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How far is Colombia from decoupling? Two-level decomposition analysis of energy consumption changes

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ABSTRACT

A decoupling elasticity analysis and a two-level decomposition analysis of energy consumption in Colombia from 2000 to 2015 are developed. Firstly, the decoupling elasticity approach is used to analyse the importance of energy consumption changes in relation to the GDP changes. Then, a Logarithmic Mean Divisia Index analysis is carried out, decomposing the changes in energy consumption into four effects: Population, Activity, Structural and Intensity. Secondly, a decoupling index determines the main drivers of the inhibiting effect on energy consumption. The results show that the Population and Activity effects contribute to the country's increase of energy consumption, while the Intensity effect and, to a lesser extent, the Structure effect help to decrease it. From a sectoral perspective, variations in the energy consumption are mainly caused by the Transport and Industrial sectors. In the light of the results obtained, current decoupling-oriented measures are steps in the right direction, but more efforts should be made because until now they have not been effective. New policy recommendations are provided.

1. Introduction

Colombia has the second largest hydropower potential in Latin America, after Brazil [1]. Brazil, Russia, Canada, the United States, Indonesia, China and Colombia are the top seven countries with water availability exceeding 2000 km^3 [2]. In 2015, Colombia had a total installed electricity generation capacity of 16.4 GW, with a share of 70% of hydropower (high, mid and small plants together). As a consequence, Colombia's electricity sector is highly vulnerable to sufficient water availability [3]. During 2015 and 2016, the droughts suffered in Colombia as a result of “El Niño" were close to causing a blackout due to the drop in the electricity generation of the hydroelectric plants. Gutiérrez and Dracup [4] provided evidence of the relationship between “El Niño” and hydrology. Arias-Gaviria et al. [3] analyse the impact of “El Niño” on Colombian's power generation. Low levels of rain caused by “El Niño” provokes more extreme and longer dry seasons than usual, reduces the country's total water reservoirs and has led to an energy crisis in Colombia. A recent state of the art of “El Niño” is available in Trenberth [5]. Even more recently, Smith and Ubilava [6] analyse a causal relationship between “El Niño” and economic growth in Colombia.

The phenomenon “El Niño" occurs with some regularity. Evidence for the period 1979–2009 with data collected from 341 data stations is provided by Córdoba-Machado et al. [7] and by Smith and Ubilava [6] for the period 1961–2015. The possibility of building predictive indicators was analysed by Gutiérrez and Dracup [3]. Colombia needs to take measures to guarantee electricity supply in particular and energy in general. These measures can come from the Generation System [8], or measures oriented to the management of demand, particularly those aimed at acting on the drivers of energy consumption. This paper focuses on the latter. A pool of policy measures is required. In this sense, the possibility of Colombia moving properly towards decoupling between energy consumption and economic growth is a desirable outcome. If limiting the global average temperature growth below 2° C is our aim, delinking between economic growth and energy consumption is a necessary part of the right roadmap regarding current fossil fuels dependence.

Colombia's economic fundamentals, including macroeconomic stability and openness to global trade and finance, have remained relatively strong in recent years. The economy has expanded by an average of around 5% annually over the past five years. Its

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population has risen to 47.7 million people with US $ 6056.1 per capita. In absolute terms, the Colombian economy is the 4th largest in the Latin American Area and the 5th in terms of per capita GDP (Purchasing Power Parity - PPP). Between 2000 and 2014, the ratio of total primary energy sources to population measured in toe/capita increased by 10.9% (2.6% for non-OECD American countries). For the same period, total energy production measured in Mtoe increased by 75.29%. Focusing only on electricity consumption measured in TWh, this increased by 83.9% and, expressed in per capita terms, electricity consumption also increased significantly, around 55.6% [9]. It should be considered that Colombia is among the countries with the greatest production of electricity [10].

The paper addresses the following questions. How far is the Colombian economy along the road to decoupling energy consumption from economic growth? Which factors have determined the changes in Colombia's energy consumption in the period examined? Was the success of past energy policies in Colombia decoupling oriented? Together with answering these questions, policy recommendations at the sectoral level are provided.

