# Departament d'Economia Aplicada

## Driving forces of CO2 emissions and energy intensity in Colombia

Lourdes Isabel Patiño, Vicent Alcántara and Emilio Padilla

DOCUMENT DE TREBALL

19.05

UAB
Universitat Autònoma de Barcelona

Facultat d'Economia i Empresa

Aquest document pertany al Departament d'Economia Aplicada.

Data de publicació : **Setembre 2019**

Departament d'Economia Aplicada
Edifici B
Campus de Bellaterra
08193 Bellaterra

Telèfon: 93 581 1680
Fax: 93 581 2292
E-mail: d.econ.aplicada@uab.es
http://www.uab.cat/departament/economia-aplicada/

# Driving forces of $CO_2$ emissions and energy intensity in Colombia


Lourdes Isabel Patiño[a], Vicent Alcántara[b] and Emilio Padilla[b]

[a] Universidad Castro Carazo, Costa Rica

[b] Department of Applied Economics, Universidad Autónoma de Barcelona, Spain



## Abstract

We analyze the driving factors of $CO_2$ emissions generation and energy intensity during almost four decades. We apply a factorial decomposition for $CO_2$ emissions, starting from the Kaya identity, using the logarithmic mean Divisia index method. The results indicate that the increase in emissions is mainly explained by the affluence effect and the population effect, but is partially offset by the effect of energy intensity and, to a lesser extent, the carbonization effect. We then analyze the driving factors of energy intensity. With this objective, we first transform final energy into its total primary energy requirements. We find that the decrease in total energy intensity is mainly due to the reduction in sectoral energy intensity and, to a lesser extent, to structural change. The most important contribution to the reduction in sectoral energy intensity is explained by efficiency improvement in the transport sector, but also by industry, while the decrease in the share of industry would be the most relevant component explaining the reduction of the structural change effect. This is the first application of this type to the Colombian case and provides useful information for the analysis and design of energy and environmental policies.



**Keywords:** $CO_2$ emissions, energy efficiency, Kaya identity, LMDI decomposition, structural change.

# 1. Introduction

Carbon dioxide ($CO_2$) emissions are strongly linked to energy consumption. According to the International Energy Agency (IEA, 2016), the production and use of energy account for two thirds of greenhouse gas emissions, mostly $CO_2$ emissions. According to the forecasts made by the IEA, by 2040 fossil fuels will continue to be relevant, estimating that the global supply of primary energy by 2040 will be divided into four almost equal parts, oil, gas, coal and sources of low $CO_2$ emissions (IEA, 2014c). However, this situation could be reversed through an adequate energy efficiency policy and, above all, through the use of a better technology and energy mix with low carbon emissions.

The industrial sector uses more energy than any other end-use sector, consuming approximately 50% of the world's total energy (EIA, 2010). In 2010, in Colombia, 53.5% of total primary energy[1] is consumed by industry, 37.8% by transport and the rest by the agricultural sector. During the period 1975–2010, this consumption in industry and transport grew at average annual rates of 2.37% and 1.86% respectively. The study of the factors that explain the $CO_2$ emissions and the energy consumption of the economic sectors is of great relevance for, first, understanding the mechanisms that generate the changes in the emissions and the use of energy and, second, helping to formulate environmental, energy and economic policies. There are numerous studies in this line of research, as well as on the different decomposition methodologies that make it possible to identify the factors that explain the growth of emissions and their relationship with energy consumption, as described below.

The analysis of the trajectory of $CO_2$ emissions and energy use in Colombia is particularly necessary for several reasons: i) Colombia is committed to the United Nations Framework Convention on Change Climate goal of mitigating greenhouse gas emissions; ii) according to some analyses (FCW-WB, 2014), the control of emissions can offer opportunities for the economic performance of the country, generate new jobs, benefit agriculture, the development of technology and the supply of energy; iii) the National Energy Plan of 2015 emphasizes the importance of energy efficiency, the mitigation of environmental impacts, security and energy

[1] The expression total primary energy refers in this investigation to the estimation of the primary energy needed to obtain the final energy, by using the Leontief model following the method developed by Alcántara and Roca (1995).

equity, within the framework of sustainable development considering technological, environmental, social, economic and political aspects (UPME , 2015); and iv) there has been a large increase in $CO_2$ emissions during the period 1971–2010, of 131.9%, as well as the supply of primary energy during the same period, of 133.8% (IEA, 2014a).

Per capita $CO_2$ emissions in 2010 amounted to 1.31 tons; that is, approximately half of the tons per capita of the set of Latin American countries (2.34 t $CO_2$ per capita) and one ninth of those of the OECD countries (10.14 t $CO_2$ per capita) (IEA, 2014a). Moreover, during the period 1971–2010 the average annual economic growth rate was 3.89%, while the growth rate of $CO_2$ emissions was 2.13% and that of primary energy consumption was 2.15%. For Colombia, it is a major challenge to sustain the goal of economic growth by keeping $CO_2$ emissions and energy consumption under control.

In this paper we analyze the trajectory of $CO_2$ emissions and energy intensity in Colombia during almost four decades. In particular, we investigate which are the main factors that determine the changes in $CO_2$ emissions and the consumption of total primary energy per unit of productive activity in the period studied. To study these factors, we use an additive decomposition methodology based on the Kaya identity approach (Bruce et al., 1996; Kaya, 1989) and for the analysis of the changes in energy consumption per unit of product, we use a sectoral multiplicative decomposition (Ang, 2004a; Ang et al., 2009; Ang and Liu, 2001).

There are no similar previous studies for the case of Colombia. As for the region, there are detailed decomposition studies at the country level for Chile, Brazil and Mexico, so that our research would cover the gap that exists in the literature regarding this issue in Colombia. In addition, from a methodological point of view, a novel element is that the decomposition of energy consumption is developed taking into account the total primary energy consumption at the sectoral level. This means that we take into account the total (direct and indirect) energy requirements and the losses due to sectoral distribution and transformation (Alcántara and Roca, 1995).

After this introduction, the document is organized as follows. Section 2 presents a conceptual and empirical frame of reference on the analysis of energy and emissions decomposition. Section 3 describes the methodology and data sources. Section 4 analyzes the results for the

Colombian case. Finally, Section 5 presents the conclusions. In addition, annexes with the detailed results are added.

## 2. Conceptual and empirical reference framework

The analysis of energy from an economic perspective has been done for more than a century. However, the oil crisis in the 70s led to a focus on the energy industry, the substitution of energies and the importance of renewable energies, as well as on the integrated planning of energy systems, especially in developing countries (United Nations, 1991).

Research work on energy was extended in the 80s and after, emphasizing the relationship between energy, economy and the environment, with the study of the effects of energy consumption on the (local, regional and global) environment becoming a fundamental part of the analysis. The main application areas of the studies were energy supply and demand, energy related gas emissions, material flows and dematerialization, energy efficiency trends and comparative studies between countries (Ang, 2004b; Ang and Zhang, 2000; Ang et al., 1998; Daly, 1990; Farla and Blok, 2000; Zhang et al., 2009).

An intuitive approach used to analyze the historical behavior and trends of the relationship between energy and $CO_2$ emissions is the Kaya identity, which describes the relationship between $CO_2$ emissions and their driving factors (Kaya, 1989). This is defined as an $I \equiv PAT$ identity[2], where I refers to the environmental pressure, which in the Kaya identity is the total $CO_2$ emissions, P is the population, A denotes the economic affluence, which is usually proxied by the gross domestic product (GDP) per capita, and T, which in the initial formulation refers to technology, is measured in the Kaya identity as the emission intensity of energy multiplied by the energy intensity of production, $\frac{C}{E} * \frac{E}{GDP}$; that is, emissions per unit of

[2] The $I \equiv PAT$ identity was proposed with constant technology by Ehrlich and Holdren (1972, 1971), authors who emphasize the size and growth of the population. Simultaneously, Commoner et al. (1971a, 1971b) posited the IPAT identity as it is currently known.

GDP[3]. For those responsible for formulating policies, the most important components are the energy intensity of production and the emissions intensity of energy (EIA, 2010; Roca, 2002).

One way to reduce energy consumption and $CO_2$ emissions is by improving energy efficiency (IEA, 2007; IEA, 2014a). Energy efficiency is related to the way energy is used or transformed. According to the IEA (2014d), energy efficiency consists of reducing energy consumption through the use of more efficient devices. Some efficiency improvements can be masked by the variation of other factors, such as the production structure, the exchange rate, the affordability of energy services, the population and the number of energy users or climate behavior (IEA, 2014d).

Frequently, energy intensity is used as a proxy for energy efficiency. However, energy intensity is the product of both the efficiency in the manufacturing process and the production structure (the composition of production). Depending on the specialization in more or less energy-intensive sectors, a greater or lesser energy intensity can be given. On the other hand, if the energy requirements per unit of product are reduced with respect to one type of production, then there is an improvement in energy efficiency. Over time there are changes both in the production structure and in energy efficiency, making it necessary to analyze the structural change and the evolution of sectoral efficiency to help the formulation of policies.

Numerous studies have made an effort to determine and quantify the main factors that explain the trajectories of different polluting gases and energy consumption through decomposition analyses. Huntington and Myers (1987) reviewed 8 studies on the decomposition analysis of energy intensity, while Ang and Zhang (2000) referenced 124 studies related to this topic. In general, these studies have focused on the energy demand of the productive sectors of the Asian economies (Taiwan, Singapore and China) and the United States. Liu and Ang (2007) examined 70 studies on energy consumption and/or energy intensity corresponding to 335 decomposition exercises for the period 1976–2005. More recently, an extensive literature has been developed referring to different pollutants. This section reviews relevant studies on decomposition techniques applied to environmental indicators (see Annex 1A). Several papers

[3] It should be noted that the factors of the Kaya identity could be interrelated and therefore not be independent factors (Alcántara and Padilla, 2005; Duro and Padilla, 2006; Kawase et al., 2006; Martín-Vide et al., 2007).

mention the difficulty of comparing the data and the quality of the information, since there are not always complete series for all the zones, and the units of measurement may change, this not being the case of the studies carried out for the United States, however.

Most studies analyze the behavior of emissions (especially $CO_2$), energy intensity and energy consumption. The most used explanatory effects for the analysis of the change in emissions are: economic activity effect, energy intensity effect, structure effect, fuel substitution effect, composition effect and total effect. In some cases, the effects are broken down into groups of activities, sectors and subsectors. In the case of energy, the analysis includes the activity effect, the intensity effect, the structure effect, the substitution effect and the total effect. One of the studies reviewed considers an input–output model of energy where the effect of final energy consumption, the transformation effect, substitution effect and an interaction are considered (Alcántara and Roca, 1995). The denominations assigned to the effects vary according to the author (see Annex 1A). A characteristic observed in developed countries is that energy intensity and GDP per capita are the factors that most significantly influence the behavior of emissions, although the amount varies depending on the case and the period analyzed.

In the studies reviewed, multiplicative and additive decompositions are made using different indexes: Laspeyres index (LM), refined Laspeyres index (RLM), logarithmic mean Divisia index (LMDI), arithmetic mean Divisia index (AMDI), conventional Divisia index, etc. (Alcántara and Roca, 1995; Ang and Zhang, 1999; Choi and Ang, 2003; Diakoulaki and Mandaraka, 2007; Farla and Blok, 2000; Hatzigeorgiou et al., 2008; Ma and Stern, 2006; Paul and Bhattacharya, 2004; Sun, 1998; Viguier, 1999; Wang et al., 2005; Zhang and Ang, 2001; Zhao et al., 2014).

The studies usually break down the Kaya identity into four components or factors (carbonization, energy intensity, affluence and scale) that give rise to the corresponding effects in the decomposition, with some variations in the name assigned to each of the factors (Alcántara and Padilla, 2005; Kawase et al., 2006; Lise, 2006; Martín-Vide et al., 2007; Zhang et al., 2009). Additionally, in some studies the decomposition is also developed at the level of economic sectors (industry, transport, agriculture, other sectors, etc.), which allows a better explanation of the factors behind the behavior of emissions (Lise, 2006; Martín-Vide et al., 2007; Paul and Bhattacharya, 2004; Viguier, 1999; Zhang and Ang, 2001; Zhang et al., 2009).

The IEA publishes annually some global data aggregated by region and by country related to the Kaya identity (IEA, 2010; IEA, 2014d) that show a general overview of the situation of the different countries. However, these descriptive data do not allow definitive conclusions to be deduced about the drivers of emissions trajectories. In addition, unlike previous studies (Alcántara and Padilla, 2005; Ang et al., 2003; Duro and Padilla, 2006; Hatzigeorgiou et al., 2008; Lin and Long, 2014; Sun, 1998; Zhang and Ang, 2001; Zhang et al., 2009), the present research carries out an analysis of the $CO_2$ emissions in Colombia disaggregating the Kaya identity into six factors, analyzing 35 years (1975–2010). The LMDI method is used for the decomposition, as this is considered an optimal tool to perform this type of measurement (Ang, 2004a; Ang and Liu, 2001). The work is complemented by a multiplicative logarithmic decomposition of energy intensity, the main influential factor in the decrease of emissions and the improvement in the country's energy efficiency. The multiplicative decomposition allows a more specialized analysis, at the sectoral level, from the perspective of an index (in percentage terms and without resorting to units of measurement). In this way, a finer analysis is achieved that is easy to understand and follows a solid approach suggested in the literature for these purposes (Ang and Zhang, 2000; Baležentis et al., 2011). Primary energy is used, instead of final energy, as primary energy is a better indicator of total energy consumption. To this end, we estimate the total primary energy required following the method of Alcántara and Roca (1995) based on Leontief's input–output model. In addition, constant aggregate value data linked with a movable base updated to the reference period (which discounts, therefore, the effect of inflation) are used. This is the first research of these characteristics carried out to analyze Colombia's emissions.

