# Energy consumption in Tunisia over 1990–2008: A decomposition analysis using Logarithmic Mean Divisia Index technique

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#### Abstract

<u>By\_We</u> apply <u>ing</u> the logarithmic mean Divisia index to a dataset of 4 <u>four</u> economicenergy-using sectors (manufacturing, agriculture, transport and tertiary) and the residential sector, <u>we and examine study</u> the <u>underlying forces factors contributing to driving the</u> growing increase in total energy consumption and <u>changes in patterns of use the contributing</u> factors of the changes of <u>in</u> Tunisia. <u>n's energy use in these sectors and</u> <u>we find that for</u> <u>economic sectors, eEnergy consumption in commercial sectors</u> is mostly influenced by activity <u>change</u> and intensity changes <u>but for and in</u> residential sector, there are income <u>change</u> and population changes <u>who</u> contribute the most to the change in final energy use.

# 1. Introduction

During <u>Over</u> the past decades, energy analysts and policy makers have shown increasing concern over about the adverse effects of energy use. Two major reasons- factors are behind this interest , the increasing energy demand and the acceleration of continuous environmental degradation. The aim of e Energy and environmental policy is aimed at to reducing e pollution ant emissions into the atmosphere, in particular those related to energy use. Energy is considered  $\frac{1}{100}$  the principal source of pollutant emissions, in particular CO<sub>2</sub> emissions. Several methodologies have been developed to surround temporal variations in energy and environmental factors for a single country or a panel-group of countries. Decomposition Analysis (DA) methodologies, i.e. Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA), were as developed to identify the specified factors responsible for which contribute to energy demand and related CO<sub>2</sub> emissions (Ang, 2004b, 1999). Reviews of IDA can be found in Ang (2004b, 1995) and Ang and Zhang (2000). IDA methods constitute are a widely accepted analytical tool for in policy making s to evaluate energy conservation programs as in the works of (Ang and Liu (2007) and Reddy and Ray (2010)) or to analyze the scenario of future evolution (Ang, 2004a). But-However, there is no consensus among researchers on about which is the 'best' decomposition method. Two-Both the main methods, are used, those based on the Laspeyres index and those based on the Divisia index, are used.-

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Boyd et al. (1988) proposed the Divisia index approach as an alternative to the Laspeyres index approach in energy decomposition analysis. Extensions of methods linked to the Divisia index have been made since the early 1990s. Relevant studies include Boyd et al. (1988), Ang (1995), Ang and Choi (1997), Ang et al. (1998), Ang and Liu (2001), Ang (2005) and Reddy and Ray (2010). Other studies have made compare risons between different decomposition approaches or methods such as Howarth et al. (1991), Greening et al. (1997), Ang and Zhang (2000) and Zhang and Ang (2001). A range of techniques have been established, among which the log-mean Divisia index (LMDI) technique has been identified as the preferred approach by Ang (2004b) and Ang and Zhang (2000) due to its mathematical properties: perfect decomposition, consistency in aggregation and ability to handle zero values. The LMDI approach has both additive and multiplicative forms. The basic mathematical formulae for of LMDI has been reported in detail in a number of studies (Ang and Zhang, 2000; Ang and Liu, 2007; Ang et al., 2009; Ang, 2005 and 2004b).

Since From the beginning of the early-80s Eighties, Tunisia has in place set up a longterm policy of energy management which we is based on four instruments: institutionsel, law<del>ful</del>, finance ial and tax. The implementation of this policy is based on s Several initiatives have been made such as the creation in 1986 of the Agency of Energy Management (ANME today) which role is to develop a mechanism for the rational use of energy as well as the promotion of renewable energies. The role of the STEG (Tunisian Company of Electricity and Gas) is also was established important in to the develop ment of renewable energies, in particular, through the development of wind parks (54 MW installed and 190 MW in progress), the promotion of the-photovoltaic solar roofs and the diffusion of solar-fired heater PROSOL. Likewise, In the same way, an Indicated(?) National Authority (AND) was established installed in since December 2004 for the approval of to consider -MDP projects (Mechanism for a Clean Development) in the sectors that have ing a potential of reducing GES such as energy sectors and industry. This mechanism makes it possible to sell Units of Certified Reduction of Emissions (URCE) and the revenue earned of this sale represents- is usedan additional source to for the national investment s and to transfer of clean technology. transfer.

