 9 in the Appendix) and increasing road construction activities, for Austrian sustainable policy, it is urgently necessary to investigate rather in local rail traffic than in road construction.

To detect more of the environmental pressures, we also have to consider other aspects like the total energetic output as an absolute energy intensity and the indirect and direct energy dissipation requirements of the "households" sector.

In the case of the total energetic output, the sectors "electricity" and "petrochemicals/chemicals" show the highest figures as demonstrated in section 4. Of course, this contributes to the Austrian economy´s dependence on fossil fuels. In this context, a more general dimension of Austrian´s energy efficiency becomes apparent by observing the "Austrian Energy Flow Figure" of the year 2000 (E.V:A., 2002), where the energy losses take 38,7% of the energy balance indicator [11] "Input to Ultimate Consumers". Here, an important aspect becomes obvious. The conversion input of a power station of any kind (kinetic energy of water power, calorific energy of fossil fuels, biomass) leads to an conversion output of electric energy. This energy transformation process causes conversion losses and an increase of entropy. On the one hand, theese lossed result from the transformation process itself, which can be explained by the "Entropy Law", for example transformator losses and ambient energy. But the energy of the conversion output has to be transported to final consumers to get useful energy. This process also causes energy losses, for example because of the electric resistance of transmission lines. In Austria, the energy supply is mainly organised centrally, which leads to significant energy losses caused by electricity transport.

Watching the indirect and direct energy dissipation requirements, as a kind of "ecological rucksack" of the "households" sector, we can observe that the sectors "agriculture/forestry…", "electricity…", "petrochemicals/chemicals…", "transport…" and "services…" reveal the highest values. Again, this implies Austrian economy´s depency on fossil fuels. The high values in the sector "agriculture/forestry…" can be explained by the huge amount of fossil fuels used for agricultural production in Austria. The high value in the "transport" sector implies Austria´s unsustainable mobility consumer behavior, whereas the high magnitude in the "service" sector is unlikely to be caused by data aggregation of some service sectors. It also reveals that the increase of services in the Austrian economic structure does not mean a movement towards sustainable development. These results should also demonstrate the imperative of energy efficiency in Austrian economic policy.

Now, let´s turn to another empirical example provided by Zandl (2005), who used a hybrid physical input-output model to get energy intensities in mixed units (TJ/million ATS-Terajoules per million Austrian Schillings). This part of Zandl´s results (the energy intensity of domestic production 1995) shows completely different magnitudes. They also have a completely different relation of the energy intensity magnitudes for each sector, when we compare Figure 3 and accordingly Figure 7 in the Appendix. The reason is, of course, that Zandl uses different methods for a different purpose. Nevertheless one might be tempted to use Zandl´s results to call for investments in the construction sector as energy- efficient means to promote economic growth. While the merits of input-output calculations in hybrid units, which are well illustrated in Weisz and Duchin (2005) and Zandl (2005) remain uncontested, my results suggest it to be necessary to draw also on the corresponding results in TJ/TJ by Proops (1977), in order to base decisions in sustainable and environmental policy and can only in combination be used to give solid advice to environmental and austainability policy.

