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Changes in Consumer Energy Intensity in Malaysia

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ABSTRACT

This paper proposes an IO-SDA model based on Hybrid input-output table, to identify the source of changes in the energy intensity, energy input and consumption level in the Malaysian household. This study is conducted in two stages: first, to identify the multiplier (energy intensities) by using the Hybrid input-output analysis, and second, to identify the sources of change in the Malaysian household energy consumption (energy and non-energy based products) for the periods 1991 to 2000, 2000 to 2005, and 1991 to 2005 by using IO-SDA model. The major finding of this study is that total household energy consumption has increased rapidly, mainly because of an increase in private consumption by household and increase in energy use in the production sector for consumer goods. From this finding, government and policy-makers should give more attention to energy consumption by promoting renewable energy resources to avoid shortage of energy supply in the future. Currently, the Malaysian economy is greatly dependent on non-renewable energy.

Keywords: Energy intensity, Input-output, Hybrid unit, Consumption and Renewable energy

INTRODUCTION

Households are the main consumers of goods and services produced by the production sector, and household not only consumes direct energy from electricity and petroleum products but also indirect energy embodied in consumer goods such as food, clothing and footwear, household equipment and all services which are produced by production activities. In this study, energy used in production activities such as manufacturing, commerce, agriculture, and transportation are considered as indirect energy consumption by household.

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The energy costs for electricity and petroleum products are crucial items in the monthly total expenditure of Malaysian household and they differ considerably with different energy-based products used at home. In 2005, Malaysian households spent 3.5% of their total expenditure on electricity and petroleum products (direct energy consumption) compared to 2.9% in 1998/99 as stated in the Household Expenditure Survey (HES) of the Department of Statistic (DOS).

Energy consumption by household (direct and indirect) grew at 6.9% compared to GDP and population which grew at only 5.4 and 2.2% respectively. Meanwhile, the energy supply grew at 6.1% from 1991 to 2006. Thus, in the future there will be shortage of energy supply if the energy consumption continuously increases at this rate because Malaysian economy is greatly dependent on non-renewable energy such as natural gas, coal and fuel fossils. The demand for non-renewable energy is expected to grow rapidly throughout the world, particularly in developing countries like Malaysia, where rapid economic growth continues growing (Mohamed and Lee, 2006).

In order to avoid the occurrence of this problem the government and researchers should seek other alternatives (renewable resources) that can replace the existing natural resources. Therefore, this study aims to identify the causes of increase in the direct (energy-based products) and indirect (non-energy based products) energy consumption through the products they use. When households consume less energy intensive product, energy can be conserved. But the trend in the total household energy consumption in Malaysia increases sharply with some variations in the pattern of consumption of energy and non-energy based products during the period of study due to positive economic growth and increase in population as well as household income.

The annual growth rate of GDP and total energy primary use are 5.7% and 6.8%, respectively in the 1990s with 2.2% growth rate in population as shown in Table 1. The total primary energy supply (TPES) in Malaysia increased from 5-10 Mtoe between 1991 and 2006. However, the economic growth slowed down from 1996 to 2000 due to economic crisis of 1997 in Asian region. The trend in energy use for Malaysia is relatively similar to the trends found in many developing countries as studied by Park and Hi-Chun (2007) for Korea and Pachauri and Spreng (2002) for India.

The high growth rates of the Malaysian economy have a large impact on energy consumption in terms of direct or indirect household energy consumption. In the 1990's, petroleum production and consumption increased tremendously together with increase in hydroelectric and coal consumption to generate electricity for the nation. The trends of energy consumption and GDP have moved in tandem. A large amount of investment on electrical infrastructure and automobile usage has caused

primary energy consumption to reach approximately 27.23 million tonnes and electricity generation to almost 6 Mtoe in 2000 and this trend will continue to rise.

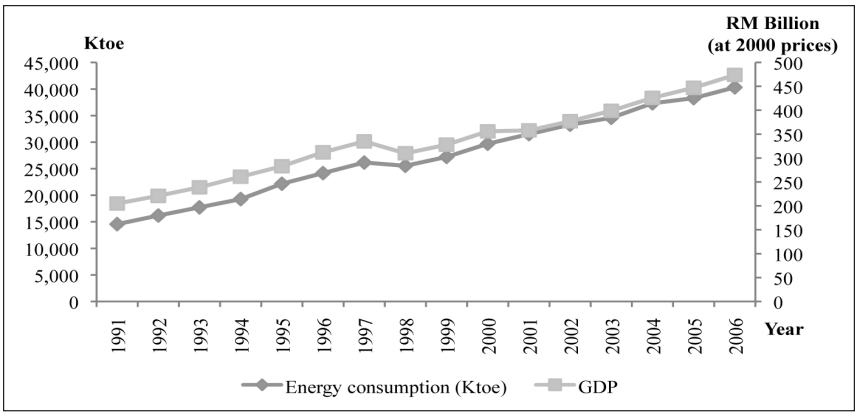
Table 1 Income, population and energy in Malaysia