This paper is an application of applies DA to the data for of the Tunisian economy which has not been examined up to until now. And aAmong the various decomposition techniques, we choose the LMDI decomposition method for our study. The rest mainder of the paper aim to presents (ii) present the energy consumption and carbon dioxide emission of 5-five energy-end-use sectors, namely, manufacturing, agriculture, transport, tertiary and residential sectors in Tunisia, (iii) identify the factors that contribute to the change of energy demand in these 5-five energy-end-use sectors over the period 1990–2008 by using the LMDI approach, and (iv) to conclude conclusion.

### 2. Tunisian energy context:

#### 2.1 Energy balance in Tunisia

<u>The major energy resources in Tunisia n energy resources are essentially composed by</u> oil and natural gas. <u>In-Since 2001</u>, Tunisia passes from the status of an active balance to the status of became a net importer of energy. <u>That is explained by the due to stagnation of the in</u> national production, <u>but while energy consumption doesn't stop kept rising</u>. growing up.



Figure 2. Energy balance in Tunisia during 1980-2010.

# 2.2 Economic growth trends

During the-1990\_2010-period, the GDP knew\_grew at an annual average growth-rate of 4.82% passing from 10<sub>2</sub>-815.8 TMD in 1990 (at constant prices 1990) to 28<sub>2</sub>-523.4 TMD in 2010 (Fig.\_2). The GDP structure has changed, especially since 2000, with a-the share-of services in the GDP-growing; in favor of the services and the industrial sector as a whole remained ing almost stagnant. for the industrial sector as a whole.



Figure 2. Value <u>addition for each-added per</u> sector <u>in Tunisia</u> and <u>growth of GDP-evolutions</u> at constant prices <u>as of</u> 1990 in Tunisia,

(1990--2008)

#### 2.3 Energy consumption

Since 1985, t Primary he Tunisian energy primary consumption in Tunisia passed grew from 3889 ktep in 1985 to 7897 ktep in 2008, with an annual average rate of 3.12% during this period.



Figure 3. <u>Sector-wise Final final energy consumption in Tunisia by sector: during</u> 1990–2008

As have regard to the initial weight of each sector in the final fuel consumption, there are <u>m</u> Manufacturing industry\_ies followed by transport and the residential sectors which contributed the most to the rise of <u>in</u> the final energy consumption <u>in Tunisia</u>. <u>in the country</u>. The While oil products are widely remain the more consumed used fuel in Tunisia, with 63% of the total, but the the share of natural gas and electricity has ve also seen their shares increased ing passing respectively to 21% and 17% in 2008 compared with only 10% and 9% in 1985.

#### 2.4 GHG emissions

The GHG emissions due to energy did not cease increase increase increased to ing to reach\_2.65 téCO<sub>2</sub>/habitant\_person in 2008 against 1.791 téCO<sub>2</sub>/person habitant in 1985, with an annual increase of 1.-4%. These emissions remain weak are relatively subdued in relation compared to the industrialized countries. The urban population in urban areas in 2008 represents a growing share accounted ting for 65% of the total population, while against 35% allowed to the rural population population represented the rest in 2008 (NSI, 2008). The GHG emissions due to energy come-emanate from two sources: energy combustion and fugitive emissions. The f Fugitive emissions emanate from are related to the production activities \_\_\_\_\_, transport and hydrocarbons distribution. These emissions kn grew at n increase of 2.6% per annum between 1985 and 2008, attributed to entry in production, since 1996, of because of the natural gas layer (?) and the development in 1996 of the transport capacity of the-Trans--Mediterranean gas pipeline. The GHG emissions due to from energy combustion come emanate from six sectors: energy processing industry (electricity production and refining) and five final energy consumption sectors: manufacturing industry, transport, residential, tertiary(?) and agriculture sectors. In Tunisia, the typology of GHG emissions due to combustion by type of gas shows that the carbon dioxide emission s (CO<sub>2</sub>) represents the dominates dominating share of total emissions with almost 98.3% share. The remainder is distributed between methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) which respectively account for 1.1% and 0.6% of the whole emissions due to combustion (Fig. 9).