A recent work shows the advantages of extended monetary models or models in mixed units (Weisz and Duchin, 2005), leading to an conclusion that input-output tables should be rather measured in mixed units and not in a single physical unit. They remain on their conviction that .”…input-output coefficient matrices should be measured in mixed units, not in a single, aggregated mass unit nor in a single, aggregated monetary unit but rather the most appropriate unit for measuring the characteristic output of each sector…” (Weisz and Duchin, 2005). Representative examples for Austrian economy´s energy efficiency can be found in two ways. On the one hand, the highest absolute energy intensities which we can seed at the sectors “electricity” and “petrochemicals/chemicals”. This reflects Austrian economy´s dependence on fossil fuels and its centrally, organised electricity sector. On the other hand, we obtained the surprising results of the energy intensities of the construction sector for both years, 1995 and 2000. Here we can observe a main aspect in free market economies that seems to be forgotten, to which Dietzenbacher (2005) calls attention: the fact that a specific sector uses a large monetary amount of a given product, but it might use only a small physical amount of the same product, and for another sector, this could be the other way round. So, "...the production structure in physical terms may be radically different from the structure in monetary terms." (Dietzenbacher, 2005). This claim is substantiated by my comparison of the results derived here for the year 1995 with the energy intensities calculated in mixed units by TJ/ Million ATS (Zandl 2005), which of course yielded fundamentally different results. Like shown in this case of calculating energy intensities in TJ/TJ, I conclude that physical input-output tables also should be used for input-output analysis in physical units and not only for accounting purposes. This reflects the physical realities of the physical compartments of societies and surely its pressures to the environment. I argue, that its indespensable that (in any case) additionally the corresponding physical input-output models should be taken into account for decision-making in environmental policies. This fact is getting obvious considering the longest necessary shift of Austrian´s economy towards sustainable development.

Zusammenfassung (Summary in German)

Der Begriff "Nachhaltige Entwicklung" samt den unterschiedlichen Auffassungen darüber ist mittlerweile ein nicht unbedeutender Begriff in der öffentlichen Diskussion geworden. Vergleicht man jedoch die umweltrelevanten Auswirkungen unseres auf Wachstum basierten Wirtschaftssystems, so scheinen die modellierten Szenarien des "Club of Rome" (Meadows et al., 2004) in Vergessenheit geraten zu sein. Dies lieferte Anlass, die Umwelteinflüsse unseres Wirtschaftssystems möglichst wahrheitsgemäß zu erfassen. Die so genannten "Physischen Kompartimente der Gesellschaft" (Fischer- Kowalski, Haberl et al., 1997) können als Schnittstelle zwischen dem sozio-ökonomschen und dem natürlichen System angesehen angesehen und beispielsweise mit physischen makroökonomischen Input-Output Analysen ermittelt werden.

Nachdem über die unterschiedlichen Formen von Input-Output Tabellen, in physischen oder hybriden Einheiten, samt deren Anwendungen in der umweltwissenschaftlichen Literatur bereits ausführlich berichtet wurde (Diezenbacher, 2005, Duchin und Weisz, 2005, Hubacek und Giljum, 2003), stellte sich die Frage nach eventuellen Vorteilen unterschiedlicher Berechnungsmethoden. So sollte in dieser Arbeit die Energieintensitäten volkswirtschaftlicher Sektoren in TJ/TJ nach Proops (1977) untersucht und eventuelle Vorteile dieser Methode erläutert werden.

Da bekanntlich üblicherweise Geld zur Darstellung der Transaktionen in der Volkswirtschaft verwendet wird, liegt es nahe, diese Einheit auch zur Berechnung von Umwelteinflüssen heranzuziehen. Dabei tritt jedoch ein Problem auf, welchens von Dietzenbacher (2005) bereits erläutert wurde: Da beispielsweise der Geldfluss zwischen zwei Sektoren innerhalb der Volkswirtschaft klein, der physische Fluss jedoch sehr groß sein kann, verhalten sich Geldflüsse nach grundlegend unterschiedlichen Regeln als die entsprechenden Material- und Energieflüsse.

Einen weiteren Aspekt liefert dabei Hall et al. (1986) und definiert Volkswirtschaft als die Wissenschaft über die Transformation natürlicher Ressourcen zu für Menschen nutzbare Gütern und Dienstleistungen. Eine Möglichkeit zur Darstellung dieser Ressourcenflüsse innerhalb einer Volkswirtschaft ist die Darstellung über Input-Output Analysen. In dieser Arbeit sollten daher die energetischen Input-Output Tabellen der Jahre 1995 und 2000 für die österreichische Volkswirtschaft errechnet werden. Aufbauend auf diesen Ergebnissen, wurden die sektoralen Energieintensitäten in rein physischen Einheiten (TJ/TJ), d.h. der gesamte erforderliche Energieverbrauch zur Erstellung eines Terajoules der Endnachfrage, ermittelt.