				Annual growth rates in %		
	1991	**2000**	**2006**	**1991-2000**	**2000-2006**	**1991-2006**
GDP in Ringgit Malaysia at 2000 constant prices (Million)	205,312	356,401	474,391	5.7	4.2	5.4
Population in million (000 people)	18,986	23,418	26,840	2.1	2	2.2
Total primary energy supply (Ktoe)	26,335	50,710	67,878	6.8	4.3	6.1
(Per capita TPES in Ktoe)	1.39	2.17	2.53	4.6	2.2	3.8
Total household primary energy use (Ktoe)	13,961	28,705	40,318	7.5	5	6.9
(Per capita total household energy in Ktoe)	0.74	1.23	1.5	5.2	2.9	4.6
Direct household primary energy use (Ktoe)	843	1,650	2,364	6.9	5.3	6.7
(Per capita direct household energy in Ktoe)	0.04	0.07	0.09	4.7	3.2	4.4

Sources: Department of Statistic Malaysia and own calculation

The consumption of energy increased tremendously from 1991-1997 as shown in Figure 1. The Malaysian economy is growing at 5.7% annually and will continue at this rate for many years. Moreover, political stability and development will continue to drive the economy forward. The Malaysian Ministry of Energy estimates that to provide for Malaysia's energy demands, 70.3 billion ringgits will be required over the next 10-15 years: 60% of it is to be allotted to energy generation and the remainder to transmission and distribution of energy. Such high economic growth and increasing infrastructure and demand will likely send the total energy use to well over 100 Mtoe by 2020.

Rising urbanization and industrialization in the economy require large amount of energy in the country. The switch towards public transportation in urban areas will potentially cause a decline in the percentage of usage of energy by the transportation sector. The energy use by residential and commercial sector remains relatively constant occupying only 13%-14% of the economy. The industrial sector contribution could increase to 50% of the nation's economy. The Tenth Malaysian Plan (10MP, 2011-2015) sets the goals and standards for the nation's



Source: Malaysia Energy Centre, 2006

Figure 1 The total energy consumption and GDP in Malaysia from 1991 to 2006.

future to become a totally developed country by the year 2020. The target is to raise the living standard of rural and urban people with high income as well as to reduce poverty, and finally to emphasize energy security and economic efficiency incorporating environmental and social considerations.

The objective of this study is to identify the sources of change in the energy intensity, energy input and consumption structure in Malaysia from 1991 to 2005 by using the hybrid input–output tables of 40 sector classification. The initial step in our analysis is the quantification of total household energy consumption. The next step involves identifying the sources of change in household energy consumption between 1991 to 2000 and 2000 to 2005 and 1991 to 2005 using IO-SDA. The results and findings regarding the sources of changes will be discussed. Lastly, conclusions and policy implication will be presented.

LITERATURE REVIEW

Some studies on energy consumption have been carried out by few researchers for developed and developing economies, such as those of Ramcharran (1990), Wu (1997), Huang (1993), Paul and Bhattacharya (2004), Shiu and Lam (2004), Yoo (2005) and Montalvo and Marta (2005). Except for Wu (1997) and Montalvo and Marta (2005), the other researchers focused on the relationship between aggregated energy consumption and economic growth. The relationship between consumer spending patterns and economic growth in China was the theme of Wu's (1997) work by employing the household survey data. Wu examined the level of consumption

by looking at the components of the goods and services consumed. Baxter et al. (1985) provided a new approach to household energy consumption and indicated the significance of several factors not measured or found significant in empirical studies. In Malaysia, Ang (2008) concluded that Malaysia is an energy dependent country due to its rapid industrialization that requires high and more efficient energy consumption. Mahlia (2002) found that the power stations for electricity generation in Malaysia have a large impact on the environment. This is supported by Jaafar et.al (2008) and Amin et.al (2009) who concluded that electricity generation that is greatly dependent on coal will cause pollution and this could be avoided by shifting from non-renewable energy source to renewable energy sources.

The first part of this study uses hybrid Leontief analysis of a sector within the input output analysis to identify the total energy consumption (household and production side). This analysis can be applied to all sectors regardless of the length and complexity of their production processes. However, as the number of sectors in a Malaysian input–output table is limited, for instance, to 120 by 120 sectors, product-specific energy requirements cannot be considered (Wright, 1974; Bullard and Herendeen, 1975; Denton, 1975; Pick and Becker, 1975; Peet et al., 1985; Peet, 1993; Lenzen, 1998; Pachauri, 2002; Pachauri and Spreng, 2002; Vringer et al., 2006; Miller and Blair, 2009).

The hybrid analysis seeks to take advantage of both methods. In other words, the process analysis is used to calculate energy requirement of energy intensive products and the input–output analysis is applied to calculate that of other products. Suh et al. (2004) classifies hybrid approaches in three groups, e.g. tiered hybrid analysis, input–output based analysis and integrated hybrid analysis. Vringer and Blok (1995a, 2000) used the so-called tiered hybrid energy analysis to calculate the total energy requirement of Dutch households. They determined the energy intensities of about 350 basic consumption categories using the expenditure of 2767 representative households from The Netherlands Household Expenditure Survey of 1990. Although they analyzed changes in consumption patterns of Dutch households in the period from 1948 to 1996, information on energy intensities of only one year (1990) was available. This method is intensive and requires detailed data (van Engelenberg et al., 1994; Vringer and Blok, 1995a, 2000; Vringer et al., 2006).