## 3. Methods and data

### 3.1. Methods

The most recognized decomposition methods in the literature that can be used in the decomposition analysis of energy and some environmental indicators are: i) structural decomposition analysis, based on the input–output model and ii) index decomposition analysis based on methods related to the Laspeyres index and the Divisia index (Ang, 2004b, 2005; Ang et al., 2009; Ang and Zhang, 2000; Chung and Rhee, 2001; Divisia, 1925; Liao et al., 2007). The latter presents several extensions and refinements.

Ang et al. (2009) and Ang and Zhang (2000) review the properties of the different decomposition methods, highlighting the advantages of the LMDI method, which we used for the present study. Many researchers and analysts from international organizations also opt for this method (Ang, 2004b; Ang and Liu, 2001; Ang and Zhang, 2000). It is also used in several official publications applied to the Kaya identity, energy consumption and energy intensity: New Zealand (EECA, 2009), United States (EERE, 2011) and Canada (OEE, 2006). Among the advantages of the LMDI method, it stands out that it yields a perfect decomposition (its residual component is zero).

#### 3.1.1. Additive decomposition method

The additive decomposition based on the Kaya identity approach is used to analyze the variation of $CO_2$ emissions (Ang and Zhang, 1999; Kawase et al., 2006; Kaya, 1989; Wang et al., 2005). This is based on the relation of four factors.

(1) $$\underbrace{C_{(t)}}_{C_t} \equiv \underbrace{\frac{C_{(t)}}{E_{(t)}}}_{a_t} * \underbrace{\frac{E_{(t)}}{GDP_{(t)}}}_{b_t} * \underbrace{\frac{GDP_{(t)}}{P_{(t)}}}_{d_t} * \underbrace{P_{(t)}}_{p_t}$$

The Kaya identity is composed of four components, though it could be extended to other relevant factors as long as the identity is maintained. The first element is the carbonization factor, $a_t = \frac{C_{(t)}}{E_{(t)}}$, that is, $CO_2$ emitted per unit of energy consumed. This factor is usually related to the combination of different energy sources used in a country. The second element corresponds to the energy intensity, $b_t = \frac{E_{(t)}}{GDP_{(t)}}$, the quantity of primary energy consumed per unit of GDP. The following element shows the economic affluence of society $d_t = \frac{GDP_{(t)}}{P_{(t)}}$, measured as per capita GDP. Finally, the population $P_{(t)}$ is a scale factor (Alcántara and Padilla, 2005; Lise, 2006; Wang et al., 2005).

To achieve a better explanation of the evolution of emissions in Colombia, following Martín-Vide et al. (2007), three factors are added that take into account the weight of fossil energy sources, energy transformation and final energy intensity. These new factors are: $s_t = \frac{FOE_{(t)}}{PE_{(t)}}$, which indicates the amount of fossil energy consumed per unit of primary energy and describes the composition of energy consumption (substitution factor); $tr_t = \frac{PE_{(t)}}{FE_{(t)}}$, indicating the amount of primary energy consumed per final energy unit and accounting for the efficiency of technical change in the energy sector (transformation factor), and $e_t = \frac{FE_{(t)}}{GDP_{(t)}}$, which reveals the amount of final energy consumed per unit of product (efficiency factor). The incorporation of these new elements implies that the first element of the equation referring to the carbonization factor is modified, since this will now be described by a more precise relationship $m_t = \frac{C_{(t)}}{FOE_{(t)}}$ , that is, $CO_2$ emitted per unit of fossil energy consumed.

Now the expression (2) can be presented as follows:

$$(2) \qquad \underbrace{C_{(t)}}_{C_t} \equiv \underbrace{\frac{C_{(t)}}{FOE_{(t)}}}_{m_t} * \underbrace{\frac{FOE_{(t)}}{PE_{(t)}}}_{s_t} * \underbrace{\frac{PE_{(t)}}{FE_{(t)}}}_{tr_t} * \underbrace{\frac{FE_{(t)}}{GDP_{(t)}}}_{e_t} * \underbrace{\frac{GDP_{(t)}}{P_{(t)}}}_{d_t} * \underbrace{P_{(t)}}_{p_t}$$

Additionally, the above equation can be decomposed using the logarithmic mean (Carlson, 1972; Tornqvist et al., 1985), defined for positive numbers *x* and *y* as:

$$(3) \qquad L(x,y) = \frac{y-x}{\ln\left(\frac{y}{x}\right)}, for x \neq y \qquad L(x,y) = x, for\ x = y$$

As noted by Tornqvist et al. (1985), *L* is symmetric and homogeneous in *x* and *y*, and continuous when $x = y$.

It should be noted that *L* separates the arithmetic and the geometric mean, that is, $\sqrt{xy} \langle\ L(x,y) \ \langle\ \frac{1}{2}(x+y)$, if x ≠y, where

(4) $$L(C_t, C_0) = \frac{C_t - C_0}{\ln\left(\frac{C_t}{C_0}\right)}$$

$$\Delta C_{m-effect} = L(C_t, C_0)\ln(m_t/m_0) \text{ Carbonization effect}$$
$$\Delta C_{s-effect} = L(C_t, C_0)\ln(s_t/s_0) \text{ Substitution effect}$$
$$\Delta C_{tr-effect} = L(C_t, C_0)\ln(tr_t/tr_0) \text{ Transformation effect}$$
$$\Delta C_{e-effect} = L(C_t, C_0)\ln(e_t/e_0) \text{ Energy intensity effect}$$
$$\Delta C_{d-effect} = L(C_t, C_0)\ln(d_t/d_0) \text{ Affluence effect}$$
$$\Delta C_{p-effect} = L(C_t, C_0)\ln(p_t/p_0) \text{ Population effect}$$

Each of the expressions in (4) defines a vector and indicates the annual variation in $CO_2$ emissions according to the partial contribution of each effect to the global $CO_2$ growth in relation to the base year (Ang and Zhang, 1999).

To check the decomposition done previously, we estimate the annual increase of total $CO_2$ emissions, according to each component of the Kaya identity, with which the following expression is obtained:

(5)
$$C_t - C_0 = L(C_t, C_0)\ln\left(\frac{m_t}{m_0}\right) + L(C_t, C_{0)})\ln\left(\frac{s_t}{s_0}\right) +$$
$$L(C_t, C_0)\ln\left(\frac{tr_t}{tr_0}\right) + L(C_t, C_0)\ln\left(\frac{e_t}{e_0}\right) +$$
$$L(C_t, C_0)\ln\left(\frac{d_t}{d_0}\right) + L(C_t, C_0)\ln\left(\frac{p_t}{p_0}\right)$$

The correct decomposition is verified when the data obtained in expression (5) are equal.

The additive decomposition fulfills the desired properties of this type of decomposition (continuous, symmetric and homogeneous) and is consistent in the aggregation (Ang and Liu, 2001; Ang and Liu, 2007a, 2007b; Ang and Zhang, 1999; Ang et al., 1998).

### 3.1.2. Multiplicative decomposition method

Multiplicative decomposition is considered in the literature as the most suitable method for the sectoral analysis of the aggregate energy intensity, defined in this case as the quotient between the total primary energy consumption and the total sectoral aggregate value (Ang, 1995, 2004a).

We use the following variables for the decomposition: $E_t$, total energy consumption of productive sectors; $E_{it}$, energy consumption in sector *i* in period *t*; $VA_t$, total productive value added; $VA_{it}$, value added in sector *i* in period *t*. We can express the aggregate sectoral energy intensity in terms of the production structure and sectoral energy intensity (Ang et al., 2009, Ang and Lee, 1994; Ang and Zhang, 2000; Liao et al., 2007; Liu and Ang, 2003).

(6)
$$I_t = \sum_i S_{i,t} I_{i,t}$$

The first component, $I_t = \frac{E_t}{VA_t}$, indicates the aggregate sector energy intensity in the period *t*; the second component, referring to the production structure, $S_{it} = \frac{VA_{i,t}}{VA_t}$, indicates the sector *i* proportion of the total VA in period *t*; and the third component, $I_{it} = \frac{E_{it}}{VA_{it}}$, shows the energy intensity of sector *i* in period *t*. It is assumed that the aggregate energy intensity varies from period 0 to period *t*, evidencing a relative change in the aggregate energy intensity of the production sectors, which can thus be expressed as:

(7)
$$\underbrace{\frac{I_t}{I_0}}_{D_{tot}} = \underbrace{\exp\left(\sum \frac{L(C_{it}, C_{i0})}{L(C_t, C_0)} \ln\left(\frac{S_{it}}{S_0}\right)\right)}_{D_{str}} + \underbrace{\exp\left(\sum \frac{L(C_{it}, C_{io})}{L(C_t, C_0)} \ln\left(\frac{I_{it}}{I_0}\right)\right)}_{D_{\text{int}}}$$

where

$$\frac{L(C_{it}, C_{i0})}{L(C_t, C_0)} = \frac{\dfrac{C_{it} - C_{i0}}{\ln\left(\dfrac{C_{it}}{C_{i0}}\right)}}{\dfrac{C_t - C_0}{\ln\left(\dfrac{C_t}{C_0}\right)}}$$

This is in terms of indexes that are related multiplicatively and can be decomposed into the structure effect $D_{str}$ and the efficiency effect $D_{int}$, which give the estimated impact of structural change and sectoral energy intensity respectively. Structural change is associated with a variation in the growth rates between the sectors, which leads to a change in the production composition. The change in energy intensity is determined by changes in the energy intensity of the production sectors, and refers to the amount of energy used per unit of product or activity, measured at the sectoral level or at the activity level (Ang, 2004a).

### 3.1.3. Methodology for the estimation of sectoral total primary energy

The data of the sectoral primary energy used for the multiplicative decomposition were estimated following the method proposed by Alcántara and Roca (1995). The procedure developed by the authors is based on the redefinition of energy balances in a similar way to an input–output model and aims to convert sectors' final energy into their total primary energy requirements. The procedure followed to obtain the primary energy vector per year is explained in Annex 2A. This process is applied to the period 1971–2010 (see Annex 3A).

## 3.2. Data

We used IEA (2014a, 2014b) data on the total requirements of primary energy and on the sectoral consumption of energy, measured in millions of tons of oil equivalent (Mtoe), $CO_2$ emissions measured in millions of tons, population measured in millions of inhabitants and GDP in trillions of 2005 dollars, in purchasing power parity values; and data from the national accounts of the National Administrative Department of Statistics (DANE) on the total and sectoral VA (in millions of Colombian pesos at constant 2005 prices).

The VA data is taken as an indicator of production because GDP has the problem of double accounting (EIA, 1998). In addition, VA information is comparable with other countries. This is a time series of chained constant VA with a movable base updated to the reference period (which discounts, therefore, the effect of inflation).

### 3.2.1. Treatment for data grouping

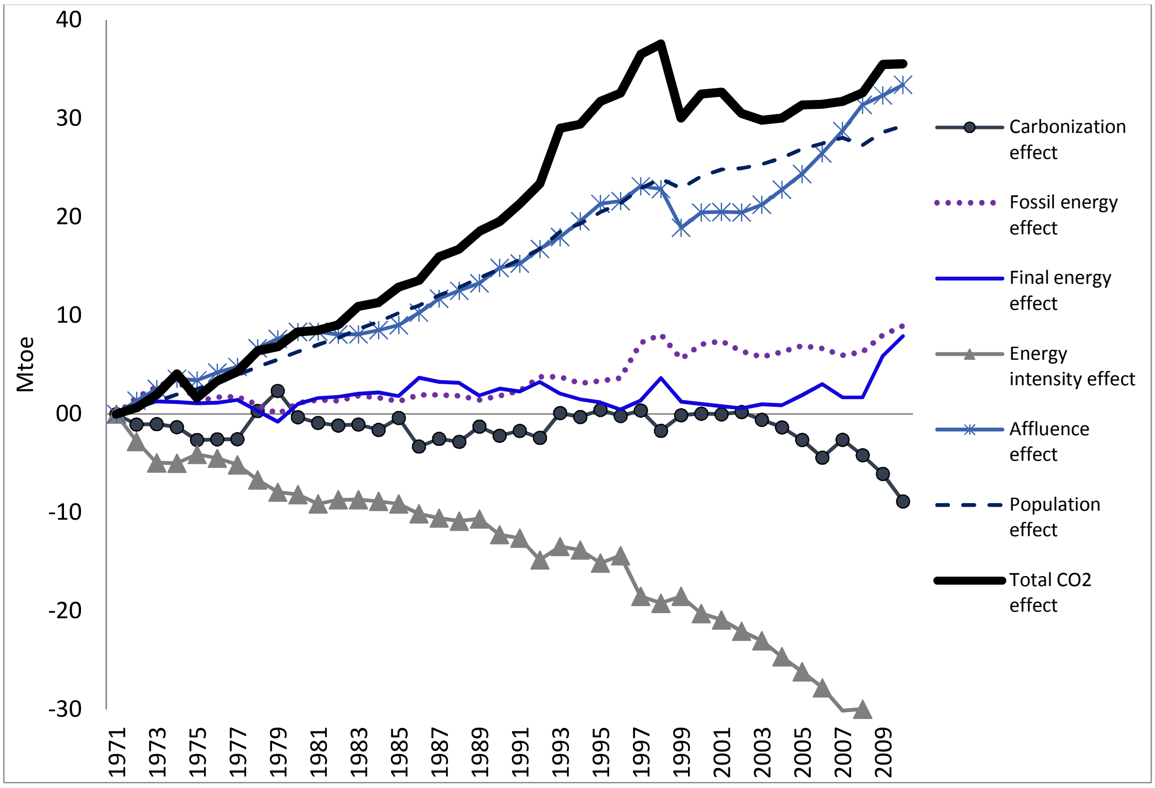
The estimation of the energy intensity index requires correspondence between the classification of the economic activities of the energy balances of the OECD and those of the national accounts system of Colombia. To achieve this consistency, a correspondence table was constructed with the help of the International Standard Industrial Classification of All Economic Activities (ISIC), which allowed the sectors' primary energy consumption information and the VA data of the productive sectors to be linked.