To answer all these questions three methodologies are combined in a novel way of providing information items that supplement each other. In a first step, the decoupling status between energy consumption and GDP growth is analysed with a decoupling elasticity index following Tapio [11] approach. In a second step, an additive decomposition analysis index (LMDI) is applied in order to identify the driving factors of the energy consumption changes in Colombia at the sectorial level. Four effects in the decomposition were considered: Population, Activity, Structure and Intensity for the period 2000–2015. The Agriculture, Mining, Industrial, Electricity, Gas and Water, Construction, Transport and Commercial and Public sectors were analysed. Finally, in a third step, considering the four effects from the LMDI analysis, a second level of decomposition was conducted to explore the efforts made to meet decoupling between energy consumption and economic growth.

The decomposition analysis is one of the most widely applied tools for analysing the mechanisms influencing energy consumption and its environmental side-effects. The literature offers two methodologic approaches for this analysis, developed exhaustively in environmental topics: Structural Decomposition Analysis (SDA), and Index Decomposition Analysis (IDA). Both methods decompose the variation experienced by a variable between their determining factors. These techniques have usually been applied in isolation to analyse the energy consumption and CO_2 emissions changes. Some of these papers are: Achão and Schaeffer [12]; Zhang et al. [13]; Ang and Su [10] and Cansino et al. [14] for the SDA method and Hoekstra and van den Bergh [15]; Hatzigeorgiou et al. [16]; Ma and Stern [17]; Andreoni and Galmarini [18] and Colinet and Román [19] for the IDA method. The latest comparisons between IDA and SDA have been shown in Su and Ang [20]. Comparatively, IDA has certain advantages over SDA. IDA enables decompositions for any aggregate (value, ratio or elasticity). Also, IDA requires less data than decomposition methods based on input-output (IO) analysis, and it is useful when decomposing changes in environmental variables between their various components [21]. It could be said that one of the main advantages of IDA methods over their competitors based on IO matrices is the abundant availability of data.

Within the IDA methods, there are two important types: the Laspeyres method and the Divisia method. Ang et al. [22]; Ang and Zhang [24]; Ang [25]; Fernández and Fernández [82]; among others, have compared these two types of analysis. Specifically the Laspeyres IDA method is proportionally less used than the Divisia IDA, as considerable residuals arise in its decomposition, although the calculation of the results can be simple and understandable as shown in Zhang et al. [27].

The LMDI method seems to offer the most advantages within these various IDA methods [22,23,27–31,33–37]. Ang et al. [38] conclude that the LMDI-I and LMDI-II methods satisfy most of the index number tests that are considered relevant for the IDA family, except that the LMDI-I fails the proportionality test, whereas the LMDI-II fails the aggregation test. Ang [28] assessed the various decomposition methods and concluded that LMDI-I is a more recommendable method due to both its theoretical base and its set of properties, which are satisfactory in the case of index decomposition. Additionally, LMDI-I provides a simple and direct association between the additive and the multiplicative decomposition form [39].

The literature offers evidence of a relationship between Colombian's energy consumption and economic growth using different approaches. Destek and Aslan [40] analysed this relationship for Colombia during the period 1980 to 2012 applying a bootstrap panel Granger causality test. A similar approach was used by Narayan and Doytch [41]; who also studied the link between economic growth and energy consumption in Colombia over the period 1971 to 2011. However, drivers of the decoupling or coupling processes between energy consumption and economic growth were not included in the above literature. The literature also offers results from LMDI decomposition analysis including Colombia in the sample of countries analysed. These are the cases of Timilsina and Shrestha [36] and Sheinbaum et al. [42]. Malpede [43] developed a Multi-Regional analysis with diverse IDA methods focused on CO_2 emissions, but not on energy consumption. Ang [10] included Colombia in his global analysis of the changes in the aggregate carbon intensity for electricity, relating CO_2 emissions to electricity production in each country. More recently, Román et al. [44] conducted a LMDI decomposition analysis for the specific case of Colombia for the period 1990 to 2012. Nevertheless, all of these papers focused on decomposing CO_2 emissions changes but not on energy consumption changes.

We take advantage of the previous decomposition analysis and try to analyse not only the driving factors of energy consumption changes during one period but also the effort needed to achieve decoupling between energy consumption and economic growth. This latter information will show us the success of previous decoupling policies carried out in Colombia. Some papers have applied a decoupling index for analysing CO_2 emissions [45–47]. Our proposal is to apply as a novelty a decoupling index for energy consumption that, as far as we are aware, is being carried out for the first time in Colombia.