A total of 40-sector classification in the input-output tables for Malaysia for the years 1991, 2000 and 2005 published by the DOS in current price is employed for this purpose. The 40 sectors consist of 37 non-energy sectors and 3 energy sectors. The hybrid analysis determines the energy requirement and energy intensity of the consumption items. For this study, to determine the total energy requirement of a household is by combining energy intensity with expenditure by household as done by Park and Hi-chun (2007) for Korean households energy requirement.

METHODOLOGY

Total Household Energy Consumption

This study converts the monetary unit input–output tables into energy input–output tables with the use of energy prices (Miller and Blair, 2009). First, average energy prices are calculated using information on energy use by energy final use of the input–output tables. Average energy prices are calculated as ratios of energy use (inputs) to the total output (intermediate plus final demand) by energy final use, expressed in Ktoe/RM, in Equation 1.

$$P_i = e_i/(X_i\text{-}m_i)\,(\text{measured in Ktoe/RM}) \quad (1)$$

where P_i is the price of energy sector 1, e.g. price of petroleum product, is used to quantify 40 intermediate inputs of petroleum product to produce goods of 40 sectors. The price differential exists within the intermediate demand for final energy use (see Lenzen (1998)). e_i is energy use or energy consumption, X_i is the production sector, m_i is the imports

$$t_{1,j} . P_1 = te_{1,j} \quad (2)$$

where $t_{1,j}$ are the intermediate outputs of sector 1 to be used for the production of goods of sectors 1 to 40, $te_{1,j}$ the intermediate energy inputs, (energy input–output tables) are computed as in Equation 2, it is easy to estimate direct energy intensities of individual sectors. Direct energy intensities are calculated as ratios of direct energy expenditure converted in energy terms to total inputs (intermediate inputs and value added inputs), also expressed in Ktoe/RM in Equation (3)

$$d_1 = e_{i,\,1}/X_i \,(\text{measured in Ktoe/RM}) \quad (3)$$

where d_1 (direct) is the direct energy intensity of sector 1. Total or cumulative energy intensities can be then computed by multiplying them with the hybrid Leontief inverse $(1\text{-}A)^{-1*}$ to obtain the multiplier or energy intensity (Ktoe/RM), and to compute the household energy consumption we multiply them with the private consumption (C) of the corresponding input–output table as expressed in

$$r = d_1 . (1\text{-}A)^{-1*} . C \quad (4)$$

where r is the total energy consumption by household (direct and indirect).

Sources of Changes in Energy Consumption

The second part of this study uses the IO-SDA model to analyze the sources of change in energy consumption. The model is based on the concept of "decomposition analysis", which is based on the I-O table and is well known in previous studies of sources of economic growth. SDA is generally used in energy studies such as Hoekstra and Van den Bergh (2003) that summarized elementary differences between various decomposition techniques.

SDA uses a full input-output table because it is able to include energy, technological and final demand effects. In general, SDA uses sectoral different time data to simplify which factors contributed the highest or the lowest changes to the total change for a certain variable. For example, increases in energy can be identified with increased levels of consumption. This new methodology has been accepted since the early 1970s by Leontief and Ford (1971). The primary rationale of SDA components is to split an identity into its components. This part can be as simple as the three-part basic form such as technological change, mix and level or as complex as desired.

Lin & Polenske (1995) identified the sources of change in the technology of energy input and the non-energy input on the embodied energy requirements by analyzing the effects of final demand and production technology changes on China's energy use structure (see Bullard & Herendeen, 1975, 1978) by applying IO-SDA model. Wier (1998) identified the effect of the changes of production technology (input-mix, emission factors, fuel mix, energy intensity) and the composition and level of final demand between 1966 and 1988 on the embodied emissions (CO_2 , NOx , SO_2). Gale (1995) estimated the effects of the changes in trade liberalization (imports and exports) and domestic production on embodied carbon dioxide emissions. However, this study is different because it only focuses on the sources of energy consumption changes by household (direct and indirect) by identifying energy intensity for each sector.