## 4. Results and discussion

### 4.1. Decomposition and analysis of the variation of $CO_2$ emissions related to energy

In order to shed light on the changes in emissions and their relationship with economic growth and energy consumption, Figure 1 presents the result of the computation of equations (4) and (5), indicating the evolution of the decomposition of $CO_2$ emissions in relation to the base year 1971. The total variation of emissions is given by the highest line. The rest of the lines indicate the contribution of each of the effects to the total variation of the emissions over the period 1971–2010, taking into account the decomposition into Kaya factors. In order to understand these variations, we also analyzed the context and the energy and environmental policies applied in Colombia in the period.

**Figure 1. Decomposition of the growth of $CO_2$ emissions**




According to Figure 1, the main effects that explain the variation of emissions in Colombia are: population, affluence, and energy intensity. The first two contributed to their increase, while the last contributed to their reduction, partially neutralizing the first two (see Annex 4A). Next, we analyze the relationship between each factor and the variation of total $CO_2$ emissions (total effect). For this purpose, it is assumed that, when analyzing the contribution of a factor, the rest of the factors remain constant. In general, during the period 1971–2010, the total $CO_2$ emissions show an ascending behavior with respect to the base year (1971), with 1998 being the year where the net increase is highest with 37.6 Mtoe.

**Population effect** (variation caused by changes in population). Throughout the period this presents an increasing tendency, a consequence of the cumulative annual average growth rate of the population, which is approximately 1.9%. The decade 1997–2007 stands out, as it is the period where this effect surpasses all others, and, in particular, the years 1997 and 1998, since they have the greatest impact on the variation of emissions, with approximately 23 Mtoe. Both years have the highest per capita emissions of the period, with 1.67 Mtoe $CO_2$ per capita.

**Affluence effect** (variation caused by changes in GDP per capita). There is an upward trajectory of the generation of emissions and GDP per capita. However, during the period 1971–1982, the growth rate of GDP per capita was slightly higher than the growth of emissions. Some factors that favored the impulse of the economic activity at the end of the decade of the 70s were the external demand for coffee and the oil bonanza. After 1982, $CO_2$ emissions grow at a faster rate than GDP per capita. It should also be noted that at the end of the nineties there was a contraction of the economy (the 1992–1998 period is known as the "bubble" of the 1990s because the excess of spending was at the cost of indebtedness), which was particularly strong during the year 1999 with a negative growth rate (-4.02%), a year that coincides with a strong decrease in emissions. As of 2003, the return to the growth path of the economy entails a growing contribution of the affluence effect that since 2007 has surpassed all others.

**Carbonization effect** (variation caused by changes in the carbonization factor). The effect presents an oscillating downward trend throughout the period with a favorable impact on the reduction of emissions. In 1979, this effect has its greatest impact, contributing 2.4 Mtoe to the generation of emissions. After this year there is a moderate downward cyclical trend until the beginning of the new millennium, where the decrease is accentuated, and the year 2010 stands out due to its negative impact on the generation of emissions, with -8.86 Mtoe, probably due to the increase in the use of natural gas and of some renewable energies[4]. In this respect, the government has carried out campaigns aimed at stimulating the use of gas in the main cities, while eliminating subsidies for other fuels[5]. This government policy has motivated the transformation of vehicles to natural gas, since conversion costs have been reduced by 50% (see Annex 4A). In this context, it is important to mention that due to the gas massification policy, during the period 2000–2013, the conversion of vehicles to gas, energy that emits 85%

[4] The use of waste as renewable primary energy grew at an average annual rate of 4.5%.
[5] Subsidies come to represent more than 1% of GDP, with the aggravating circumstance that they basically benefit the highest strata of the population.

less $CO_2$ emissions than gasoline, grew at an average rate of 38.7%.[6,7]

**Substitution effect** (variation caused by changes in fossil energy consumed per unit of total primary energy). This effect has remained relatively stable with an upward trend, which is unfavorable to emission savings, throughout the years analyzed. Two periods are distinguished. The first is characterized by a slight contribution to the increase of emissions (varying from 1 to 4 Mtoe) during the period 1971–1996, and the second, by a greater influence on the increase of emissions (from 6 to 9 Mtoe) during the period 1997–2010. The upward trend is due to the increase in the consumption of natural gas and indicates that fossil energy has been replaced less than expected by other types of energy, such as hydroelectric or other renewable primary energies[8].

**Transformation effect** (the variation caused by changes in the primary energy consumed per unit of final energy). This effect presents a stable oscillatory trend with a relatively slight influence on the increase of emissions during the period 1971–2008, ranging between 0.3 and 3.7 Mtoe per year. After 2008, there is an upward trend, with a greater contribution to the increase in emissions, since it exceeds 5.9 Mtoe per year, reflecting an apparent deterioration in the transformation of primary energy into final energy.

**Energy intensity effect** (variation caused by changes in the amount of final energy used per unit of product (Toe / US $ PPP)). Energy intensity shows a decreasing trend during the four decades, being the factor that contributes most to the reduction of emissions over the period analyzed. Specifically, in 2010 it contributes to the reduction with -35.13 Mtoe with respect to the base year (see Annex 4A). This means that there has been a decrease in energy consumption per unit of product. Some possible explanations could be the incorporation of efficient technologies in the use of energy (in households, gas installations increased by 11.4% during the period 1994–2013) and efficient use in the vehicle fleet (UPME, 2007).

---

[6] According to ECOPETROL, this increase has been favored by the vehicle conversion incentive program, which provides between $ 400,000 and $ 1,000,000 Colombian pesos per vehicle. In euros this figure varies between 154.7–386.7, since one euro equals 2586.29 Colombian pesos as of June 2, 2014. http://www.colombia.com/cambio_moneda/.

[7] Own calculations with UPME statistics from http://www1.upme.gov.co/InformacionCifras/

[8] If the estimate is made including only oil and coal as fossil fuels (excluding natural gas), the combined influence of these two fuels on the increase in emissions becomes negative throughout the period.

When observing the trajectory of the energy intensity data of the economy during the period 1971–2011, an apparent improvement in energy efficiency is evident, since this indicator decreased at an average annual rate of -1.6%, making a favorable contribution to the reduction of $CO_2$ emissions (see Annex 4A). As indicated by the IAEA (2005), this situation could be explained by technical changes in the production process of goods or by changes in the production structure; for example, the tertiarization of the economy through the promotion of the commerce sector and the services sector, which probably consume less direct energy, with the exception of the transport sector.[9] Given the relevance of this factor, we will carry out a decomposition broken down by sectors, since the disaggregated indicators will help us to better understand the evolution of energy intensity and a better orientation of appropriate energy and environmental policies.

### 4.2. Sectoral decomposition and analysis of the variation in energy intensity

The total primary energy consumption of the production sectors in Colombia during the period 1975–2010 increased by 11,530 Mtoe, from 10,622 Mtoe in 1975 to 22,592 Mtoe in 2010, with an average annual growth rate of 2.1%, this being lower than the average annual growth rate of the VA at constant prices (3.5%). The energy intensity considering the VA at constant prices in the same period decreased by 0.04112 (Toe per thousands of pesos at constant 2005 prices), going from 0.0987 in 1975 to 0.05758 in 2010. This means that it fell at an average annual rate of -1.5% during this period.

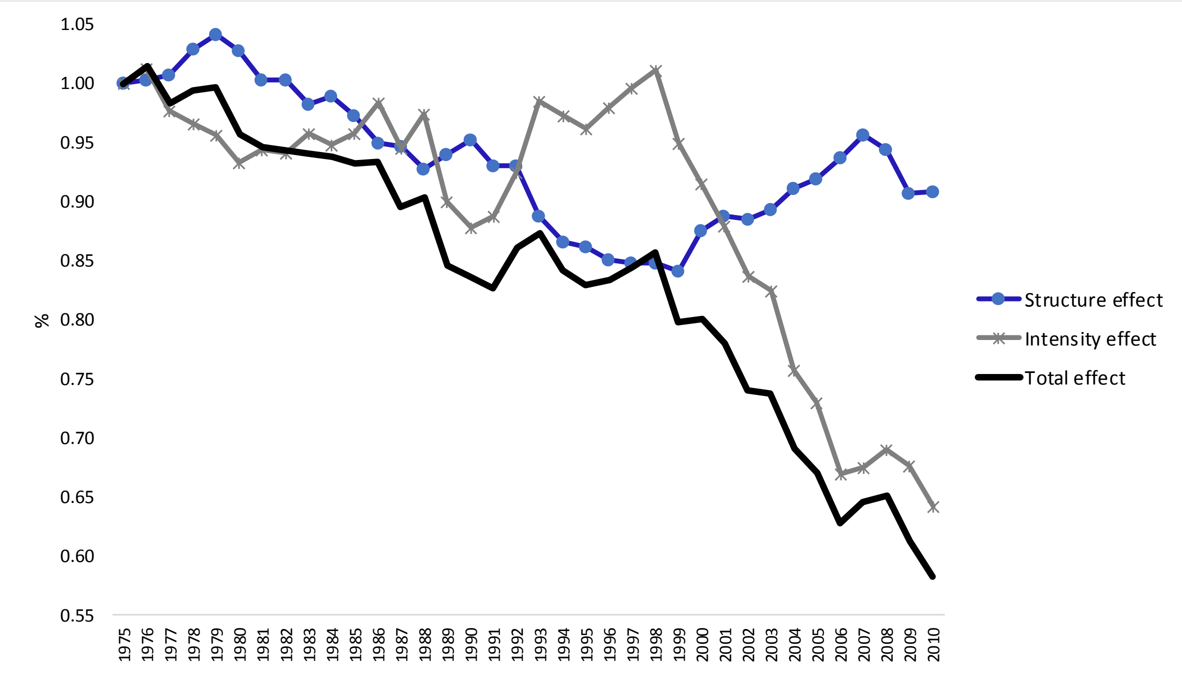
In order to see in greater detail which factors have driven the decrease in total energy intensity, we present its decomposition considering the intensity effect and the structure effect. We made the estimates using the multiplicative decomposition method, applying equations (6) and (7) (Figure 2). An increase in energy intensity (in relation to the base year) implies an apparent decrease in efficiency, while a decrease in energy intensity indicates an apparent increase in efficiency. Energy intensity was calculated at the aggregate level and by sectors.

The estimations indicate that the structure and energy intensity effects show downward trends during the period. The sectoral energy intensity effect is the one that contributes most to the

[9] However, there are studies that emphasize that the activities of services are linked to diverse activities that have strong impacts on the environment (Alcántara and Padilla, 2007).

decrease in aggregate energy intensity, especially in the new millennium. However, during the nineties, this effect reflects an ascending behavior, showing a lower apparent efficiency in the use of energy. The contribution of structural change to the decrease in aggregate energy intensity reaches its maximum in the year 2010, when the contribution of this effect is -9.2%, while the change in the sectoral energy intensity is -35.75%, resulting in a net variation of -41.7% in aggregate energy intensity (see Figure 2 and Annex 5A)[10]. The results are comparable to those presented by the IEA for the United States for the period 1985–1994 (EIA, 1998) and by Howarth et al. (1991) for eight OECD countries for the period 1973–1987.

**Figure 2. Multiplicative decomposition of energy intensity**




[10] The annex presents the final results of the multiplicative decomposition. The presentation of the complete procedure of multiplicative decomposition is available upon request.