Die Berechnung der Tabellen basierte auf der Methodik von Fleissner et al. (1993), Katterl und Kratena (1990) und Miller and Blair (1985). Dabei sollte auch ein Beitrag für eine Standardberechnung energiestatistisch auf ÖNACE 2003 (Statistik Austria, 2003) basierender Daten für energetische Input-Output Tabellen geleistet werden. Die in dieser Form vorliegenden sektoralen Energiebilanzdaten bildeten die Grundlage zur Berechnung einer Energiebilanz im so genannten "Make-Use" Schema, woraus schliesslich die energetischen Input-Output Tabellen der beiden Jahre ermittelt wurden. Zur Berechnung der Energieintensitäten wurde die Methode von Proops (1977) durch Prä- Multiplikation der Leontief-Inversen mit dem Eins- Zeilenvektor (Bildung der Spaltensummen) herangezogen. Ein Problem bildete dabei die unzufriedenstellende Datenlage vom Jahr 2000, indem der Energiebilanz- Indikator "Lagerveränderungen der Verbraucher" unter anderem aus Gründen der Energiewirtschaftsliberalisierung (Statistik Austria, 2005) nicht verfügbar war. Da diese Daten lediglich bis 1997 erhältlich waren, verwendete ich aus wirtschaftsstrukturellen Überlegungen diese zeitlich nächstgelegenen verfügbaren Daten.

Hinsichtlich einer Art “Trend” in der Energieintensität, zeigten die errechneten Ergebnisse im Vergleich 1995 und 2000 lediglich sinkende Energieintensitätswerte für die Sektoren: ”Landwirtschaft“, “Nahrungs,- und Genussmittel”, “Papier”, “Eisen- und Stahlerzeugung”, “Fahrzeugbau” und der Sektor “Bau”. Letzterer zeigte jedoch trotz eines sinkenden Werts im Jahr 2000 überraschend hohe relative Energieintensitäten (trotz den niedrigsten absoluten Energieintensitäten) im Vergleich zu den anderen Sektoren. Die Werte lagen bei 2735,01 TJ/TJ für 1995 und 1850,74 TJ/TJ im Jahr 2000. Der Wert für 1995 betrug ein 15,4 faches des nächst niedrigeren Werts für den Sektor “Fahrzeugbau”, jener für 2000 ein 8,5 faches des nächst gelegenen Wertes für den “Maschinenbau”-Sektor. Vergleichsweise niedrige Werte dieser relativen Energieintensitäten wiesen lediglich die primären Sektoren “Landwirtschaft”, “Bergbau”, “Elektrizitätsversorgung” und “Fernwärmeversorgung” sowie die produzierenden Sektoren “Holzverarbeitung”, “Chemie und Petrochemie” und “Nichteisen Metalle” auf.

Für die hohen Energieintensitäten des Bausektors können mehrere Ursachen in Betracht gezogen werden. Grundsätzlich sind dabei mögliche energiestatistische Probleme bei der Datenzusammenführung zu beachten, wodurch in Wirklichkeit die Werte niedriger anzunehmen sind. Hinsichtlich der Begründung der hohen Energieintensitäten im Bausektor weisen einerseits Kratena und Wüger (2005) auf die jährliche Erhöhung des Energiebilanz Indikators “Einsatz bei Letztverbrauchern” [11] um 10,5% von 1990 bis 2003 hin. Aus diesem Indikator wird die Matrix A der Input-Output Koeffizienten herangezogen, wodurch das Zustandekommen der hohen Werte zum Teil erklärbar wäre. Andererseits können diese auch durch eine relativ lange und energieintensive “Energieverbrauchskette” sowie durch relativ geringe Lieferungen an die Endnachfrage erklärt werden. Da es die österreichische Verkehrspolitik derzeit noch nicht geschafft hat, den Großteil des Güter- und Personenverkehrs zu dezimieren bzw. “von der Strasse auf die Schiene zu bringen”, ist ein Einfluss auf die hohen Werte durch intensive Straßenbauaktivitäten sehr wahrscheinlich. Darüber hinaus besteht der Energieverbrauch des Bausektors überwiegend aus fossilen Energieträgern, wie aus den Use Tabellen (siehe Anhang) beider Jahre zu entnehmen ist.