Reformulating Equation (4), changes in the household energy consumption can be attributed to changes in the factors **d (energy intensity), L (technical coefficient), and C (private consumption)**. Changes in the Leontief inverse (technical coefficient) are more difficult to understand, even though changes in the energy intensity and input coefficient matrix can be interpreted as technological changes. Therefore, the Leontief inverses of periods *1 and 0* can be rewritten as follows:

$$\mathbf{L_1 = L_1 (I - a_0) L_0 = L_0 (I - a_0) L_1} \quad (5a)$$

and

$$\mathbf{L_0 = L_1 (I - a_1) L_0 = L_0 (I - a_1) L_1} \quad (5b)$$

With these equations, the first polar decomposition expresses the relationship as

$$\Delta \mathbf{r} = (\Delta \mathbf{d})\, \mathbf{L}_1\, \mathbf{C}_1 + \mathbf{d}_0\, \mathbf{L}_0\, \Delta \mathbf{a}\, \mathbf{L}_1\, \mathbf{C}_1 + \mathbf{d}_0\, \mathbf{L}_0\, \Delta \mathbf{C}_1 \quad (5c)$$

and the second polar decomposition becomes

$$\Delta \mathbf{r} = (\Delta \mathbf{d})\, \mathbf{L}_0\, \mathbf{C}_0 + \mathbf{d}_1\, \mathbf{L}_1\, \Delta \mathbf{a}\, \mathbf{L}_0\, \mathbf{C}_0 + \mathbf{d}_1\, \mathbf{L}_1\, \Delta \mathbf{C}_0 \quad (5d)$$

The average of these two methods yields the final equation of the decomposition method that will be used in the analysis:

$$\Delta \mathbf{r} = \tfrac{1}{2}\, (\Delta \mathbf{d})\, (\mathbf{L}_1 \mathbf{C}_1 + \mathbf{L}_0\, \mathbf{C}_0) + \quad (6a)$$

(Change in energy intensity)

$$\tfrac{1}{2}\, (\mathbf{d}_1\, \mathbf{L}_1\, \Delta \mathbf{a}\, \mathbf{L}_0\, \mathbf{C}_0 + \mathbf{d}_0\, \mathbf{L}_0\, \Delta \mathbf{a}\, \mathbf{L}_1 \mathbf{C}_1) + \quad (6b)$$

(Change in technical coefficient)

$$\tfrac{1}{2}\, (\mathbf{d}_1\, \mathbf{L}_1\, \Delta \mathbf{C}_0 + \mathbf{d}_0\, \mathbf{L}_0\, \Delta \mathbf{C}_1) \quad (6c)$$

(Change in consumption level)

Equations 6a to 6c express the changes in energy use as a result of three factors: changes in energy intensity (energy coefficients), changes in input coefficients (technical coefficient), and changes in the composition of consumption (excluding other final demand-government, investment and export) which is the method used by Heon and Mulder, (2002).

The first factor is the effects of technological change that changed the direct energy intensity per unit of output in (6a) while the second factor is the effects of technological change that changed the products required as inputs in the production activities of a certain sector in (6b). It reflects how much the energy intensity decreases due to a shift from energy intensive inputs to energy extensive inputs. The last factor is the effects on the energy intensity due to changes in the composition of consumption structure (6c). If consumption of energy extensive inputs increases relative to demand for energy intensive products, it shows a decrease in the total energy requirement, even if consumption of both products increases, since it only takes into account the composition of the consumption level.

This study uses the 40-sector classification input-output tables for Malaysia in current prices for the years 1991 and 2005 published by the Department of Statistic (DOS). The 40 sectors consist of 37 non-energy sectors and 3 energy sectors which are petroleum products (motor petrol, gasoline, diesel, kerosene, LPG, refinery gas, non-energy, aviation fuel and fuel oil), coal and natural gas, and electricity. Input–output tables in constant deflated prices provided by the DOS are used to calculate

energy intensities to make the values for different years comparable. There are 37 sector classification input output tables for the years 1991, 2000 and 2005 in 2000 constant prices. This study compares energy intensities at constant deflated prices of only two years, e.g. 1991, 2000 and 2005. The reason is that the DOS publishes the input–output tables of three years with the same sector classification.

Energy consumption data for 1991, 2000 and 2005 are obtained from the National Energy Balance of Malaysia Energy Centre (PTM, 2006) and the Ministry of Energy, Water and Communications Malaysia. However, these data are not detailed enough to construct a 3 (energy sectors) x 40 energy input–output table which is needed to calculate 40 direct energy intensities. The Malaysian energy statistics gives information on energy consumption of only the following sectors: agriculture, transport, industrial, commercial, household and non-energy use sectors.

FINDINGS AND RESULT

Total Energy Consumption of Household

The results show that from 1991 to 2000, the total energy consumption by households has increased by about 52 percent compared to 34 percent in the 2000-2005 period. Therefore, consumption (private consumption) by households increased about 133 percent from 1991 to 2000 compared to 62 percent from 2000 to 2005 (input-output table). In 2005, household consumption on energy and non-energy based products constituted almost half of the change in total consumption in 2000 (62 percent out of 133 percent), when perhaps energy consumption was relatively high during this period compared with 1991 to 2000.