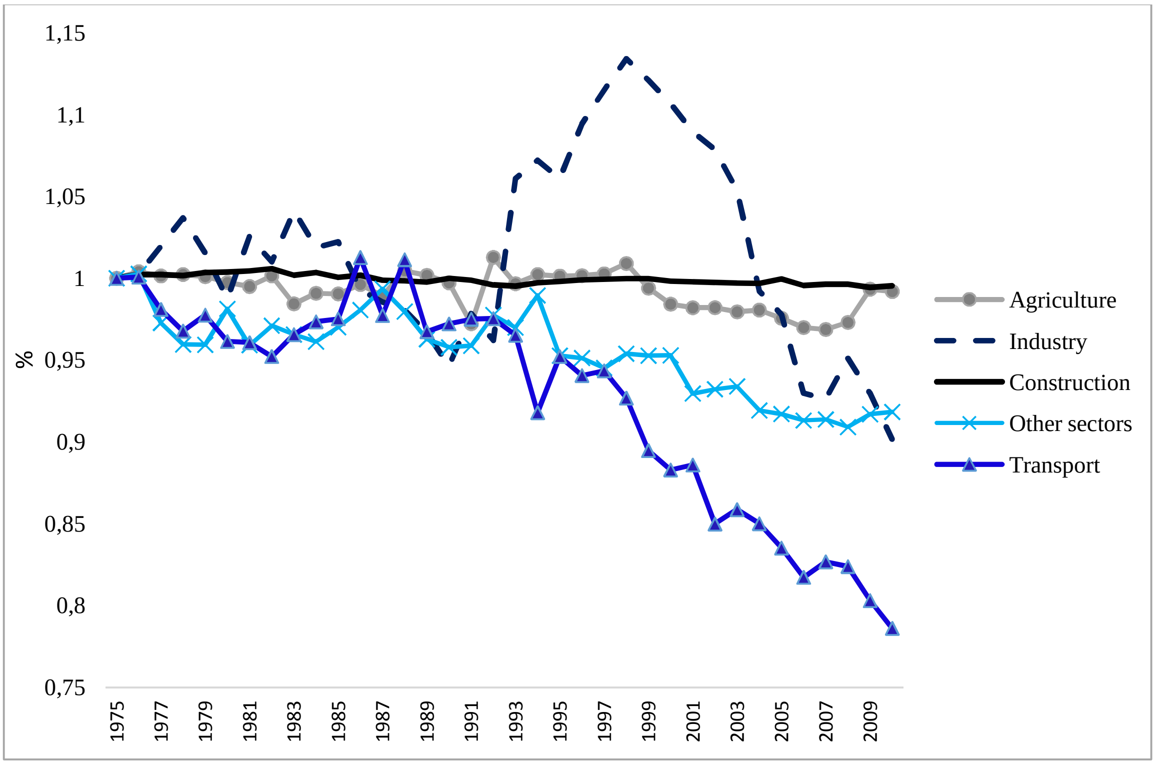
**Intensity effect**. The effect associated with sectoral energy intensity is the most important to explain the decline in Colombia's energy intensity. Likewise, disaggregated sector estimates suggest that the increase in energy intensity observed in the nineties in Figure 2 is mainly explained by the increase in the energy intensity of the industrial sector during the same period, as illustrated in Figure 3 (see also Annex 5A). The greatest decrease in sectoral energy intensity, especially at the end of the nineties, occurred in the transport sector and the industrial sector[11], while those with the smallest decrease were construction and other sectors[12] (see Figure 3). Within the industrial sector, chemical and petrochemical activities (4.2%) and iron, steel and non-ferrous metals (3.5%) stand out, as they presented the highest average annual growth rates of energy consumption during the period analyzed (see Annex 5A).

The improvement in the energy intensity of the transport sector and the industrial sector can be associated with measures of energy saving, technological changes and energy substitution, as well as the implementation of policies with a global impact on the decrease in energy consumption.

**Figure 3. Sectoral intensity effect (at constant 2005 prices).**

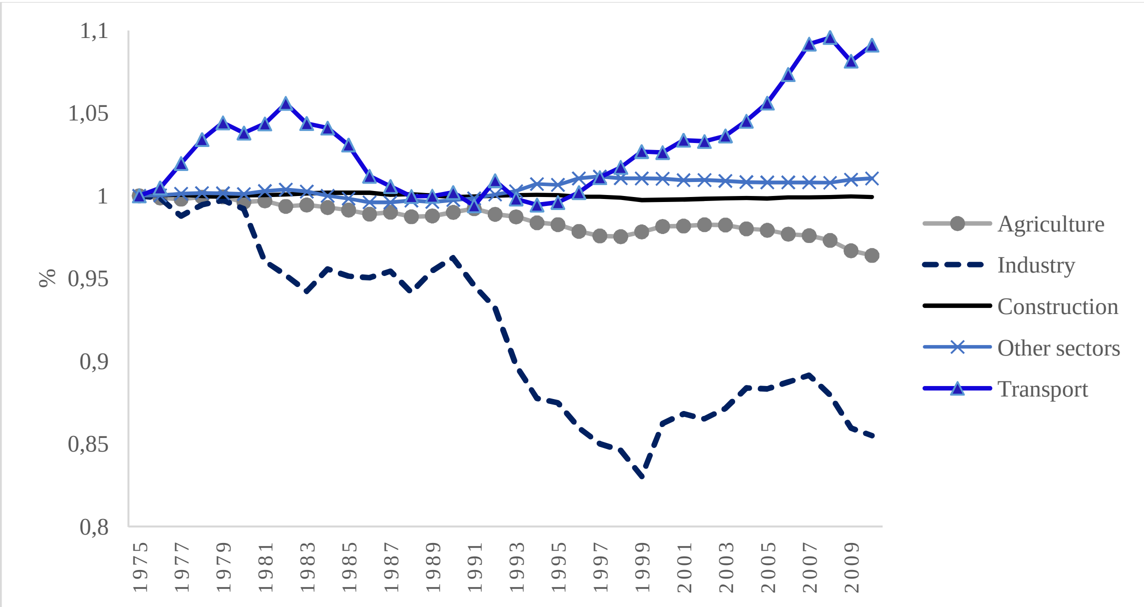
[11] The industrial sector groups together food and tobacco, textiles and leather, wood and wood products, paper and printing, chemistry and petrochemicals, non-metallic minerals, non-specific industry, machinery and equipment, and iron, steel and non-ferrous metals.

[12] Other services according to ISIC 3.1 include divisions 50–55 and 65–99.




**Structure effect** (variation caused by the change in the composition of production). The structural change had a significant influence on the decrease in energy intensity during the period 1993–1999, which is clearly observed in the aggregate estimates (see Figure 2). For example, in 1998 it is observed that the contribution of structural change to the decrease in total primary energy intensity was -15.3%, while sectoral energy intensity contributed with a rise of 1.1%, resulting in a net decrease of -14.3% in the total energy intensity observed. This effect is of fundamental importance in the case of the industrial sector and the transport sector, while in the rest of the sectors its influence is lower (see Figure 4). In the case of the industrial sector, the structural effect favors the reduction of energy intensity. However, in the case of the transport sector, there is an opposite effect, especially at the end of the new millennium, as shown in Figure 4, while the weight of the sector increased.

**Figure 4. Sectoral structural change effect (at constant 2005 prices).**




## 5. Conclusions

This research allows a better understanding of the behavior of $CO_2$ emissions and energy intensity in the case of Colombia. We identified the main driving forces of $CO_2$ emissions and their change over time, and we studied the influence that structural change and sectoral energy intensity had on the evolution of total primary energy intensity over the period studied.

The effects that contributed most to the increase in emissions in the period were the scale effect, related to the change in the population factor, and the affluence effect, measured through GDP per capita. To a much lesser degree, in an oscillatory way but with an upward trend, the transformation effect and the substitution effect also contributed to this increase. On the contrary, the effect that most contributed to counteract this growth was the energy intensity (that is, less energy is required per monetary unit of production, which translates into less environmental pressure). The carbonization effect also contributed to the reduction, although to a lesser degree, evidencing some positive changes in the combination of fossil fuels used. However, the favorable performance of these two effects was not enough to prevent a significant growth of emissions in the period.

In addition, the results show that the decrease in the aggregate energy intensity of the productive sectors is mainly due to the decrease in sectoral energy intensity and, to a lesser extent, to structural change. Regarding structural change, it was found that this occurred mainly in the period 1993–1999 and was more relevant in some sectors, among which the industrial sector and the transport sector stand out.

The energy intensity effect is the one that had the greatest impact on the reduction of emissions and the improvement in energy efficiency (as the energy intensity of the different sectors is reduced). This reflects a satisfactory panorama, in line with the international trend, which is characterized by technological improvements and the creation of new technical standards. Among the most outstanding facts during the almost four decades analyzed, is the constant growth of the supply of hydroelectricity and natural gas. The latter was intensified in the new millennium as one of the most important policy objectives of the energy sector, increasing its percentage share in final energy consumption. This was helped by the existence of competitive prices that turned the trend towards energy sources that are more environmentally friendly, replacing electricity, firewood and the use of fuels such as “cocinol” (oil for stoves). It also highlights the policies that are favorable to the use of natural gas by the Colombian mobile fleet.

Our estimations take into account the total primary energy requirements (including transformation losses) of the economic sectors. Instead of making underestimates using the final energy data, by applying the methodology developed by Alcántara and Roca (1995) we achieve a more precise quantification of the vector of total (direct and indirect) energy requirements for almost four decades at a sectoral level. In addition, chained VA data are used, which makes it possible to better track the behavior of the variables. A greater breakdown of sectoral information on emissions data and of the type of energy used would allow a further deepening of the determination of the contribution of the different sectors and energies to the changes in the period 1971–2010, so this is one of our recommendations for the institutions in order to better refine the definition of policies.

In order to consolidate and intensify the improvement in energy efficiency (lower energy consumption per unit of product), it is necessary to expand the knowledge and information related to good practices in the use of energy and new technologies related to energy saving in the services and construction sector, specifically, in aspects such as lighting systems, air conditioning, refrigeration, new materials under construction, management of the organization (Energy management system ISO 50001), etc. Likewise, it is necessary to continue with the measures of rational use of energy in the industrial sector and the transport sector, especially in relation to the substitution of energy sources, since the transformation factor ratio and the carbonization factor reflect a slight increase in the last five-year period, evidencing a negative behavior. Therefore, it is necessary to: a) improve the technology and efficiency of the equipment used in industry (high efficiency engines) and in the processes and procedures associated with the transformation of energy (cogeneration); b) promote the use of waste from industrial processes as sources of energy, reincorporating them back into the process (such as, for example, hot gases or steam).

## 6. References


Alcántara, V., Padilla, E. (2005) Análisis de las emisiones de CO2 y sus factores explicativos en las diferentes áreas del mundo. *Revista de Economía Crítica*, *4*, 17–37.

Alcántara, V., Roca, J. (1995). Energy and $CO_2$ emissions in Spain: Methodology of analysis and some results for 1980 -1990. *Energy Economics*, *17*(3), 221-230.

Ang, B. W. (1995). Decomposition methodology in industrial energy demand analysis. *Energy, 20*(11), 1081-1095.

Ang, B. W. (2004a). Decomposition analysis applied to energy. *Encyclopedia of Energy, 1*, 761-769.

Ang, B. W. (2004b). Decomposition analysis for policymaking in energy: which is the preferred method? *Energy Policy, 32*(9), 1131-1139.

Ang, B. W. (2005). The LMDI approach to decomposition analysis: a practical guide. *Energy Policy, 33*(7), 867-871.

Ang, B. W., Huang, H. C., Mu, A. R. (2009). Properties and linkages of some index decomposition analysis methods. *Energy Policy, 37*(11), 4624-4632.

Ang, B. W., Lee, S. Y. (1994). Decomposition of industrial energy consumption : Some methodological and application issues. *Energy Economics, 16*(2), 83-92.

Ang, B. W., Liu, F. L. (2001). A new energy decomposition method: perfect in decomposition and consistent in aggregation. *Energy*, *26*(6), 537-548.

Ang, B. W., Liu, F. L., Chew, E. P. (2003). Perfect decomposition techniques in energy and environmental analysis. *Energy Policy, 31*(14), 1561-1566.

Ang, B. W., Liu, N. (2007a). Handling zero values in the logarithmic mean Divisia index decomposition approach. *Energy Policy, 35*(1), 238-246.

Ang, B. W., Liu, N. (2007b). Negative-value problems of the logarithmic mean Divisia index decomposition approach. *Energy Policy, 35*(1), 739-742.

Ang, B. W., Zhang, F. Q. (1999). Inter-regional comparisons of energy-related CO2 emissions using the decomposition technique. *Energy*, *24*(4), 297-305.

Ang, B. W., Zhang, F. Q. (2000). A survey of index decomposition analysis in energy and environmental studies. *Energy*, *25*(12), 1149-1176.

Ang, B. W., Zhang, F. Q., Choi, K.H. (1998). Factorizing changes in energy and environmental indicators through decomposition. *Energy*, *23*(6), 489-495.

Baležentis, A., Baležentis, T., Streimikiene, D. (2011). The energy intensity in Lithuania during 1995 - 2009: A LMDI approach. *Energy Policy, 39*(11), 7322-7334. doi: http://dx.doi.org/10.1016/j.enpol.2011.08.055

Bruce, J. P., Hoesung, L., Haites, E. F. (Eds.). (1996). *Climate Change 1995. Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Carlson, B. C. (1972). The Logarithmic Mean. *The American Mathematical Monthly, 79*(6), 615-618.

Commoner, B., Corr, M., Stamler, P. J. (1971a). The causes of pollution. *Environment, 13*(3), 2-19.

Commoner, B., Corr, M., Stamler, P. J. (1971b). *The closing circle: nature, man, and technology*. New York: Knopf.

Choi, K.H., Ang, B. W. (2003). Decomposition of aggregate energy intensity changes in two measures: ratio and difference. *Energy Economics*, *25*(6), 615-624.

Chung, H.S., Rhee, H.C. (2001). A residual-free decomposition of the sources of carbon dioxide emissions: a case of the Korean industries. *Energy*, *26*(1), 15-30.

Daly, H. (1990). Toward some operational principles of sustainable development. *Ecological Economics, 2*(1), 1-6.