### 2.5 Energy intensity

During the eighteens\_80s, both primary and final energy intensities recorded a rise due to accelerated growth rate of industrial sectors in highly intensive in energy-use areas such as the IMCCV (construction materials, ceramic and glass industries) and the mines. But since Between 1985, they remained rather stable and until the end of the nineties 90s they remained rather stable. Since, these two intensities, and started to decreased thereafter. This fall is due to a consequence of two main-reasons: -i) the energy management policy followed by the

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country since 1986 (creation of National Energy Management Agency: ANME) and <u>ii)</u> the structural change <u>brought of the in</u> production in <u>the</u> Tunisian economy in favor of <u>lower-less</u> energy\_-intensive industries and <u>of the services</u>. In <u>fF</u>igure 4, we <u>represents</u> the <u>results-data</u> of final energy intensity <u>calculated by of different sectors in Tunisia from between 1990 to and</u> 2008. We find It shows that that the transport sector has s the highest <u>energy</u>-intensity <u>relative</u> to other sectors of Tunisian economy during all the 1990 2008 period, followed by manufacturing industry and agriculture sectors.



Source: <u>a A</u>uthor calculations

### Figure 4. Energy intensity for Tunisia by sector, 1990-2008

#### 3. Decomposition of total energy consumption in Tunisia: data and application

<u>In this study, w We</u> apply LMDI formulae <u>to for decompose sing</u> changes in industrial energy consumption in a time--series analysis as presented in Ang (2005, 2004a) in <u>order</u> to separate <u>all</u> the three effects <u>cited above mentioned earlier</u>. <u>In detail, t</u> The methodology focuses on the analysis of the following driving forces-<u>effects</u>:

- Activity effect, which gauges the effect of total output change on the assessed indicator.

- Structural effect, which measures the effect of a variation in the production shares of economic sectors.

- Intensity effect, a technological effect which measures the energy use per unit of constant monetary value of output. This indicator is preferred in this analysis here as because it allows a comparison across end-energy-use sectors, in contrast to physical energy intensity, i.e. energy use per unit of physical output, that as it is better suitable for the analysis of energy efficiency, and permits international comparisons of a certain manufacturing subsector on a global scale (Reddy and Ray, 2010, Ang and Zhang, 2000).

The d\_Decomposition analysis was <u>done conducted</u>-using data <u>for om</u> the period 1990– \_2008. <u>However</u>, **T** the major challenge <u>of for</u> the estimation is that <u>there are no consistent</u> <u>reliable</u> final energy use and CO<sub>2</sub> emission<u>s</u> data sources <u>are available in Tunisia</u> for the classifying <u>ication of the different</u> economic sectors <u>in Tunisia</u>. Owing to <u>the time</u> and data constraints, the economy was <u>structured</u> <u>divided</u> into five <u>sectors categories</u>: agriculture, manufacturing, transport, tertiary and residential <u>sectors</u>. The residential sector <u>doesn't present is</u> <u>not</u> a value-added <u>one</u>; its energy intensity is calculated as the ratio between final energy use and total private consumption expenditure <u>during the period</u>. We'll <u>analyse do the decomposition of</u>-its energy use <u>and present its results</u> separately.