In greater detail, much energy is used in goods and services due to rising private consumption. The income growth, improvement in living standards, increasing amount of electrical and electronic consumption, construction and private transportation, all determined the energy consumption. In the case of energy consumption in Malaysia as shown in Table 2, sectors of the economy have different impact on consumption and the share of total output over 1991 to 2005. In the energy-based products group, households used the most electricity in 1991 (about 21 percent) of the total energy consumption while petroleum products used the most (about 15 percent) of the total energy consumption in 2000. But in 2005 electricity was the most used (about 28 percent) of the total energy consumption. The rise in electricity demand from 1999 was about 65.5 percent due to the high economic growth rate of Malaysia. In the non-energy based products group ”manufacture of foods” is the most energy intensive sector with respect to energy consumption accounting for 13 percent and 14 percent of total energy consumption in 1991 and 2000, respectively, but in 2005 the ”wholesale and retail trade” sector was the

most energy intensive sector accounting for 12 percent. Other services sector is not considered as the most energy intensive sector because it is a combination of many service sectors such restaurant, hotel, health, defense, etc.

Table 2 Energy consumption by products consumed by household (in toe)

Sector	1991		2000		2005	
Energy based products		%		%		%
Petroleum product	347,762	7	1,157,507	15	166,784	2
Electricity	1,062,714	21	583,456	8	2,814,460	28
Non-energy based products						
Agriculture	337,043	7	774,668	10	119,586	1
Mining	-	-	-	-	259	0
Manufacture of oils and fats	99,298	2	488,597	6	20,095	0
Manufacture of other foods	560,268	11	902,909	12	367,815	4
Manufacture of yarns and cloth	44,763	1	175,260	2	13,761	0
Manufacture of other textiles	7,790	0	35,352	0	35,435	0
Manufacture of wearing apparels	31,690	1	90,865	1	22,401	0
Manufacture of wood product	78,204	2	184,873	2	175,983	2
Manufacture of industries chemical	22,860	0	16,409	0	2,425	0
Manufacture of paints and lacquers	6,726	0	10,922	0	2,207	0
Manufacture of drugs and medicines	1,365	0	9,469	0	13,379	0
Manufacture of soap etc.	17,501	0	30,049	0	27	0
Other chemical industries	8,877	0	2,378	0	115,997	1
Manufacture of others products	229,654	5	243,052	3	444,071	4
Other non-metallic manufacture	319	0	-	-	37	0
Manufacture of cement etc.	187	0	60	0	-	-
Iron and steel industries	-	-	-	-	-	-
Manufacture of non-ferrous metals	2,625	0	-	-	-	-
Structural metal industries	17,874	0	5,575	0	-	-
Other metal industries	22,765	0	2,329	0	79,680	1
Manufacture of industries machinery	11,443	0	480	0	39,517	0
Manufacture of household machinery	7,227	0	10,925	0	4,042	0

Table 2 (Cont'd)

Manufacture of radio, television etc.	37,005	1	3,927	0	84,013	1
Man. of electric appliances etc.	16,804	0	10,838	0	9	0
Man. of other electric machinery	6,405	0	1,923	0	69,326	1
Manufacture of motor vehicle	119,553	2	149,376	2	1,159,228	11
Building, construction	34,528	1	36,455	0	614,207	6
Wholesale and retail trade	447,457	9	49,954	1	1,203,233	12
Transport	418,688	8	568,754	7	591,651	6
Communication	64,920	1	212,183	3	301,289	3
Real estate	130,617	3	411,961	5	759,240	7
Business services	95,176	2	178,294	2	572,111	6
Education	17,960	0	46,238	1	114,561	1
Private non-profit institution	24,143	0	13,678	0	2,986	0
Recreation	48,360	1	124,499	2	77,087	1
Recycling	2,754	0	0	0	-	-
Others services	629,418	13	1,104,760	14	236,778	2
Total Energy Consumption	**5,012,742**	**100**	**7,637,976**	**100**	**10,223,681**	**100**

Sources: computed from Equation (4)

The impact of household consumption on non-energy based products for nine years (1991-2000) was obviously relatively similar in other sectors, viz. Other services (13 to 14 percent), Manufacture of other foods (11 to 12 percent), Transportation (8 to 7 percent), Agriculture (7 to 10 percent) and Other products (5 to 3 percent). However, the impact of household consumption on energy based products changed drastically in 2005 particularly on Manufacture of motor vehicles (11 percent), Wholesale and retail trade (12 percent), Construction (6 percent) and Real estate (7 percent). It is very useful to note that amongst the 40 sectors, the 10 leading energy consuming sectors accounted for 61, 66 and 61 percent of the total energy for 1991, 2000 and 2005, respectively.

The share of energy consumption for electricity, manufacturing and services sector have increased from 2000 to 2005 as shown in Table 2 due to energy inefficiency and less public awareness on excesses in energy consumption. Another reason that induced the increases in household energy consumption is shifts in the structure of industries from agro-based products to manufacturing and services sector.

Sources of Change in Energy Consumption

Total changes in energy consumption

In the period of 1991-2000, as shown by the total effects in the final column in Table 3, the total energy requirements had increased by 2.6 Mtoe within 9 years compared to the total energy requirement for the period of 2000-2005 which had greatly increased by 2.5 Mtoe within 5 years. Thus, within the period of 1991-2005, the total energy requirement had increased by 5.2 Mtoe.