Diakoulaki, D., Mandaraka, M. (2007). Decomposition analysis for assessing the progress in decoupling industrial growth from CO2 emissions in the EU manufacturing sector. *Energy Economics*, *29*(4), 636-664.
Divisia, F. (1925). L'indice monetaire et la theorie de la monnaie. *Revue d'Economie Politique, 9*(2), 109-135.
Duro, J. A., Padilla, E. (2006). International inequalities in per capita CO2 emissions: A decomposition methodology by Kaya factors. *Energy Economics, 28*(2), 170-187.
EECA-Energy Efficiency and Conservation Authority. (2009). Energy Efficiency and Renewable Energy in New Zealand. Year Six Report: March 2001 to 2007 Wellington: Monitoring and Technical Group Energy Efficiency and Conservation Authority.
EERE -Energy Efficiency and Renewable Energy. (2011). Industrial Total Energy Consumption *Planning, Budget, and Analysis. Energy Intensity Indicators*: U.S. Department of Energy.
Ehrlich, P., Holdren, J. (1972). A bulletin dialogue on the 'Closing Circle'. Critique: One dimensional ecology. *Bulletin of the Atomic Scientists, 28*(5), 16-27.
Ehrlich, P. R.,, Holdren, P. J. (1971). Impact of population growth. *Science, 171*(3977), 1212-1217.
EIA - Energy Information Administration. (1998). *Changes in energy intensity in the manufacturing sector 1985–1994* Washington, D.C.: U.S. Department of Energy.
EIA - Energy Information Administration. (2010). *International Energy Outlook*. Washington, D.C.: U.S. Department of Energy.
Farla, J. C. M., Blok, K. (2000). Energy Efficiency and Structural Change in the Netherlands, 1980–1995. *Journal of Industrial Ecology, 4*(1), 93-117. doi: 10.1162/108819800569203
FCW-WB -Foundation Climate Works, Grupo Banco Mundial. (2014). *El desarrollo adaptado al cambio climático. La suma de los beneficios derivados de las medidas que contribuyen a generar prosperidad, poner fin a la pobreza y combatir el cambio climático.* Washington,: Grupo Banco Mundial.
Hatzigeorgiou, E., Polatidis, H., Haralambopoulos, D. (2008). CO2 emissions in Greece for 1990-2002: A decomposition analysis and comparison of results using the Arithmetic Mean Divisia Index and Logarithmic Mean Divisia Index techniques. *Energy, 33*(3), 492-499.
Huntington, H. G., Myers, J. G. (1987). Sectoral Shift and Industrial Energy Demand: What Have We Learned. In A. Farunqui, J. J. Broehl & G. C.W. (Eds.), *The ChangingStructure of American Industry and Energy Use Patterns*. Columbus, Ohio: Battelle Press.
IAEA -International Atomic Energy Agency. (2005). *Energy Indicators for Sustainable Development: Guidelines and Methodologies*. Vienna: IAEA.
IEA -International Energy Agency. (2007). *Tracking industrial energy efficiency and CO2 emissions*. Paris: OECD/IEA.
IEA -International Energy Agency. (2010). *Carbon Capture and Storage. Model Regulatory Framework*. Paris: OECD/IEA.
IEA -International Energy Agency. (2014a). *CO2 Emissions from fuel combustion highlights*. Paris: OCDE/IEA.
IEA -International Energy Agency. (2014b). World Energy Balances. Documentation for beyond 2020 files. Available at http://www.iea.org/statistics/topics/energybalances/.
IEA -International Energy Agency. (2014c). *World Energy Outlook 2014*. Paris: OECD/IEA.
IEA -International Energy Agency. (2014d). *Energy Efficiency indicators: essentials for policy making*. Paris: OECD/IEA.
IEA -International Energy Agency. (2016). World Energy Outlook.Special Report. Energy and air pollution. Available at https://www.iea.org/publications/freepublications/publication/WorldEnergyOutlookSpecialReportEnergyandAirPollution_Executivesummary_EnglishVersion.pdf
Kawase, R., Matsuoka, Y., Fujino, J. (2006). Decomposition analysis of CO2 emission in long-term climate stabilization scenarios. *Energy Policy*, *34*(15), 2113-2122.

Kaya, Y. (1989). Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios. Paper presented to the Energy and Industry Subgroup, Response Strategies Working Group, Intergovernmental Panel on Climate Change. París.
Liao, H., Fan, Y., Wei, Y.-M. (2007). What induced China's energy intensity to fluctuate: 1997-2006? *Energy Policy, 35*(9), 4640-4649.
Lin, B., Long, H. (2014). How to promote energy conservation in China's chemical industry. *Energy Policy, 73*(0), 93-102.
Lise, W. (2006). Decomposition of CO2 emissions over 1980-2003 in Turkey. *Energy Policy, 34*(14), 1841-1852.
Liu, F. L., Ang, B. W. (2003). Eight methods for decomposing the aggregate energy-intensity of industry. *Applied Energy, 76*(1-3), 15-23.
Liu, N., Ang, B. W. (2007). Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix. *Energy Economics, 29*(4), 609-635.
Ma, C., Stern, D. I. (2006). Environmental and ecological economics: A citation analysis. *Ecological Economics, 58*(3), 491-506.
Martín-Vide, J., Llebot, R., Padilla, E., Alcántara, V. (2007). Actividad económica y emisiones de CO2 en España *Aspectos económicos del cambio climático en España* (pp. 42-64). Barcelona: Estudios Caixa Catalunya.
OEE -Office of Energy Efficiency. (2006). *Energy efficiency trends in Canada 1990-2004*. Ottawa: Natural Resources Canada; Office of Energy Efficiency.
Paul, S., Bhattacharya, R. N. (2004). CO2 emission from energy use in India: a decomposition analysis. *Energy Policy, 32*(5), 585-593.
Roca, J. (2002). The IPAT formula and its limitations. *Ecological Economics, 42*, 1-2.
Sun, J. W. (1998). Changes in energy consumption and energy intensity: A complete decomposition model. *Energy Economics, 20*(1), 85-100.
Tornqvist, L., Vartia, P., Vartia, Y. O. (1985). How Should Relative Changes Be Measured? *The American Statistician, 39*(1), 43-46.
United Nations. (1991). *Energy statistics: a manual for developing countries*. New York: United Nations.
UPME -Unidad de Planeación Minero Energética. (2007). *Plan Energético Nacional 2006-2025*. Bogotá, D.C.: MINMINAS-UPME.
UPME -Unidad de Planeación Minero Energética. (2015). Plan Energético Nacional Colombia: Ideario energético 2050. Available at http://www.upme.gov.co/docs/pen/pen_idearioenergetico2050.pdf
UPME -Unidad de Planeación Minero Energética. (2016). Balance de Gas Natural en Colombia 2016-2025. Available at http://www.upme.gov.co/SeccionHidrocarburos_sp/Publicaciones/2016/Balance_Gas_Natural_2016_2025.pdf
Viguier, L. (1999). Emissions of $SO_2$, NOx and $CO_2$ in Transition Economies: Emission Inventories and Divisia Index Analysis. *The Energy Journal, 20*(2), 59-87.
Wang, C., Chen, J., Zou, J. (2005). Decomposition of energy-related CO2 emission in China: 1957-2000. *Energy, 30*(1), 73-83.
Zhang, F. Q., Ang, B. W. (2001). Methodological issues in cross-country/region decomposition of energy and environment indicators. *Energy Economics, 23*(2), 179-190.
Zhang, M., Mu, H., Ning, Y., Song, Y. (2009). Decomposition of energy-related CO2 emission over 1991-2006 in China. *Ecological Economics, 68*(7), 2122-2128.
Zhao, Y., Ke, J., Ni, C. C., McNeil, M., Khanna, N. Z., Zhou, N., Fridley, D., Li, Q. (2014). A comparative study of energy consumption and efficiency of Japanese and Chinese manufacturing industry. *Energy Policy, 70*, 45-56.

## Annex 1A. Review of decomposition studies and their characteristics

| Author and year | Pressure indicator | Base year | Period | Type of data | Method used | Region / Country | Decomposition effects | Sectors analyzed |
|---|---|---|---|---|---|---|---|---|
| Alcántara and Roca, 1995 | $CO_2$ and energy | 1980 | 1980 -1990 | Time series | Additive decomposition (Laspeyres) | Spain | Final energy consumption effect, energy transformation effect, final energy consumption substitution effect and interaction effect. | Economic, residential and transport sectors |
| Sun , 1998 | Energy consumption and energy intensity | | 1973-1990 | Time series | Additive decomposition (complete decomposition model) | Developing countries (without China), China, developing countries, East Europe and former USSR and world | Activity effect, intensity effect, structure and total effec | - |
| Ang and Zhang, 1999 | $CO_2$ (total and per capita) | - | 1993 | Cross-section | Additive decomposition (AMDI, LMDI and Laspeyres index) | North America, OECD Europe , OECD Pacific, Rest of the world OECD, former USSR and Central and Eastern Europe | Income effect, energy intensity effect, fuel substitution effect, and population effect | - |
| Viguier, 1999 | NOx, $SO_2$ y $CO_2$ | | 1971-2004 | Time series | Multiplicative decomposition (Divisia index method) | Hungary, Poland, Russia, France, United Kingdom and USA | Emission factors effect, fuel composition, economic structure effect and energy intensity effect | Industry, transport and other sectors |
| Zhang and Ang, 2001 | $CO_2$ | | 1993 | Cross-section | Additive decomposition (LM, RLM, AMDI, LMDI) | OECD, former Soviet Union countries along with central and eastern Europe, and rest of the world | Substitution effect, energy intensity effect, income effect, population effect, and residual effect | Agriculture, transport, industry and other sectors |
| Paul and Bhattacharya, 2004 | $CO_2$ | 1980 | 1980-1996 | Time series | Additive decomposition (conventional Divisia index) | India | Pollution coefficient effect, energy intensity effect, structure effect and economic activity effect | Industrial, residential, agricultural, transportation and other sectors |

Source: Prepared by the authors based on the reviewed literature.

Note: Laspeyres index method (LM), refined Laspeyres index method (RLM), log mean Divisia index (LMDI), arithmetic mean Divisia index (AMDI).

**Annex 1A. Review of decomposition studies and their characteristics (continuation).**

| Author and year | Pressure indicator | Base year | Period | Type of data | Method used | Region / Country | Decomposition effects | Sectors analyzed |
|---|---|---|---|---|---|---|---|---|
| Alcántara and Padilla, 2005 | $CO_2$ | 1971 | 1971-1990 | Time series | Multiplicative decomposition (Kaya identity) | North America, OECD Europe, OECD Pacific, Asia (without China), Latin America, Africa, non-OECD Europe, Middle East, World, etc | Carbonization index, energy intensity, GDP per capita and population | - |
| Wang et al., 2005 | $CO_2$ | 1957 | 1957-1979<br>1979-2000 | Time series | Additive decomposition (LMDI) | China | Energy intensity effect, income effect, fossil fuel composition effect, carbon-free fuel entry effect | - |
| Kawase et al., 2006 | $CO_2$ (capture and storage) | | 1960-2000<br>2000-2050 | Time series | Additive and multiplicative decomposition (Kaya indentity) | Japan, France, Germany, United Kingdom | Carbonization intensity effect, energy efficiency effect, energy intensity effect and economic activity effect | - |
| Lise Wietze, 2006 | $CO_2$ (total and per capita) | 1980 | 1980-2003 | Time series | Additive decomposition (Kaya identity) | Turkey | Scale effect, energy intensity effect, emission intensity effect, composition effec | Agriculture, transport, industry and services |
| Ma and Stern, 2006 | Intensidad energética | | 1980-2003 | Time series | Additive decomposition (LMDI) | China | Fuel substitution effect, technological change effect, structural change effect at the level of subsectors, sectors and industries and total effect | - |
| Martín-Vide et al., 2007 | $CO_2$ | 1960 | 1960-2003 | Time series | Multiplicative decomposition (Kaya identity) | Spain | Carbonization effect, intensity effect, activity effect, structure effect and total effect | 12 economic sectors |

Source: Prepared by the authors based on the reviewed literature.

Note: Laspeyres index method (LM), refined Laspeyres index method (RLM), log mean Divisia index (LMDI), arithmetic mean Divisia index (AMDI).

## Annex 1A. Review of decomposition studies and their characteristics (continuation).

| Author and year | Pressure indicator | Base year | Period | Type of data | Method used | Region / Country | Decomposition effects | Sectors analyzed |
|---|---|---|---|---|---|---|---|---|
| Diakoulaki and Mandaraka, 2007 | $CO_2$ | 1990 | 1990-2003 | Time series | Additive decomposition (RLM, dissociation index, dissociation readjustment index) | 14 EU countries | Production effect, energy intensity effect, structure effect, fuel substitution effect and utility composition effect | - |
| Hatzigeorgiou et al., 2008 | $CO_2$ | 1990 | 1990-2002 | Time series | Additive decomposition (AMDI, LMDI) | Greece | Income effect, energy intensity effect, carbonization effect, and population effect | - |
| Zhang et al., 2009 | $CO_2$ | 1991 | 1991-2006 | Time series | Additive and multiplicative decomposition (Kaya indentity) | China | $CO_2$ intensity effect, energy intensity, structural change and economic activity | Agriculture, transport, industry, other sectors and tota |
| Baležentis et al. (2011) | Energy consumption | | 1995-2009 | Time series | LMDI decomposition | Lithuania | Activity effect, structure effect and intensity effect | Agriculture, industry, transportation, and the rest of the economy |
| Duro and Padilla, 2006 | Theil index CO2 per capita | 2000 | 1990 - 2009 | Time series | LMDI decomposition (Kaya identity) | UE-27, North Europe, South Europe, East Europe | Carbonization effect, intensity effect, economic affluence effect and population effect | - |
| Lin and Long, 2014 | Fossil energy consumption | 1981 | 1981-2010 | Time series | LMDI decomposition | China | Intensity effect, structure effect, productivity effect and scale effect | Chemical industry |
| Zhao et al., 2014 | Energy consumption | 2005 | 1965-2010<br>1980-2010 | Time series | LMDI decomposition | Japan and China | Production effect, intensity effect and structure eff | Industrial sector |

Source: Prepared by the authors based on the reviewed literature.

Note: Laspeyres index method (LM), refined Laspeyres index method (RLM), log mean Divisia index (LMDI), arithmetic mean Divisia index (AMDI).