This <u>paper\_work has</u> made use of various data sources. These data comprise yearly observations over the years 1980\_2008, namely:

- Gross domestic product in million Tunisian dinars (MDT) in 2005 constant prices,
- Value-added per sector in study in MDT in 2005 constant prices,
- Total and per sector final energy consumption in thousand tons of oil equivalent (ktoe),
- Total and per sector energy intensity in tep/1000 DT.
- Total population

Energy data are collected forom the National Energy Efficiency Agency (ANME). The GDP and the data are collected value added per sector are taken category-wise from the National Accounts, International Financial Statistics and the from National Institute of Statistics in with 1990-constant prices as the base; and we do transformations on these data to let them are recalculated at be in 2005 constant prices. Population is data are taken from the National Institute of Statistics.

### 3.1 Industry energy use decomposition for Tunisia, 1990-2008:

We <u>have</u> examined the contribution of the activity effect ( $\Delta E_{act}$ ), the structure effect ( $\Delta E_{str}$ ) and the energy intensity effect ( $\Delta E_{int}$ ) of 4-<u>four</u> sectors: manufacturing industries, agriculture, transport and tertiary??? by decomposing the aggregate energy consumption are expressed as follows:

$$E_{t} = \sum_{i=1}^{4} \frac{E_{it}}{VA_{it}} \frac{VA_{it}}{\sum_{i=1}^{4} VA_{it}} \sum_{i=1}^{4} VA_{it}$$
(1)  
$$E_{t} = \sum_{i=1}^{4} I_{it} * S_{it} * Y_{t}$$
(2)

₩<u>w</u>here

 $E_{it}$  = energy consumption of sector i at time t

$$VA_{it}$$
 = value--added of sector i at time t

 $Y_{t} = \sum VA_{it} = \text{total value of output at time t}$   $I_{it} = \frac{E_{it}}{VA_{it}} = \text{energy intensity of sector i at time t}$   $S_{it} = \frac{VA_{it}}{\sum_{i} VA_{it}} = \text{share of value of output of sector i at time t}$ 

Applying LMDI in its additive form, the change in total energy consumption between any two years (t and t-1),  $\Delta E_{tot}$ , is decomposed as follows:

$$\Delta E_{total} = \Delta E_{activity} + \Delta E_{structure} + \Delta E_{intensity} \quad (3)$$

₩<u>w</u>here:

$$\Delta E_{act} = \sum_{i} \frac{E_{i}^{t} - E_{i}^{t-1}}{\ln E_{i}^{t} - \ln E_{i}^{t-1}} \ln \left( \frac{Y_{t}}{Y_{t-1}} \right)$$
(4)

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$$\Delta E_{str} = \sum_{i} \frac{E_{i}^{t} - E_{i}^{t-1}}{\ln E_{i}^{t} - \ln E_{i}^{t-1}} \ln \left(\frac{S_{t}}{S_{t-1}}\right)$$
(5)  
$$\Delta E_{int} = \sum_{i} \frac{E_{i}^{t} - E_{i}^{t-1}}{\ln E_{i}^{t} - \ln E_{i}^{t-1}} \ln \left(\frac{I_{t}}{I_{t-1}}\right)$$
(6)

Then

$$\Delta E = E_t - E_{t-1} = \sum_i \frac{E_i^t - E_i^{t-1}}{\ln E_i^t - \ln E_i^{t-1}} \left[ \ln \left( \frac{Y_t}{Y_{t-1}} \right) + \ln \left( \frac{S_t}{S_{t-1}} \right) + \ln \left( \frac{I_t}{I_{t-1}} \right) \right]$$
(7)

The results of energy consumption decomposition analysis are presented below in  $\underline{tT}$  able 3.

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Table 2. Results of il Industry energy use	<i>decomposition for Tunisia</i> , 1990–2008:
LMDI additive	decomposition