Table 3 Total of composition of energy consumption by household (ktoe)

Period	Δdirect energy intensity	ΔTechnical coefficient	Δ in consumption	Total
Sub-period, 1991 - 2000	-2,815	560	4,880	2,625
Sub-period, 2000 - 2005	-2,136	2,320	2,401	2,585
Sub-period, 1991 - 2005	4,500	3,845	5,866	5,210

This change in total energy requirement is mainly due to changes in the non-energy based products. The impact of the changes in the non-energy based products is largely induced by the shifts in household consumption in Malaysia. The large increase is due to shifts in the level of household consumption rather than the pattern shifts.

Sources of Significant Increases in Total Energy Requirement

Sub period, 1991-2000

Table 4 shows that the total energy consumption of each product has substantially changed in only 9 years for 10 highest sectors. In particular, the energy consumption of Agriculture increased by 674 ktoe of about 62 percent mainly because of the changes in direct energy intensity. The energy use of Petroleum products, Communication, Yarns and cloth, Transportation and Wood product had increased by 578 ktoe,188 ktoe,166 ktoe,140 ktoe and 121 ktoe, respectively due to changes in consumption pattern of households about 292, 173, 77, 219 and 103 percent of the total changes for each sector, respectively. The energy use of Foods, Oils and fats and Real estate increased by 531 ktoe, 447 ktoe and 391 ktoe, respectively mainly because of changes in direct energy intensity which were about 61, 45and 46, percent respectively. Recreation sector's energy consumption increased by 108 ktoe which was greatly induced by input mix (technical coefficient) which was about 46 percent.

Table 4 Analysis of changes in household energy consumption by the 10 highest sector 1991-2000 (toe)

Sources of Changes (toe)	Δ in direct energy intensity	(%)	Δ Technical coefficient	(%)	Δ Consumption level	(%)	Total
Agriculture	419,436	62	99,059	15	155,652	23	674,147
Petroleum product	-1,105,474	-191	-2,373	0	1,686,117	292	578,271
Foods	322,378	61	184,655	35	24,920	5	531,953
Oils and fats	201,801	45	49,277	11	196,569	44	447,647
Real estate	181,097	46	65,870	17	144,488	37	391,455
Communication	-109,534	-58	-27,529	-15	326,004	173	188,941
Yarns and cloth	9,051	5	28,660	17	128,571	77	166,283
Transport	-214,696	-152	46,744	33	308,912	219	140,959
Wood product	-6,023	-5	1,981	2	125,624	103	121,581
Recreation	9,740	9	50,135	46	48,779	45	108,653
Total Changes of 40 Sectors	**-2,815,357**		**560,513**		**4,880,077**		**2,625,234**

Sources: computed from Equation (6)

Positive sources of change in the agricultural sector for this period shows that the use of energy intensive products has become more dominant in the economy than before since it was the main source of inputs for the manufacturing activity in Malaysia in producing foods, oils and fats, wood products, printed materials, furniture and rubber products.

Sub period, 2000-2005

Within 5 years, the total energy requirement of each commodity has greatly changed for the 10 highest sectors as shown in Table 5. In particular, the energy requirement of Electricity, Wholesale and Retail trade, Motor vehicles, Construction, Other products, Other chemical and, Radio and television, etc. increased by 2,637 ktoe, 1,394 ktoe, 1,083 ktoe, 655 ktoe , 183 ktoe, 95 ktoe and 85 ktoe respectively, because of the changes in consumption pattern by households. The energy requirement of Business services, Real estate and Communication increased by 479 ktoe, 398 ktoe and 118 ktoe, respectively mainly because of changes in input mix. Within this period, most sectors used high energy technology with intensive energy inputs.

Demand for electricity in the household sector is expanding rapidly with urbanization and diverse urban growth pattern involving many basic structural changes in the economy particularly in energy consumption. Urbanization carries changes on how the resources were collected, distributed and used. The rising household income also causes urbanization to increase rapidly resulting in increasing demand for energy and non-energy based products and services (such as Wholesale and retail trade, Motor vehicles, Construction, Business services, Real estate and others products) during this period.

Table 5 Analysis of changes in household energy consumption by the 10 highest sectors 2000-2005 (toe)

Sources of Changes (toe)	Δ in direct energy intensity	(%)	Δ Technical coefficient	(%)	Δ Consumption level	(%)	Total
Electricity	965,186	37	378,828	14	1,293,646	49	2,637,660
Wholesale and retail trade	225,794	16	338,481	24	830,056	60	1,394,331
Motor vehicle	129,379	12	248,013	23	706,493	65	1,083,885
Construction	21,395	3	55,965	9	578,272	88	655,631
Business services	46,135	10	258,254	54	174,949	36	479,338
Real estate	22,604	6	287,272	72	88,989	22	398,865
Others products	-193,433	-106	74,036	40	302,666	165	183,269
Communication	48,897	41	131,496	111	-62,329	-53	118,064
Other chemical industries	-51,015	-53	8,385	9	138,567	144	95,937
Radio, television etc.	-29,676	-35	31,753	37	83,450	98	85,527
Total Changes of 40 sectors	**-2,136,039**		**2,320,134**		**2,401,610**		**2,585,705**