Ein grundsätzlich zu betrachtender Aspekt hinsichtlich der Energieeffizienz der österreichischen Volkswirtschaft wird wie folgt ersichtlich. Zur umfangreicheren Erfassung der Umwelteinflüsse werden auch die absoluten Energieintensitäten (entspricht dem energetischen Output) untersucht. Dabei weisen die Sektoren „Elektrizitätsversorgung“ mit 312506 TJ im Jahr 1995 und 354640 TJ im Jahr 2000, sowie „Petrochemie/Chemie“ mit 421126 TJ und 438378 TJ für beide Jahre die höchsten absoluten Energieintensitäten auf. Die höchsten Werte für die indirekten und direkten energetischen Vorleistungen des privaten Endkonsums traten bei den Sektoren „Landwirtschaft/Forstwirtschaft“, „Elektrizitätsversorgung“, „Petrochemie/Chemie“, „Verkehr“ und „Öffentliche und private Dienstleistungen“ auf. Diese Ergebnisse spiegeln Energieeffizienzprobleme im Verkehr und den Dienstleistungen bzw. die primäre Abhängigkeit der österreichischen Wirtschaft von fossilen Energieträgern in diesen beiden Jahren wieder, welches auch anhand der Rolle der Umwandlungsverluste ersichtlich wird. Diese betrugen im Jahr 2000 38,7% des Energetischen Endverbrauchs. Umwandlungsverluste werden zu einem beachtlichen Teil durch elektrische Leitungsverluste des Transports per Überlandleitung verursacht. Diese zentralistisch, marktwirtschaftliche Form der wirtschaftlichen Organisation führt zwangsläufig zu jährlichen Absatzsteigerungen, wodurch ein Bemühen der österreichischen Politik in Richtung Energieeffizienz im Sinne nachhaltiger Entwicklung nicht sehr glaubwürdig erscheint. Zur Lösung des Problems im Sinne nachhaltiger Entwicklung, erscheint eine alternative wirtschaftliche Organisation des Energiesektors unumgänglich. Um eine bessere Energieeffizienz zu erreichen, sollte dieser dezentral, gemeinwirtschaftlich und bedarfsorientiert organisiert sein.

Einen weiteren Aspekt liefert der Vergleich der Energieintensitätswerte für 1995 mit jenen von Zandl (2005). Aufbauend auf einer Input-Output Tabelle in hybriden Einheiten, berechnete Zandl Energieintensitäten für die Sektoren der österreichischen Volkswirtschaft in TJ/ Millionen ATS. Seine Ergebnisse lieferten besonders hinsichtlich des Bausektors vollkommen unterschiedliche und vergleichsweise niedrige Werte, wie aus Abbildung 7 im "Anhang" zu entnehmen ist.

Duchin und Weisz (2005) erläuterten die Vorteile von Input-Output Tabellen in hybriden Einheiten. Diese dienen als Grundlage zur Berechnung von Energieintensitäten in Energieeinheit/Geldeinheit, wobei die beiden Autoren die Verwendung von Koeffizienten Matrizen in hybriden Einheiten bei Input-Output Analysen empfohlen haben. Anhand dieses Beispiels wird jedoch die Notwendigkeit ersichtlich, für umweltpolitische Entscheidungen nicht nur Energieintensitäten in Energieeinheit pro Geldeinheit zu berücksichtigen, sondern auch die jeweiligen Intensitäten in Energieeinheit/Energieeinheit. Mit letzterer Methode können möglicherweise die physischen Kompartimente der Gesellschaft realistischer erfasst werden, da Geld- und physischen Flüsse vollkommen unterschiedlichen Charakteristika aufweisen.