	Actu <u>a</u> el va	E	conom	у		Shares in total effect (%)			
Year	Total Energy Consumption	Differences	ΔE <sub>act</sub>	ΔE <sub>str</sub>	ΔE <sub>int</sub>	Model Difference_s	ΔE <sub>act</sub>	ΔE <sub>str</sub>	ΔE <sub>int</sub>
1991	2-971	-17	127	-57	-87	-17	-747.2	333.0	514.3
1992	3-143	172	240	14	-82	172	139.4	8.1	-47.5
1993	3-250	107	83	32	-8	107	77.4	29.6	-7.1
1994	3-383	133	111	65	-43	133	83.3	49.2	-32.4
1995	3-452	69	73	21	-24	69	105.2	29.7	-34.9
1996	3-586	134	154	-207	187	134	115.0	-154.2	139.3
1997	3-733	147	390	-81	-161	147	265.0	-55.3	-109.6
1998	3-886	153	186	20	-53	153	121.6	12.9	-34.5
1999	4-076	190	272	-2	-80	190	143.3	-1.2	-42.1
2000	4-322	246	154	40	52	246	62.6	16.4	21.0
2001	4-479	157	225	-12	-56	157	143.4	-7.4	-36.0
2002	4-423	-56	48	-82	-22	-56	-84.9	146.3	38.6
2003	4-525	102	286	-130	-54	102	280.5	-127.4	-53.1
2004	4-736	211	279	-59	-9	211	132.3	-27.9	-4.4
2005	4-671	-65	152	-11	-206	-65	-235.3	17.0	318.3
2006	4-782	111	317	-95	-111	111	285.4	-85.7	-99.6
2007	4-959	177	278	5	-106	177	157.1	3.0	-60.1
2008	4-891	-68	247	11	-327	-68	-363.6	-16.9	480.5
Total			3621	-527	-1191	1903	190.3	-27.7	-62.6

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Notes:  $\Delta E_{act}$ : changes in energy due to activity effect;  $\Delta E_{str}$ : changes in energy due to structure effect; and  $\Delta E_{int}$ : changes in energy due to intensity effect.

Energy consumption in kilo tonnes of oil equivalent (ktep); industrial production in million Tunisian dinars (MDT) in 2005 constant prices and energy intensity in tep/1000 DT.

We note that LMDI gives perfect decomposition, i.e. the results do not contain an unexplained residual term. The total change\_s in energy consumption shares which results from activity, structure and energy intensity effect, respectively, are: 190.3%, -27.7% and -62.6%. The output effect is positive when more output can be produced with the same energy use (Reddy and Ray, 2010). If this effect is positive, it implies an improvement in energy use. The structural effect shows the changes in product mix in the economy, which was induced by changes in the composition of GDP. This effect is negative, it implying a shift ies a movement to wards less-energy\_intensive industries: thus, and then we'll find energy intensity decreased ing during the period in study (1990\_2008). Finally, intensity effect measures improvements in energy efficiency, changes in technology, efficient energy management practice or any other factor which is not related to the volume of output or composition. In Tunisian case, this effect is negative. There is a decrease in total energy use per unit of GDP which implies improvements in energy use.

Figure 5 shows the annual trends in energy consumption at the macroeconomic level in chaining and decomposition between two consecutive years.



Note: AE= activity effect, SE= structural effect, IE= energy intensity effect and TE= total effect

#### Figure 5: Decomposition of change in total energy consumption (1990-2008)

The analysis shows that energy consumption is mostly influenced by activity change and intensity changes. Activity effect (AE) has positive impact and intensity effect (IE) has negative impact. The negative impact of structural effect (SE) is also clear in the figure.

As shown in <u>F</u>-figure 5, AE is the <u>main-significant explaining</u>-factor for the increase of <u>in</u> total energy use in <u>the</u> Tunisian economy. It accounts for (+190.3%) of change in energy use over the period 1990\_-2008. The IE has <u>more-greater</u> impact than the structural effect (approximately twice) than the structural effect on change in total energy consumption and both are negative. This means implying that there was a significant improvement in energy efficiency. <u>Thus</u>, and that the composition of Tunisian economy has become somewhat less energy intensive over time. Hence, the overall effect on energy consumption was is always positive during the period of study, <u>but although</u>-it\_turned negative doesn't improve, during the laster period of study years, due to as the negative signs of both intensity and structural effect offset ting the positive impacts of AE.