Sources: computed from Equation (6)

Table 6 Analysis of changes in household energy consumption by the 10 highest sector 1991-2005 (toe)

Sources of changes (toe)	Δ in direct energy intensity	(%)	Δ Technical coefficient	(%)	Δ Consumption level	(%)	Total
Motor vehicle	28,756	2	519,359	39	795,260	59	1,343,376
Real estate	133,246	14	492,368	52	325,926	34	951,540
Electricity	-1,673,394	-181	859,048	93	1,738,158	188	923,812
Business services	-75,406	-12	310,297	51	370,263	61	605,154
Wholesale and retail trade	-476,553	-90	271,850	51	734,420	139	529,717
Construction	-218,436	-41	149,210	28	598,177	113	528,952
Others products	-109,073	-29	130,241	35	348,707	94	369,876
Communication	-50,385	-19	115,608	44	198,150	75	263,373
Transport	-548,832	-269	309,642	152	442,863	217	203,674
Wood product	-46,748	-28	42,958	26	171,360	102	167,570
Total Changes of 40 sectors	**-4,500,107**		**3,845,018**		**5,866,028**		**5,210,939**

Sources: computed from Equation (6)

Sub period, 1991-2005

Within 14 years, the total energy requirement of each commodity has greatly changed for 10 highest sectors as shown in Table 6. In particular, the energy requirement of Motor vehicle, Electricity, Business services, Wholesale and retail trade, Construction, Other products, Communication, Transportation and Wood products increased by 1,343 ktoe, 923 ktoe, 605 ktoe, 529 ktoe , 528ktoe, 369 ktoe , 263ktoe, 203 ktoe and 167 ktoe, respectively, because of marked changes in consumption structure. The structural change is relatively similar to the changes in the energy requirement within 5 years. The energy requirement of real estate increased by 951 ktoe mainly due to changes in input mix.

Demand for motor vehicles had rapidly increased from 1991 to 2005 by 683 percent. The modern society involving people and places cannot function without motor vehicles. The imbalance in distribution of population, wealth and industries give rise to the need for motor vehicles. When income increases the demand for motor vehicles also increases particularly for motor cars.

CONCLUSION AND POLICY IMPLICATION

The results of IO-SDA indicate that total energy use in Malaysia has increased, mainly because of changes in the consumption structure rather than the changes in technology. The commodities that played a central role in the energy increase for every sub period were Agriculture (1991-2000), Electricity (2000-2005) and Motor vehicle (1991-2005). The GDP during the nine years (1991-2000) increased from RM205 billion to RM356 billion with a growth rate of 5.7%, while GDP during the later five years (2000-2005) increased from RM 356 billion to RM474 billion with a growth rate of 4.2%. Over a longer term, the GDP during 14 year period (1991-2005) increased from RM 205 billion to RM 474 billion with a growth rate of 5.4%.

Malaysian households (direct and indirect) were responsible for about 59% of the total primary energy supply (TPES) in 2006. About 94% of the total primary energy use came from production side and 6% of total primary energy use came from household side. Thus, households should be the main target group of the energy conservation policies since “households” is the main sector in energy consumption for both direct and indirect energy consumption. Consequently, future energy policy should give more attention to indirect energy consumption of households. The positive relationship between income, population and energy consumption suggests that with further increases in income level and population growth, the energy consumption of household will probably increase. However, power saving campaigns by the government contributed substantially to reduce the increase in the total household energy requirement.

Changes in consumption pattern have a direct impact on the changes in energy requirement by households. Based on the analysis, changes in consumption pattern had affected the increase in energy requirement for the nine year period (1991-2000) and the shift in consumption pattern is the main contributor to the highest changes in energy requirement for the five year period (2000-2005). The analysis proves that the increase in energy requirement is due to changes in consumption pattern. As income increases, there is a rapidly growing demand in the Transportation, Petroleum products, Oils and fats, and services sectors.

The findings of this study provide useful implications for energy efficiency policies: the reduction of direct energy intensity and adjustments in the consumption structure. There are differences in the changes in the household energy requirement for nine years and 5 years. For nine years and five years, household energy requirement increased by 2.6 mtoe and 2.5 mtoe, respectively. This shows that the change in energy requirement within the more recent five years is remarkable because the change doubled compared to the changes in energy requirement during the earlier nine years. Hence, the government and policy-makers should give more attention to energy consumption to avoid a shortage of energy supply in the future by promoting renewable energy resources because the Malaysian economy has been greatly dependent on non-renewable energy.

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REFERENCES

Ang, J. B. (2008) Economic Development, Pollutant Emissions and Energy Consumption in Malaysia, *Journal of Policy Modeling*, **30**, 271–278.

Amin, A. Q., Siwar, C. and Jaafar, A. H. (2009) Energy Use and Environmental Impact of New Alternative Fuel Mix in Electricity Generation in Malaysia, *The Open Renewable Energy Journal***, 2,** 25–32.