# Annex 2A. Redefinition of energy balances according to Alcántara and Roca (1995).

**Energy inputs and outputs in Colombia. Colombia 2010**

Millions of tons of oil equivalent

| | Product / Flow | Coal and coal products | Crude, LNG and raw materials | Refined oil imports | Electricity import | Hydroelectric power | Renewable fuels and waste | Natural gas | Oil derivatives | Electricity | Intermediate consumption | Exports | Transference | Statistical differences | Final consumption of energy | Total consumption of energy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coal and coal products | 0.529234 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.043547 | 1.572781 | 0 | 0 | 0.552716 | 1.092158 | **3.21766** |
| 2 | Crude, LNG and raw materials | 0 | 0.335998 | 0 | 0 | 0 | 0 | 0 | 15.572975 | 0 | 15.90897 | 0 | 0.266 | 1.364174 | 0.325908 | **17.865** |
| 3 | Refined oil imports | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.487951 | 0 | 2.487951 | 0 | 0 | 0 | 0 | **2.48795** |
| 4 | Electricity imports | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00086 | 0.00086 | 0 | 0 | 0 | 0 | **0.00086** |
| 5 | Hydroelectric power | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.474486 | 3.474486 | 0 | 0 | 0 | 0 | **3.47449** |
| 6 | Renewable fuels and waste | 0 | 0 | 0 | 0 | 0 | 0.020092 | 0 | 0 | 0.137727 | 0.157819 | 0 | 0 | 0.011297 | 3.144325 | **3.31344** |
| 7 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 1.891808 | 0 | 2.304158 | 4.195966 | 0 | 0 | 0.451118 | 3.580084 | **8.22717** |
| 8 | Oil derivatives | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.545848 | 0.143908 | 0.689756 | 6.13595 | -0.26 | 0.13464 | 10.167215 | **16.8716** |
| 9 | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.882876 | 0.882876 | 0.06863 | 0 | -0.173032 | 4.1065 | **4.88497** |
| | Intermediate consumption | 0.529234 | 0.335998 | 0 | 0 | 0 | 0.020092 | 1.891808 | 18.606774 | 7.987562 | 29.37147 | 6.20458 | 0.01 | 2.340913 | 22.41619 | **60.3432** |
| | **Total uses of (primary and secondary) energy** | | | | | | | | | | | | | | | |
| | Production | 48.327145 | 40.922808 | 0 | 0 | 3.474486 | 3.313441 | 9.422376 | 14.530604 | 4.884112 | | | | | | 124.875 |
| | Import balance | -45.109489 | -23.074924 | 2.487951 | 0.00086 | 0 | 0 | -1.19521 | 2.487951 | 0.00086 | | | | | | -64.402 |
| | Reserve variation | 0 | 0.017153 | 0 | 0 | 0 | 0 | 0 | -0.146965 | 0 | | | | | | -0.1298 |
| | Energy needs | **3.217656** | **17.865037** | **2.487951** | **0.00086** | **3.474486** | **3.313441** | **8.227167** | **16.87159** | **4.884972** | | | | | | **60.3432** |

**Matrix of direct energy relations (technical coefficients of energy)**

Millions of tons of oil equivalent

| | Product / Flow | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coal and coal products | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.214 |
| 2 | Crude, LNG and raw materials | 0 | 0.01880757 | 0 | 0 | 0 | 0 | 0 | 0.923029374 | 0 |
| 3 | Refined oil imports | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.147463914 | 0 |
| 4 | Electricity imports | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Hydroelectric power | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.711 |
| 6 | Renewable fuels and waste | 0 | 0 | 0 | 0 | 0 | 0.006063787 | 0 | 0 | 0.028 |
| 7 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0.229946 | 0 | 0.472 |
| 8 | Oil derivatives | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.032353082 | 0.029 |
| 9 | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.181 |
| | Intermediate consumption | 0.16447817 | 0.01880757 | 0 | 0 | 0 | 0.006063787 | 0.229946 | 1.10284637 | 1.635 |

**Matrix of total energy relations (inverse of Leontief) of primary energy**

Millions of tons of oil equivalent

| | Product / Flow | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coal and coal products | 1.19685682 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.312 |
| 2 | Crude, LNG and raw materials | 0 | 1.01916808 | 0 | 0 | 0 | 0 | 0 | 0.97217493 | 0.035 |
| 3 | Refined oil imports | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.152394341 | 0.005 |
| 4 | Electricity imports | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.000 |
| 5 | Hydroelectric power | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0.868 |
| 6 | Renewable fuels and waste | 0 | 0 | 0 | 0 | 0 | 1.006100781 | 0 | 0 | 0.035 |
| 7 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 1.298611 | 0 | 0.748 |
| 8 | Oil derivatives | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.033434801 | 0.037 |
| 9 | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.221 |

**Matrix of total primary energy needs (without double counting)**

Millions of tons of oil equivalent

| | Product / Flow | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Final energy | Total* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coal and coal products | 1.19685682 | 0 | 0 | 0 | 0 | 0 | 0.312081 | 1.09 | 4.4 |
| 2 | Crude, LNG and raw materials | 0 | 1.01916808 | 0 | 0 | 0 | 0.97217493 | 0.034958 | 0.33 | 3.7 |
| 3 | Refined oil imports | 0 | 0 | 0 | 0 | 0 | 0.152394341 | 0.00548 | 3.58 | 0.5 |
| 4 | Electricity imports | 0 | 0 | 0 | 0 | 0 | 0 | 0.000215 | 4.11 | 0 |
| 5 | Hydroelectric power | 0 | 0 | 1 | 0 | 0 | 0 | 0.868167 | 0 | 12.4 |
| 6 | Renewable fuels and waste | 0 | 0 | 0 | 1.006101 | 0 | 0 | 0.034624 | 3.14 | 4.4 |
| 7 | Natural gas | 0 | 0 | 0 | 0 | 1.29861097 | 0 | 0.747659 | 10.17 | 7 |
| | Total primary energy | | | | | | | | | 32 |

* Verification test.The total primary energy in Energy Balances is 32 Mtoe

Source: Prepared by the authors with IEA (2014) data.

## Annex 3A. Summary table of the total primary energy vector.

| Year | Agriculture, forestry and fishing | Food and tobacco | Textiles and leathers | Wood and wood products | Paper and printing | Chemistry and petrochemical | Nonmetallic minerals | Iron, steel and non-ferrous metals | Non-specific industry | Machinery and equipment | Construction | Other sectors | Road transport sector | Water transport sector | Air transport sector |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 0.9077 | 0.9585 | 0.6292 | 0.0350 | 0.4096 | 0.7048 | 1.3681 | 0.2496 | 0.2722 | 0.0787 | 0.0685 | 1.3334 | 3.5338 | 0.0281 | 0.0450 |
| 1976 | 0.9793 | 1.0116 | 0.6867 | 0.0328 | 0.4346 | 0.7747 | 1.4160 | 0.2610 | 0.2254 | 0.0900 | 0.0999 | 1.4256 | 3.7593 | 0.0303 | 0.0412 |
| 1977 | 0.9834 | 1.0164 | 0.6677 | 0.0373 | 0.4515 | 1.0320 | 1.4700 | 0.2271 | 0.2178 | 0.0908 | 0.1073 | 1.1507 | 3.8607 | 0.0311 | 0.0431 |
| 1978 | 1.0625 | 1.0459 | 0.6889 | 0.0589 | 0.4944 | 1.1157 | 1.7645 | 0.2843 | 0.2332 | 0.1018 | 0.0962 | 1.0503 | 4.0842 | 0.0307 | 0.0426 |
| 1979 | 1.0922 | 1.1387 | 0.5841 | 0.0295 | 0.5027 | 1.1438 | 1.7415 | 0.2946 | 0.2529 | 0.1105 | 0.1175 | 1.0885 | 4.4999 | 0.0360 | 0.0437 |
| 1980 | 1.0958 | 1.1812 | 0.5158 | 0.0353 | 0.5009 | 1.1621 | 1.7742 | 0.3077 | 0.2619 | 0.1142 | 0.1402 | 1.4954 | 4.5882 | 0.0383 | 0.0448 |
| 1981 | 1.0819 | 1.1550 | 0.4886 | 0.0339 | 0.5071 | 1.5537 | 1.8142 | 0.2876 | 0.0257 | 0.1030 | 0.1561 | 1.2220 | 4.6796 | 0.0397 | 0.0476 |
| 1982 | 1.1556 | 1.1637 | 0.3977 | 0.0312 | 0.4868 | 1.5230 | 1.7490 | 0.3220 | 0.0250 | 0.1045 | 0.1841 | 1.4406 | 4.8530 | 0.0418 | 0.0459 |
| 1983 | 0.9495 | 1.2848 | 0.3872 | 0.0295 | 0.5578 | 1.5452 | 1.6048 | 0.4960 | 0.2020 | 0.1094 | 0.1412 | 1.3768 | 4.9972 | 0.0446 | 0.0427 |
| 1984 | 1.0575 | 1.1858 | 0.4305 | 0.0270 | 0.5995 | 1.6056 | 1.6580 | 0.5055 | 0.2124 | 0.1126 | 0.1761 | 1.3242 | 5.2726 | 0.0443 | 0.0336 |
| 1985 | 1.0671 | 1.4009 | 0.4559 | 0.0319 | 0.6533 | 1.3897 | 1.7390 | 0.5057 | 0.2239 | 0.1445 | 0.1391 | 1.4863 | 5.3410 | 0.0457 | 0.0317 |
| 1986 | 1.1855 | 1.3246 | 0.4348 | 0.0347 | 0.6274 | 1.4734 | 1.7252 | 0.5212 | 0.2078 | 0.1167 | 0.1686 | 1.7161 | 5.9791 | 0.0502 | 0.0348 |
| 1987 | 1.1546 | 1.4381 | 0.4431 | 0.0430 | 0.5633 | 1.3500 | 1.8289 | 0.4724 | 0.4123 | 0.2036 | 0.1009 | 2.0265 | 5.5906 | 0.0513 | 0.0254 |
| 1988 | 1.4300 | 1.3700 | 0.4534 | 0.0440 | 0.6358 | 1.5362 | 1.8584 | 0.4551 | 0.2127 | 0.1904 | 0.1058 | 1.9008 | 6.3476 | 0.0553 | 0.0407 |
| 1989 | 1.4583 | 1.3357 | 0.4272 | 0.0362 | 0.6119 | 1.6844 | 1.9497 | 0.5475 | 0.3219 | 0.1896 | 0.0874 | 1.6764 | 4.9605 | 0.9416 | 0.0402 |
| 1990 | 1.4742 | 1.5397 | 0.4516 | 0.0371 | 0.6629 | 1.5849 | 1.9958 | 0.4996 | 0.2183 | 0.1620 | 0.1111 | 1.6744 | 6.1377 | 0.1466 | 0.0267 |
| 1991 | 1.0895 | 1.6833 | 0.4748 | 0.0380 | 0.6940 | 1.8185 | 1.9796 | 0.5205 | 0.2854 | 0.2041 | 0.1026 | 1.7734 | 6.2548 | 0.1542 | 0.0260 |
| 1992 | 1.8462 | 1.3193 | 0.5901 | 0.0466 | 0.7739 | 1.7028 | 1.8816 | 0.5628 | 0.1966 | 0.2000 | 0.0537 | 2.2362 | 6.7118 | 0.1684 | 0.0324 |
| 1993 | 1.5744 | 1.4416 | 0.6129 | 0.0474 | 0.8294 | 2.7618 | 2.2324 | 0.5760 | 0.1763 | 0.2116 | 0.0493 | 2.2267 | 6.6072 | 0.1882 | 0.0234 |
| 1994 | 1.7174 | 1.4532 | 0.6090 | 0.1496 | 0.7512 | 2.8636 | 2.2819 | 0.6065 | 0.2411 | 0.2177 | 0.1065 | 2.8989 | 5.8607 | 0.1795 | 0.0201 |
| 1995 | 1.7657 | 1.4985 | 0.6990 | 0.1523 | 0.7960 | 2.9217 | 1.7837 | 0.9356 | 0.2770 | 0.3102 | 0.1228 | 2.1822 | 7.0502 | 0.2067 | 0.0236 |
| 1996 | 1.7039 | 1.5041 | 0.6985 | 0.1620 | 0.8149 | 3.2772 | 1.8969 | 0.9458 | 0.2917 | 0.2515 | 0.1260 | 2.2701 | 7.0052 | 0.2244 | 0.0229 |
| 1997 | 1.7159 | 1.6655 | 0.7883 | 0.1777 | 0.8777 | 3.2012 | 1.9775 | 0.9958 | 0.3157 | 0.3384 | 0.1361 | 2.2121 | 7.5501 | 0.1756 | 0.0472 |
| 1998 | 1.8726 | 1.6856 | 0.8009 | 0.1707 | 0.8831 | 3.4998 | 1.9861 | 1.0687 | 0.3251 | 0.3124 | 0.1371 | 2.4269 | 7.3342 | 0.1721 | 0.0457 |
| 1999 | 1.5289 | 1.4478 | 0.6570 | 0.1283 | 0.8065 | 3.2995 | 1.8913 | 0.8883 | 0.2677 | 0.2163 | 0.0994 | 2.3171 | 6.4838 | 0.1524 | 0.0443 |
| 2000 | 1.4053 | 1.4510 | 0.7531 | 0.0967 | 0.9270 | 3.4297 | 2.0565 | 1.0273 | 0.2580 | 0.3703 | 0.0670 | 2.3615 | 6.2818 | 0.1621 | 0.0422 |
| 2001 | 1.3889 | 1.4142 | 0.6743 | 0.0710 | 0.9111 | 3.5571 | 2.1214 | 0.9559 | 0.2216 | 0.3883 | 0.0679 | 1.8101 | 6.6109 | 0.1973 | 0.0417 |
| 2002 | 1.4664 | 1.3408 | 0.6810 | 0.1387 | 1.6911 | 3.4369 | 1.3520 | 0.8768 | 0.3158 | 0.4593 | 0.0711 | 1.9618 | 5.8980 | 0.1561 | 0.0404 |
| 2003 | 1.4553 | 1.4976 | 0.6441 | 0.0781 | 0.8336 | 3.7418 | 2.0792 | 0.9062 | 0.2886 | 0.2364 | 0.0696 | 2.0700 | 6.4039 | 0.2079 | 0.0431 |
| 2004 | 1.5321 | 1.3973 | 0.6272 | 0.0720 | 0.7962 | 3.5433 | 1.9859 | 0.8813 | 0.2741 | 0.2024 | 0.0753 | 1.8194 | 6.8212 | 0.1994 | 0.0410 |
| 2005 | 1.4667 | 1.4058 | 0.6280 | 0.0789 | 0.8168 | 3.5339 | 2.0743 | 0.8967 | 0.2688 | 0.1954 | 0.1415 | 1.8658 | 6.9984 | 0.2096 | 0.0394 |
| 2006 | 1.3803 | 1.4023 | 0.6054 | 0.0716 | 0.7483 | 3.4501 | 1.8343 | 0.8603 | 0.2764 | 0.1932 | 0.0670 | 1.9352 | 7.3935 | 0.2317 | 0.0398 |
| 2007 | 1.3893 | 1.5733 | 0.6506 | 0.0746 | 0.7999 | 3.5004 | 1.9569 | 0.9361 | 0.3084 | 0.2130 | 0.0918 | 2.0477 | 8.6150 | 0.2605 | 0.0435 |
| 2008 | 1.4733 | 1.6028 | 0.6445 | 0.0849 | 0.8287 | 3.8119 | 2.2562 | 0.9727 | 0.3349 | 0.1694 | 0.0984 | 1.9518 | 8.8915 | 0.2789 | 0.0449 |
| 2009 | 1.9565 | 1.5022 | 0.6529 | 0.0783 | 0.8596 | 3.3059 | 1.9998 | 0.9453 | 0.2164 | 0.1594 | 0.0572 | 2.3613 | 8.0301 | 0.2703 | 0.0383 |
| 2010 | 1.9279 | 1.4320 | 0.6264 | 0.0831 | 0.7180 | 3.1493 | 1.8561 | 0.8686 | 0.2497 | 0.2039 | 0.0846 | 2.5702 | 8.0827 | 0.2632 | 0.0370 |
| Average growth rate 1975-2010 | 2.11 | 1.12 | -0.01 | 2.43 | 1.57 | 4.25 | 0.85 | 3.52 | -0.24 | 2.68 | 0.59 | 1.84 | 2.32 | 6.41 | -0.54 |