 Table 3. Results of decomposition of change in energy consumption in Tunisia: 1990–2008

Activity Level Impact						s	tructure	Leve	l Impa	ct	Intensity Level Impact				:
		Manuf					Manuf.					Manuf.			
	Agr	Indust	Trans	Tertiar	Econ	Agr	Indust	Trans	Tertiar	Econ	Agr	Indust	Transp	Tertiar	Econ
1991	10.3	59.3	44.6	12.8	127.0	21.2	28.9	-97.3	-9.4	-56.6	-5.5	-142.2	53.7	6.6	-87.4
1992	20.9	108.0	85.7	25.2	239.9	-6.8	-20.1	36.2	4.6	13.9	9.8	-63.9	-29.9	2.2	-81.8
1993	7.7	36.0	30.2	9.0	82.8	-23.0	47.0	2.4	5.3	31.7	50.4	-85.0	22.3	4.7	-7.6
1994	10.4	47.0	41.2	12.1	110.7	-43.1	59.3	41.5	7.7	65.4	27.7	-63.3	0.2	-7.8	-43.1
1995	6.6	30.5	27.5	8.0	72.6	-38.9	30.1	18.2	11.1	20.5	33.3	-46.6	-8.7	-2.1	-24.1
1996	14.0	64.4	58.5	17.1	154.1	68.8	-253.0	-38.8	16.2	-206.7	-61.8	245.5	23.3	-20.4	186.6
1997	34.5	161.9	149.5	43.6	389.5	-33.9	-27.6	-45.8	25.8	-81.4	-14.6	-93.3	-7.7	-45.5	-161.1
1998	15.9	77.6	72.3	20.2	186.0	-11.4	14.8	14.4	2.0	19.8	12.5	5.5	-30.7	-40.1	-52.8
1999	23.2	114.5	106.4	28.1	272.2	12.2	-1.4	-8.4	-4.6	-2.3	-24.4	-42.1	-3.0	-10.5	-80.0
2000	13.2	65.1	59.2	16.6	154.0	-14.6	33.9	21.0	0.0	40.3	30.4	31.0	-63.2	53.5	51.7
2001	19.5	96.7	83.6	25.3	225.1	-29.3	26.5	-19.5	10.7	-11.6	22.9	-21.3	-37.1	-21.0	-56.5
2002	4.0	20.7	17.5	5.4	47.6	-42.8	13.1	-74.3	22.0	-82.0	4.8	-51.8	41.7	-16.4	-21.6
2003	23.2	123.5	105.4	34.0	286.1	36.9	-102.8	-69.5	5.4	-130.0	-39.1	-5.8	-6.9	-2.4	-54.1
2004	23.0	120.1	101.5	34.4	279.0	25.4	-101.7	15.6	1.8	-58.8	-31.5	89.5	-73.1	5.8	-9.3
2005	12.8	64.4	56.1	19.2	152.5	-44.9	-34.0	46.3	21.5	-11.0	39.1	-150.2	-56.4	-38.7	-206.3
2006	26.3	133.9	116.9	39.6	316.8	3.6	-70.0	-40.2	11.4	-95.2	-40.0	79.1	-91.8	-58.0	-110.6
2007	22.1	119.7	101.7	34.5	278.0	-18.9	29.1	-9.7	4.9	5.4	-4.2	-93.8	-3.0	-5.4	-106.4
2008	19.3	106.0	91.1	30.9	247.3	-22.9	10.7	17.1	6.5	11.5	-2.4	-142.7	-133.2	-48.4	-326.7

# The activity effect

Of the three effects, T the activity effect had the largest cumulative impact of the three effects and it was also the best explains er of the cumulative change in energy consumption. Over the entire analysis period, the activity effect had a positive effect but it did not show a constant growth rate. Large activity effects between 1996 and 1997 (389.5) were closely tied to the expansion of GDP growth rate during this time (11% in 1997) as shown in f (Figure 6). The-leading main contributors or sectors to the total activity a effect are manufacturing industries and transport, followed by tertiary and agriculture sectors.