Blok, K. (2004) Lifestyles and energy. In: Cleveland, C.J., Matsumara, R. (Eds.), Encyclopedia of Energy, vol. 3. *Academic Press–Elsevier, Winconsin, USA,* 655–662.

Bullard, C. W. and Herendeen, R. A. (1975) The Energy Costs of Goods and Services: An Input–output Analysis for the USA, 1963 and 1967, *Energy Policy,* **3**, 268–278.

Denton, R. V. (1975) The energy costs of goods and services in the Federal Republic of Germany, *Energy Policy,* **3**, 279–284.

Department of Statistics, Malaysia 1998/99. Report on Expenditure Survey in Malaysia. Department of Statistics, Malaysia. Input-Output Tables for 1983, 19987, 1999 and 2000.

Department of Road Transport, Malaysia 2004. Data of New Transportation Registered.

Department of Environment, Malaysia. Malaysia Environmental Quality Report, 2004.

Hoen, A. and Mulder. (2002) A decomposition analysis of the emission of CO_2. Peper presented at the 43rd European Congress of the Regional Science Association, Jyvaskyla, Finland, August 27 to Ausgust 30, 2003.

Hoekstra, R. and van der Bergh, .J. C. J. M. (2002) Structural decomposition analysis of physical flows in the economy. Environment Resource Economics**, 23**,357–378.

Jaafar, A. H., Al-Amin, A. Q. and Siwar, C. (2008) Environment Impact of Alternative Fuel Mix in Electricity Generation in Malaysia, *Renewable Energy*, **33**, 2229–2235.

Kagawa, S and Inamura, H. (2001) A Structural Decomposition of Energy Consumption Based on a Hybrid Rectangular Input-Output Framework: Japan's Case'. *Economic Systems Research*, **13**, 339 – 363.

Lenzen,M. (1998) Primary energy and greenhouse gases embodied in Australian final consumption: an input–output analysis. *Energy Policy*, **26**, 495 – 506.

Leontief, W. and Ford, D. (1971) Air pollution and the economic structure: empirical results of input–output computations. Paper presented at Fifth International Conference on Input–Output Techniques, January, Geneva, Switzerland.

Mahlia,T. M. I. (2002) Emissions from electricity generation in Malaysia. *Renewable Energy*, **27**, 293–300.

Malaysia Energy Centre, National Energy Balance Malaysia, 2006.

Miller, R. E. and Blair, P. D. (2009) *Input–output Analysis: Foundations and Extensions*. Prentice Hall: Englewood Cliffs, NJ.

Ministry of Housing and Local Government, national Physical Plan, 2005.

Mohamed, A. R. and Lee, K. T. (2006) Energy for Sustainable Development in Malaysia: Energy Policy and Alternative Energy, *Energy Policy*, **34**, 2388 – 2397.

Pachauri, S.and Spreng, D. (2002) Direct and Indirect Energy Requirements of Households in India, *Energy Policy*, **30**, 511–523.

Park, A. and Hi-chun, A. (2007) The Direct and Indirect Household Energy Requirements in the Republic of Korea from 1980 to 2000 – An input-output Analysis, *Energy Policy*, **35**, 2839–2851.

Peet, N. J., Carter, A. J. and Baines, J. T. (1985) Energy in the New Zealand Household, 1974–1980, *Energy,* **10** , 1197–1208.

Peet, N. J. (1993) Input–output Methods of Energy Analysis, *International Journal of Global Energy Issues (Special Issue on Energy Analysis)*, 5, 10–18.

Pick, H. J. and Becker, P. E. (1975) Direct and Indirect Use of Energy and Materials in Engineering and Construction, *Applied Energy*, **1**, 31–51.

Suh, S., Lenzen, M., Treloar, G.J., Honko, K., Horvath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J. and Norris, G. (2004) System Boundary Selection in Life Cycle Inventories Using Hybrid Approaches, *Environmental Science & Technology*, **38**, 657 – 664.

van Engelenberg, B. C. W., van Rossum, T. F. M., Blok, K. and Vringer, K. (1994) Calculating the Energy Requirements of Household Purchases: A Practical Step-by-step Method, *Energy Policy*, **21**, 648–656.

Vringer, K. and Blok, K. (1995a) The Direct and Indirect Energy Requirements of Households in The Netherlands. *Energy Policy*, **23**, 893–910.

Vringer, K. and Blok, K. (2000) Long-term Trends in Direct and Indirect Household Energy Intensities: A Factor in Dematerialization? *Energy Policy,* **28**, 713–727.

Vringer, K., Blok, K. and van Engelenburg, B. (2006) Determining the Primary Energy Requirement of Consumption Patterns. In: Suh, S. (Ed.), Handbook of Input–Output Economics for Industrial Ecology. Springer, Dordrecht, The Netherlands, 20–40.

Wright, D. J. (1974) Goods and Services: An Input–output Analysis, *Energy Policy,* **2,** 307–315.