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Appendix

Figure 6:
Austrian Energy Balance by (Fleissner, Böhme et al., 1993)
INDIKATOR

Make Side	**Column**
Domestic Generation of Raw Energy	[1]
Imports of Raw-and Derived Energy	[2]
Stock Changes of Producers and Importers (+ = adit from the stock, - = disposal to the stock)	[3]
Stock Changes of Consumers (+ = adit from the stock, - = disposal to the stock)	[4]
Use Side	
Exports of Raw- and Dirived Energy	[5]
Own Consumption and Losses	[6]
Conversion Input	[7]
Conversion Output	[8]
Non- Energetic Consumption	[9]
Gross Energetic Consumption	[10]
Input to Ultimate Consumers	[11]

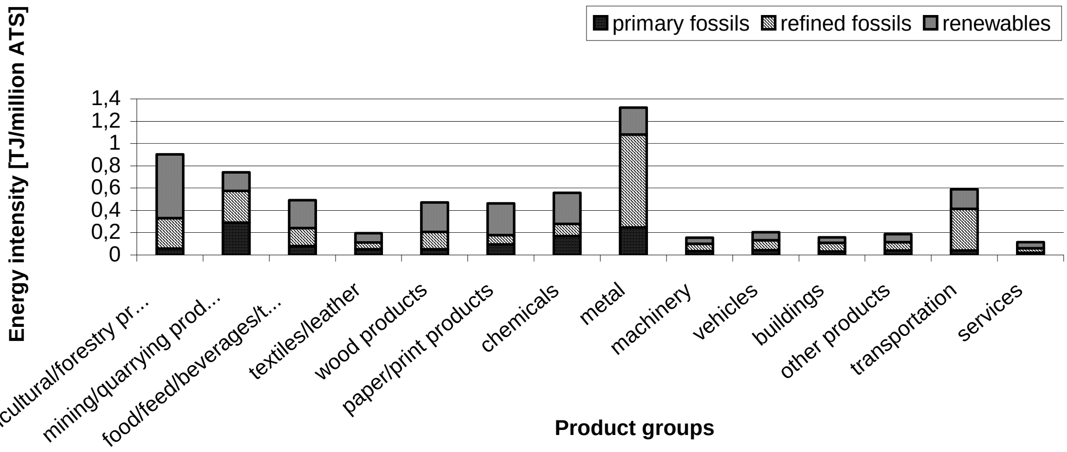

Fig. 7: Gradient of energy intensity (y-axis) in relation to industrial sectors.

Table 2:

Indirect and direct energy dissipation requirements of the "households" sector in TJ		
	1995	**2000**
agriculture/forestry…	98146,64329	89944,30295
mining/quarrying…	10830,52431	16010,53895
electricity….	80844,25034	88377,99106
steam/hot water….	15555,11241	23429,62245
non-metallic mineral products…	9455,419409	5287,481527
food/beverages…	12907,21236	9303,271769
textiles/leather	4781,130628	3637,576439
wood products…	2327,426229	7597,921853
paper/printing…	51861,80327	43351,59661
petrochemicals/chemicals...	120224,4762	87831,03252
non-ferreous metals…	3586,470618	3680,350944
metals…	34823,23146	32378,33664
machinery…	12459,34439	11670,67102
transport equipment…	4657,922437	7166,074817
construction…	0	4000,367796
other manufacturing products…	14565,08027	5318,921028
transport…	76151,48032	73852,66459
services…	91042,95143	104590,5341