Figure 6: Growth rate of GDP (%) in Tunisia (1990-2008)

# The il Intensity effect

The intensity effect was the second largest effect. <u>It and</u> is the <u>main significant</u> factor operating in the opposite direction with <u>its</u> negative effect. In certain years, <u>the its</u> <u>direction river of intensity effect</u> was clear, in particular <u>during</u> the last year of the <u>study</u> period (2008).

Aggregate intensity changes are affected by intensity changes in the underlying sectors (agriculture, manufacturing, transport and tertiary sectors) as well as by changes in <u>the</u> composition (product mix). We note that <u>t</u> The share of <u>the</u> intensity effect becaome more evident when the share of <u>the</u> manufacturing industries increased as in 1996, 1997, 2005 and 2008.

#### The s\_Structure effect

The <u>e</u> Compositional changes defined as the structure effect is a component of energy consumption. The positive structure effect shows that the sector has been more energy-intensive during the study period (Zhao et al., 2012). The structure effect embodies two effects: (<u>i</u>+) the structural shift in sectoral consumption between energy\_-intensive activities and those that do not directly use energy in final consumption, and (<u>2ii</u>) the energy efficiency changes in energy-using products. We notice that <u>the</u> total structure effect is always negative during the <u>study</u> period-<u>in study</u>. The negative result shows that energy efficiency gain has over compensated that of <u>the</u> structural shift towards more energy-using activities on economic structure.

### 3.2 Residential sector decomposition

We use the LMDI approach in its additive form to explore the driving factors behind the growth of residential energy consumption.

The steady growth in residential energy consumption is caused by a combination of factors, such as steady growth in population (population effect:  $\Delta E_{pop}$ ), and continual rise in per capita income (income effect:  $\Delta E_{inc}$ )<sub>2,7</sub>  $\underline{\bullet}$  These two aggregate changes are defined as scale effects, share of private consumption on total revenue (structure effect:  $\Delta E_{str}$ ) and the share of households expenditure in energy use relative to total private consumption (intensity effect:  $\Delta E_{int}$ ). The total annual residential energy consumption is factored in the following expression:

$$E_{rest} = \frac{E_{rest}}{C_t} \frac{C_t}{Y_t} \frac{Y_t}{Po_t} Po_t$$
  

$$E_{rest} = I_t * S_t * R_t * Po_t$$
  

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$$E_{rest} = residential energy consumption at time t$$
  

$$Ct = total private consumption at time t$$
  

$$Yt = total output (GDP) at time t$$
  

$$Pt = total population at time t$$

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 $I_t = \frac{E_{rest}}{Ct}$  = Energy intensity of residential sector in year t measured by the ratio between energy consumption in the residential sector and total private consumption used to calculate Intensity effect ( $\Delta E_{int}$ ).

 $S_t = \frac{C_t}{Y_t}$  = The share of total private consumption on total employ<u>ee</u>s of total output

(GDP) used to calculate Structure effect ( $\Delta E_{str}$ ).-

$$R_t = \frac{Y_t}{Po_t}$$
 = Total output per capita at time t used to define Income effect ( $\Delta E_{inc}$ )

 $Po_t = Total population at time t used to calculate Population effect (\Delta E_{po}).$ 

Applying LMDI in its additive form, the change in residential energy consumption between any two years (t and t-1),  $\Delta E_{res}$ , is decomposed as follows:

$$\Delta E_{res} = Eres_t - Eres_{t-1} = \Delta E_{intensity} + \Delta E_{structure} + \Delta E_{income} + \Delta E_{population}$$

₩<u>w</u>here

$$\begin{split} \Delta E_{\text{int}} &= \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln \left( \frac{I_t}{I_{t-1}} \right) \\ \Delta E_{act} &= \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln \left( \frac{S_t}{S_{t-1}} \right) \\ \Delta E_{inc} &= \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln \left( \frac{R_t}{R_{t-1}} \right) \\ \Delta E_{po} &= \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \ln \left( \frac{Po_t}{Po_{t-1}} \right) \end{split}$$