Source: Prepared by the authors following the method described in the text with IEA (2014) data.

## Annex 4A. Decomposition into six factors of the growth of $CO_2$ emissions.

| Year | Sectoral CO2 (Mton) | GDP (billions of 2005 U$ PPP) | Fossil primary Energy (Mtoe) | Total primary energy supply (Mtoe) | Total final energy Consumption (Mtoe) | Population (Millions) | $CO_{2}t$ - $CO_{2}t$-1 | Carboni-zation effect | Substitution effect | Transformation effect | Energy intensity effect | Affluence effect | Population effect | Total effect | Carboni-zation effect | Substitution effect | Transformation effect | Energy intensity effect | Affluence effect | Population effect | Total effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | 26.68 | 88.21 | 8.86 | 13.85 | 11.63 | 23.07 | | | | | | | | | | | | | | | |
| 1972 | 27.33 | 94.97 | 9.43 | 13.86 | 11.30 | 23.62 | 0.65 | -1.06 | 1.68 | 0.80 | -2.77 | 1.36 | 0.64 | 0.65 | -162.3 | 258.6 | 123.2 | -425.8 | 208.6 | 97.8 | 100 |
| 1973 | 28.64 | 101.36 | 9.86 | 13.95 | 11.18 | 24.17 | 1.96 | -1.01 | 2.78 | 1.29 | -4.94 | 2.55 | 1.29 | 1.96 | -51.6 | 142.0 | 65.7 | -252.3 | 130.4 | 65.7 | 100 |
| 1974 | 30.75 | 107.18 | 10.69 | 14.77 | 11.88 | 24.73 | 4.07 | -1.32 | 3.56 | 1.24 | -4.98 | 3.59 | 1.99 | 4.07 | -32.4 | 87.3 | 30.3 | -122.2 | 88.2 | 48.9 | 100 |
| 1975 | 28.32 | 109.59 | 10.34 | 15.44 | 12.45 | 25.30 | 1.64 | -2.62 | 1.29 | 1.10 | -4.09 | 3.43 | 2.54 | 1.64 | -160.0 | 78.4 | 67.2 | -249.6 | 209.2 | 154.7 | 100 |
| 1976 | 30.04 | 114.87 | 10.91 | 16.05 | 12.93 | 25.89 | 3.36 | -2.56 | 1.74 | 1.17 | -4.48 | 4.21 | 3.27 | 3.36 | -76.2 | 51.9 | 34.9 | -133.4 | 125.5 | 97.3 | 100 |
| 1977 | 30.99 | 119.64 | 11.24 | 16.53 | 13.20 | 26.49 | 4.31 | -2.54 | 1.77 | 1.45 | -5.14 | 4.79 | 3.98 | 4.31 | -58.9 | 41.1 | 33.6 | -119.1 | 111.1 | 92.2 | 100 |
| 1978 | 33.10 | 129.76 | 10.87 | 16.46 | 13.67 | 27.11 | 6.42 | 0.32 | 0.96 | 0.32 | -6.68 | 6.69 | 4.80 | 6.42 | 5.0 | 14.9 | 5.0 | -104.0 | 104.2 | 74.9 | 100 |
| 1979 | 33.52 | 136.75 | 10.28 | 16.07 | 13.84 | 27.73 | 6.84 | 2.36 | 0.02 | -0.76 | -7.92 | 7.63 | 5.51 | 6.84 | 34.5 | 0.3 | -11.1 | -115.8 | 111.5 | 80.6 | 100 |
| 1980 | 35.03 | 142.35 | 11.75 | 17.71 | 14.38 | 28.36 | 8.35 | -0.31 | 1.13 | 1.02 | -8.16 | 8.34 | 6.33 | 8.35 | -3.7 | 13.5 | 12.2 | -97.8 | 100.0 | 75.8 | 100 |
| 1981 | 35.19 | 145.57 | 12.02 | 17.94 | 14.27 | 28.99 | 8.51 | -0.89 | 1.45 | 1.65 | -9.10 | 8.38 | 7.02 | 8.51 | -10.5 | 17.1 | 19.4 | -107.0 | 98.5 | 82.5 | 100 |
| 1982 | 35.74 | 146.96 | 12.32 | 18.45 | 14.64 | 29.62 | 9.06 | -1.16 | 1.34 | 1.75 | -8.69 | 8.07 | 7.75 | 9.06 | -12.8 | 14.8 | 19.3 | -95.9 | 89.1 | 85.5 | 100 |
| 1983 | 37.63 | 149.28 | 12.91 | 19.05 | 14.99 | 30.27 | 10.95 | -1.05 | 1.86 | 2.07 | -8.67 | 8.10 | 8.65 | 10.95 | -9.6 | 17.0 | 18.9 | -79.2 | 74.0 | 79.0 | 100 |
| 1984 | 38.00 | 154.29 | 13.26 | 19.69 | 15.43 | 30.91 | 11.32 | -1.60 | 1.67 | 2.20 | -8.84 | 8.53 | 9.36 | 11.32 | -14.1 | 14.7 | 19.5 | -78.1 | 75.4 | 82.7 | 100 |
| 1985 | 39.57 | 159.06 | 13.29 | 19.99 | 15.88 | 31.56 | 12.89 | -0.39 | 1.28 | 1.81 | -9.10 | 9.03 | 10.25 | 12.89 | -3.0 | 9.9 | 14.1 | -70.6 | 70.1 | 79.5 | 100 |
| 1986 | 40.26 | 168.34 | 14.76 | 21.76 | 16.34 | 32.22 | 13.58 | -3.282 | 1.95 | 3.69 | -10.11 | 10.30 | 11.03 | 13.58 | -24.2 | 14.3 | 27.2 | -74.5 | 75.9 | 81.2 | 100 |
| 1987 | 42.63 | 177.39 | 15.23 | 22.50 | 17.15 | 32.88 | 15.95 | -2.50 | 1.95 | 3.28 | -10.55 | 11.72 | 12.06 | 15.95 | -15.7 | 12.2 | 20.6 | -66.1 | 73.4 | 75.6 | 100 |
| 1988 | 43.42 | 184.59 | 15.64 | 23.18 | 17.74 | 33.54 | 16.74 | -2.81 | 1.85 | 3.18 | -10.86 | 12.52 | 12.86 | 16.74 | -16.8 | 11.1 | 19.0 | -64.9 | 74.8 | 76.8 | 100 |
| 1989 | 45.22 | 190.9 | 15.56 | 23.37 | 18.59 | 34.21 | 18.54 | -1.26 | 1.43 | 1.89 | -10.64 | 13.28 | 13.84 | 18.54 | -6.8 | 7.7 | 10.2 | -57.4 | 71.6 | 74.7 | 100 |
| 1990 | 46.23 | 202.43 | 16.32 | 24.22 | 18.92 | 34.88 | 19.55 | -2.19 | 1.86 | 2.57 | -12.24 | 14.84 | 14.70 | 19.55 | -11.2 | 9.5 | 13.2 | -62.6 | 75.9 | 75.2 | 100 |
| 1991 | 48.02 | 207.04 | 16.71 | 24.49 | 19.31 | 35.55 | 21.34 | -1.70 | 2.35 | 2.28 | -12.58 | 15.28 | 15.70 | 21.34 | -8.0 | 11.0 | 10.7 | -58.9 | 71.6 | 73.6 | 100 |
| 1992 | 50.08 | 217.46 | 17.73 | 25.05 | 19.25 | 36.22 | 23.40 | -2.40 | 3.79 | 3.28 | -14.80 | 16.77 | 16.76 | 23.40 | -10.3 | 16.2 | 14.0 | -63.3 | 71.7 | 71.6 | 100 |
| 1993 | 55.68 | 222.6 | 18.43 | 26.20 | 20.87 | 36.90 | 29.00 | 0.11 | 3.77 | 2.07 | -13.44 | 17.97 | 18.51 | 29.00 | 0.4 | 13.0 | 7.1 | -46.3 | 62.0 | 63.8 | 100 |
| 1994 | 56.11 | 235.59 | 18.76 | 27.12 | 21.93 | 37.58 | 29.43 | -0.29 | 3.12 | 1.50 | -13.79 | 19.57 | 19.32 | 29.43 | -1.0 | 10.6 | 5.1 | -46.9 | 66.5 | 65.6 | 100 |
| 1995 | 58.41 | 247.85 | 19.18 | 27.60 | 22.50 | 38.26 | 31.73 | 0.43 | 3.38 | 1.19 | -15.11 | 21.35 | 20.48 | 31.73 | 1.4 | 10.7 | 3.8 | -47.6 | 67.3 | 64.6 | 100 |
| 1996 | 59.26 | 252.95 | 19.76 | 28.27 | 23.46 | 38.95 | 32.58 | -0.19 | 3.64 | 0.48 | -14.36 | 21.63 | 21.38 | 32.58 | -0.6 | 11.2 | 1.5 | -44.1 | 66.4 | 65.6 | 100 |
| 1997 | 63.23 | 261.62 | 20.81 | 27.43 | 22.29 | 39.63 | 36.55 | 0.37 | 7.24 | 1.38 | -18.49 | 23.13 | 22.92 | 36.55 | 1.0 | 19.8 | 3.8 | -50.6 | 63.3 | 62.7 | 100 |
| 1998 | 64.27 | 263.11 | 22.19 | 28.73 | 22.14 | 40.32 | 37.59 | -1.69 | 8.09 | 3.66 | -19.20 | 22.85 | 23.87 | 37.59 | -4.5 | 21.5 | 9.7 | -51.1 | 60.8 | 63.5 | 100 |
| 1999 | 56.75 | 252.05 | 18.89 | 25.69 | 20.90 | 41.00 | 30.07 | -0.11 | 5.57 | 1.27 | -18.48 | 18.92 | 22.91 | 30.07 | -0.4 | 18.5 | 4.2 | -61.5 | 62.9 | 76.2 | 100 |
| 2000 | 59.18 | 263.19 | 19.62 | 25.81 | 21.13 | 41.68 | 32.50 | 0.04 | 7.06 | 1.04 | -20.24 | 20.46 | 24.13 | 32.50 | 0.1 | 21.7 | 3.2 | -62.3 | 63.0 | 74.3 | 100 |
| 2001 | 59.35 | 267.61 | 19.71 | 25.71 | 21.17 | 42.35 | 32.67 | -0.02 | 7.42 | 0.80 | -20.88 | 20.53 | 24.82 | 32.67 | -0.1 | 22.7 | 2.5 | -63.9 | 62.8 | 76.0 | 100 |
| 2002 | 57.22 | 274.31 | 18.89 | 25.20 | 20.85 | 43.02 | 30.54 | 0.22 | 6.36 | 0.59 | -22.04 | 20.47 | 24.94 | 30.54 | 0.7 | 20.8 | 1.9 | -72.2 | 67.0 | 81.7 | 100 |
| 2003 | 56.53 | 285.06 | 19.04 | 25.74 | 21.07 | 43.68 | 29.85 | -0.57 | 5.80 | 1.01 | -23.01 | 21.25 | 25.38 | 29.85 | -1.9 | 19.4 | 3.4 | -77.1 | 71.2 | 85.0 | 100 |
| 2004 | 56.74 | 300.26 | 19.48 | 26.00 | 21.33 | 44.32 | 30.06 | -1.34 | 6.32 | 0.92 | -24.63 | 22.79 | 26.01 | 30.06 | -4.5 | 21.0 | 3.1 | -81.9 | 75.8 | 86.5 | 100 |
| 2005 | 58.05 | 314.39 | 20.56 | 27.08 | 21.69 | 44.95 | 31.37 | -2.62 | 6.93 | 1.91 | -26.14 | 24.37 | 26.92 | 31.37 | -8.4 | 22.1 | 6.1 | -83.3 | 77.7 | 85.8 | 100 |
| 2006 | 58.14 | 335.45 | 21.53 | 28.57 | 22.24 | 45.56 | 31.46 | -4.42 | 6.64 | 3.05 | -27.76 | 26.47 | 27.48 | 31.46 | -14.0 | 21.1 | 9.7 | -88.2 | 84.1 | 87.4 | 100 |
| 2007 | 58.42 | 358.6 | 20.68 | 27.92 | 22.49 | 46.12 | 31.74 | -2.60 | 5.96 | 1.69 | -30.10 | 28.74 | 28.05 | 31.74 | -8.2 | 18.8 | 5.3 | -94.8 | 90.6 | 88.4 | 100 |
| 2008 | 59.28 | 371.32 | 21.80 | 29.21 | 23.52 | 45.01 | 32.60 | -4.17 | 6.31 | 1.71 | -29.94 | 31.40 | 27.29 | 32.60 | -12.8 | 19.4 | 5.2 | -91.8 | 96.3 | 83.7 | 100 |
| 2009 | 62.17 | 377.45 | 23.85 | 30.82 | 22.48 | 45.65 | 35.49 | -6.07 | 8.01 | 5.89 | -33.33 | 32.36 | 28.63 | 35.49 | -17.1 | 22.6 | 16.6 | -93.9 | 91.2 | 80.7 | 100 |
| 2010 | 62.24 | 392.55 | 25.51 | 32.24 | 22.42 | 46.30 | 35.56 | -8.86 | 8.96 | 7.91 | -35.13 | 33.43 | 29.24 | 35.56 | -24.9 | 25.2 | 22.3 | -98.8 | 94.0 | 82.2 | 100 |