Then,

$$\Delta E_{res} = E_{rest} - E_{rest-1} = \sum \frac{Eres_t - Eres_{t-1}}{\ln Eres_t - \ln Eres_{t-1}} \left[ \ln \left( \frac{I_t}{I_{t-1}} \right) + \ln \left( \frac{S_t}{S_{t-1}} \right) + \ln \left( \frac{R_t}{R_{t-1}} \right) + \ln \left( \frac{Po_t}{Po_{t-1}} \right) \right]$$

The results of residential energy consumption decomposition analysis are presented <u>below in  $\underline{T}$ -table 5 (not Table 4?</u>).

 Table 4. Results of residential energy use decomposition for Tunisia, 1990–2008:

 LMDI additive decomposition

	Residential		ΔE due	ΔE due	∆E due		
	Energy		to	to	to	∆E due to	Model
Year	Consumption	Diffrences	intensity	Structure	Income	population	Differences
1990	480						
1991	527	47	41	-13	9	10	47
1992	565	38	2	-5	30	11	38
1993	607	42	23	6	1	11	42
1994	616	9	-9	-1	8	11	9
1995	653	37	18	4	5	10	37
1996	684	31	2	-17	36	10	31
1997	724	40	-7	10	28	10	40

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1998	762	38	1	3	25	9	38
1999	806	44	-0.1	-2	36	10	44
2000	777	-29	-63	-3	27	9	-29
2001	809	32	-14	7	32	7	32
2002	836	27	-1	14	6	8	27
2003	880	44	4	-6	38	8	44
2004	938	58	12	-7	45	9	58
2005	964	26	-19	7	28	9	26
2006	931	-33	-74	-8	40	9	-33
2007	931	-	-50	-7	48	9	0
2008	925	-6	-50	1	33	9	-6
Total			-185	-17	476	170	445

LMDI gives perfect decomposition and the results do not contain any unexplained residual term when dealing with residential sector. The total changes in the share of energy consumption shares which result from intensity, structure, income and population effects are is, respectively: -41.5%, -3.76%, 106.95% and 38.30% (Table 4). The income effect ( $\Delta E_{inc}$ ) and the population effect ( $\Delta E_{po}$ ) are both scale effects indicating the positive impacts of rising income levels and population. In fact, o On one hand, the income effect dominates positive contribution to the overall residential energy consumption growth and it is very robust<sub>s</sub>- but, O on the other hand, growing population and rapid urbanization have also significantly contributed to the increased residential energy consumption in cities. The structural effect shows the changes in private consumption contribution to total output functions in the economy. This effect It on energy use is negative on energy use. Finally, intensity effect measures improvements in energy efficiency and in Tunisian case, this effect it is negative. This implies a decrease in total energy use per unit of private consumption expenditure.

### 4. Conclusion:

In this paper, we <u>have</u> studied the underlying forces driving the growing total energy consumption in Tunisia. By applying the logarithmic mean Divisia index to a dataset of 4 <u>four</u> economic end-energy-use sectors (manufacturing, agriculture, transport and tertiary) and the residential sector compiled from a wide range of sources, we are able to <u>detail identify</u> the contributing factors of the changes of Tunisian's energy use in these sectors. The analysis shows that <u>for economic sectors</u>, energy consumption is mostly influenced by activity <u>change</u> and intensity changes. But <u>for in the case of</u> residential sector, <u>there are-</u>income <u>change</u> and population changes, <u>who</u> contribute the most to the change in final energy use besides <u>the</u> intensity change.

In terms of further work, <u>d</u> Decomposition analysis presents <u>much-great</u> opportunities <u>y for ....</u> although it depends to a great extent on data availability. Our objective is to <u>realize</u> <u>present a</u> decomposition analysis, <u>to</u>\_determine the contributing factors of polluting <u>ant</u> emissions <u>and with more</u> investigate<u>ion into</u>-the impact of renewable energy in reducing CO<sub>2</sub> emissions in Tunisia.

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