Source: Prepared by the authors following the methodology described in the text with IEA (2014) data.

## Annex 5A. Decomposition of energy intensity into two factors.

| | Structure effect | | | | | Intensity effect | | | | | Sectoral | Sectoral | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Agriculture | Industry | Construction | Other sectors | Transport | Agriculture | Industry | Construction | Other sectors | Transport | structure effect | intensity effect | effect |
| 1975 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1976 | 0.999 | 0.999 | 1.000 | 1.000 | 1.005 | 1.004 | 1.003 | 1.002 | 1.003 | 1.001 | 1.0028 | 1.0123 | 1.0151 |
| 1977 | 0.998 | 0.988 | 1.001 | 1.001 | 1.020 | 1.001 | 1.019 | 1.002 | 0.973 | 0.981 | 1.0069 | 0.9762 | 0.9829 |
| 1978 | 0.999 | 0.994 | 1.000 | 1.002 | 1.034 | 1.002 | 1.037 | 1.002 | 0.959 | 0.968 | 1.0290 | 0.9665 | 0.9945 |
| 1979 | 0.999 | 0.997 | 0.999 | 1.002 | 1.044 | 1.001 | 1.015 | 1.003 | 0.959 | 0.977 | 1.0417 | 0.9564 | 0.9963 |
| 1980 | 0.996 | 0.992 | 1.000 | 1.001 | 1.038 | 0.997 | 0.987 | 1.004 | 0.981 | 0.961 | 1.0270 | 0.9324 | 0.9576 |
| 1981 | 0.997 | 0.960 | 1.000 | 1.003 | 1.043 | 0.995 | 1.025 | 1.004 | 0.959 | 0.961 | 1.0024 | 0.9441 | 0.9463 |
| 1982 | 0.994 | 0.952 | 1.001 | 1.004 | 1.056 | 1.001 | 1.010 | 1.006 | 0.971 | 0.952 | 1.0033 | 0.9407 | 0.9438 |
| 1983 | 0.994 | 0.942 | 1.001 | 1.003 | 1.044 | 0.984 | 1.041 | 1.002 | 0.966 | 0.966 | 0.9817 | 0.9574 | 0.9399 |
| 1984 | 0.993 | 0.956 | 1.002 | 1.000 | 1.041 | 0.991 | 1.019 | 1.003 | 0.961 | 0.973 | 0.9897 | 0.9477 | 0.9379 |
| 1985 | 0.991 | 0.951 | 1.002 | 0.998 | 1.031 | 0.990 | 1.022 | 1.001 | 0.970 | 0.975 | 0.9726 | 0.9582 | 0.9319 |
| 1986 | 0.989 | 0.950 | 1.002 | 0.996 | 1.012 | 0.996 | 0.993 | 1.002 | 0.981 | 1.013 | 0.9491 | 0.9841 | 0.9340 |
| 1987 | 0.990 | 0.954 | 1.000 | 0.996 | 1.006 | 0.989 | 0.985 | 0.999 | 0.994 | 0.977 | 0.9470 | 0.9454 | 0.8952 |
| 1988 | 0.987 | 0.942 | 1.001 | 0.997 | 1.000 | 1.005 | 0.980 | 0.998 | 0.980 | 1.011 | 0.9275 | 0.9743 | 0.9037 |
| 1989 | 0.988 | 0.955 | 1.000 | 0.996 | 1.000 | 1.002 | 0.967 | 0.998 | 0.963 | 0.967 | 0.9395 | 0.9000 | 0.8455 |
| 1990 | 0.990 | 0.963 | 0.999 | 0.997 | 1.002 | 0.997 | 0.946 | 1.000 | 0.958 | 0.972 | 0.9516 | 0.8784 | 0.8359 |
| 1991 | 0.992 | 0.946 | 1.000 | 0.998 | 0.994 | 0.972 | 0.978 | 0.999 | 0.959 | 0.975 | 0.9308 | 0.8880 | 0.8265 |
| 1992 | 0.989 | 0.932 | 1.000 | 1.001 | 1.009 | 1.013 | 0.962 | 0.996 | 0.978 | 0.975 | 0.9308 | 0.9250 | 0.8610 |
| 1993 | 0.987 | 0.898 | 1.000 | 1.003 | 0.998 | 0.997 | 1.061 | 0.995 | 0.970 | 0.965 | 0.8872 | 0.9849 | 0.8739 |
| 1994 | 0.984 | 0.878 | 1.001 | 1.007 | 0.994 | 1.002 | 1.072 | 0.997 | 0.989 | 0.918 | 0.8652 | 0.9732 | 0.8420 |
| 1995 | 0.983 | 0.875 | 1.000 | 1.007 | 0.996 | 1.001 | 1.061 | 0.998 | 0.953 | 0.952 | 0.8622 | 0.9615 | 0.8289 |
| 1996 | 0.979 | 0.860 | 0.999 | 1.010 | 1.002 | 1.002 | 1.094 | 0.999 | 0.951 | 0.941 | 0.8514 | 0.9795 | 0.8339 |
| 1997 | 0.976 | 0.850 | 0.999 | 1.012 | 1.011 | 1.003 | 1.115 | 0.999 | 0.945 | 0.943 | 0.8478 | 0.9962 | 0.8445 |
| 1998 | 0.975 | 0.846 | 0.999 | 1.011 | 1.017 | 1.009 | 1.134 | 1.000 | 0.954 | 0.927 | 0.8474 | 1.0113 | 0.8570 |
| 1999 | 0.978 | 0.830 | 0.997 | 1.010 | 1.027 | 0.994 | 1.121 | 1.000 | 0.953 | 0.895 | 0.8406 | 0.9494 | 0.7981 |
| 2000 | 0.981 | 0.862 | 0.998 | 1.010 | 1.026 | 0.984 | 1.107 | 0.998 | 0.953 | 0.883 | 0.8753 | 0.9145 | 0.8005 |
| 2001 | 0.982 | 0.868 | 0.998 | 1.009 | 1.034 | 0.982 | 1.090 | 0.998 | 0.929 | 0.886 | 0.8873 | 0.8791 | 0.7800 |
| 2002 | 0.983 | 0.865 | 0.998 | 1.010 | 1.033 | 0.982 | 1.079 | 0.997 | 0.932 | 0.850 | 0.8846 | 0.8369 | 0.7403 |
| 2003 | 0.982 | 0.871 | 0.998 | 1.009 | 1.036 | 0.979 | 1.054 | 0.997 | 0.934 | 0.859 | 0.8936 | 0.8252 | 0.7375 |
| 2004 | 0.980 | 0.884 | 0.999 | 1.008 | 1.045 | 0.981 | 0.992 | 0.997 | 0.919 | 0.850 | 0.9115 | 0.7576 | 0.6906 |
| 2005 | 0.979 | 0.883 | 0.998 | 1.008 | 1.056 | 0.976 | 0.978 | 1.000 | 0.917 | 0.835 | 0.9192 | 0.7301 | 0.6712 |
| 2006 | 0.977 | 0.887 | 0.999 | 1.008 | 1.073 | 0.970 | 0.930 | 0.996 | 0.913 | 0.817 | 0.9369 | 0.6696 | 0.6274 |
| 2007 | 0.976 | 0.892 | 0.999 | 1.008 | 1.092 | 0.969 | 0.926 | 0.996 | 0.914 | 0.827 | 0.9567 | 0.6751 | 0.6459 |
| 2008 | 0.973 | 0.880 | 0.999 | 1.008 | 1.096 | 0.973 | 0.951 | 0.996 | 0.909 | 0.824 | 0.9444 | 0.6903 | 0.6519 |
| 2009 | 0.967 | 0.859 | 1.000 | 1.010 | 1.081 | 0.993 | 0.930 | 0.994 | 0.917 | 0.803 | 0.9070 | 0.6760 | 0.6131 |
| 2010 | 0.964 | 0.855 | 0.999 | 1.010 | 1.091 | 0.992 | 0.902 | 0.995 | 0.918 | 0.786 | 0.9080 | 0.6425 | 0.5834 |

Source: Prepared by the authors following the methodology described in the text with IEA (2014) data and DANE (2014) national accounts data.

# Últims documents de treball publicats

| NUM | TÍTOL | AUTOR | DATA |
|---|---|---|---|
| 19.04 | The relation of GDP per capita with energy and CO2 emissions in Colombia | Lourdes Isabel Patiño, Emilio Padilla, Vicent Alcántara and Josep Lluis Raymond | Setembre 2019 |
| 19.03 | Cruise activity and pollution: the case of Barcelona | Jordi Perdiguero, Alex Sanz | Juliol 2019 |
| 19.02 | Transportation and storage sector and greenhouse gas emissions: an input-output subsytem comparison from supply and demand side perspectives | Lidia Andrés, Vicent Alcántara and Emilio Padilla | Juliol 2019 |
| 19.01 | Selection and educational attainment: Why some children are left behind? Evidence from a middle-income country. | Luciana Méndez-Errico, Xavier Ramos | Gener 2019 |
| 18.03 | Equality of opportunity in four measures of well-being | Daniel Gerszon Mahler, Xavier Ramos | Desembre 2018 |
| 18.02 | Higher education and economic development: can public funding restrain the returns from tertiary education? | Paola Azar Dufrechou | Gener 2018 |
| 18.01 | Electoral politics and the diffusion of primary schooling: evidence from Uruguay, 1914-1954 | Paola Azar Dufrechou | Gener 2018 |
| 17.04 | Defence Spending, Institutional Environment and Economic Growth: Case of NATO | Natalia Utrero-González, Jana Hromcová and Francisco J. Callado-Muñoz | Juliol 2017 |
| 17.03 | Pro-environmental behavior:<br>On the interplay of intrinsic motivations and external conditions | Mariateresa Silvi and Emilio Padilla Rosa | Abril 2017 |
| 17.02 | Driving factors of GHG emissions in EU transport activity | Lidia Andrés and Emilio Padilla | Març 2017 |
| 17.01 | Innovation, public support and productivity in Colombia | Isabel Busom, Jorge-Andrés Vélez-Ospina | Gener 2017 |
| 16.10 | How do road infrastructure investments affect the regional economy? Evidence from Spain | Adriana Ruiz, Anna Matas, Josep-Lluis Raymond | Juny 2016 |
| 16.09 | Euro, crisis and unemployment:<br>Youth patterns, youth policies? | Atanu Ghoshray, Javier Ordóñez, Hector Sala | Maig 2016 |
| 16.08 | Changes in fuel economy: An analysis of the Spanish car market | Anna Matas, José-Luis Raymond, Andrés Domínguez | Maig 2016 |
| 16.07 | Institutional Reforms to Integrate Regulation and Competition Policy: Economic Analysis, International Perspectives, and the Case of the CNMC in Spain | Francesc Trillas, Ramon Xifré | Maig 2016 |