The contribution of this paper to the specialised literature is based on the following points: i) The combination of three methodologies - the elasticity index, the LMDI analysis and the decoupling index - is applied for the first time, as far as we are aware, to analyse the energy consumption changes in Colombia over the period 2000–2015, ii) a more comprehensive updated dataset analysis dissagregated at the sectoral level that contributes to better understanding energy consumption changes in Colombia, iii) the analysing of past decoupling-oriented policy measures and the proposal of energy policy recommendations.

The results are interesting not only for researchers but also for policy-makers. In fact, this paper speaks directly to the authorities of Colombia and the policy agenda regarding several issues, mainly energy saving.

The paper is structured as follows. After the introduction, the methodological approaches are described in Section 2. Section 3 describes the database used. The results are presented in Section 4. In the light of the results, past policies are commented upon in

Section 5. The main conclusions and policy recommendations appear in Section 6.

2. Methodological approaches

2.1. Decoupling analysis. The elasticity index

The decoupling index proposed by the Tapio model has been widely used to analyse the relationship between economic growth and energy consumption. Recent papers based on Tapio [48] and [11] include those by Diakoulaki and Mandaraka [45,47]; Aiwen and Dong [49]; Gray et al. [50]; Li et al. [51] and, more recently, Jiang et al. [46] and Wang et al. [52]. The later papers linked the Tapio [11] decoupling index with the LMDI approach described in the next Subsection.

Technically, the Tapio decoupling index shows the energy consumption elasticity compared to changes in GDP. Consequently, it measures the percentage change in energy consumption resulting from a 1-percent increase in GDP between two periods of time. Thus, decoupling elasticity (δ) can be expressed as equation (1):

$$\delta = \frac{\frac{\Delta E}{E}}{\frac{\Delta GDP}{GDP}} \quad (1)$$

Although De Bruyn [53] initially only distinguished between weak decoupling ($\Delta\frac{E}{GDP}<0$) and strong decoupling ($\Delta E<0$), Tapio [11] and Vehmas et al. [47] provided a broader list of possible statuses. Table 1 shows the decoupling statuses established by Tapio [11]; which are not dissimilar from those provided by Vehmas et al. [47].

From Table 1, eight logical possibilities can be distinguished [52]. Tapio defines the area where the value of (δ) is between 0.8 and 1.2 as the state of the connection or coupling. The zone for all the other values is defined as the state of dissociation or decoupling. The results are also divided into diverse classifications: expansive negative decoupling, weak decoupling, strong decoupling, recessive coupling, weak negative decoupling and strong negative decoupling.

2.2. LMDI analysis

The Impact = Population × Affluence × Technology (IPAT) equation is the starting point for the LMDI-I performed. Specifically, the IPAT model [54,55] and [56] and the 'Kaya Identity' [57,58] are extended using IDA [29,59,60] to assess the key drivers behind Colombia's energy consumption. The 'Kaya Identity' has been used in a number of studies addressing energy, economy and climate-related intensities at the global level [24,61–63]; and [64]. Thus, the final energy consumption can be decomposed in the following manner:

Table 1
Possible status of elasticity index.

	$\frac{\Delta GDP}{GDP}<0$		$\frac{\Delta GDP}{GDP}>0$	
$\frac{\Delta E}{E}>0$	$\delta<0$	Strong negative decoupling	$\delta>1.2$	Expansive negative decoupling
			$0.8<\delta<1.2$	Negative coupling
			$0<\delta<0.8$	Weak decoupling
$\frac{\Delta E}{E}<0$	$0<\delta<0.8$	Weak negative decoupling	$\delta<0$	Strong decoupling
	$0.8<\delta<1.2$	Recessive coupling		
	$\delta>1.2$	Recessive decoupling		

Source: Own elaboration from Ref. [52] and from Tapio [11].

$$E = P\cdot A\cdot S\cdot I \quad (2)$$

where P measures the population, A the economic Activity, S the economic Structure and I the Intensity of the energy use, respectively. The Population factor acts as a proxy of the energy demand in the country; the Activity factor is measured through the production per capita; the Structure factor indicates the relative weight of the production of the economic sectors in the total production of the country; and, the Intensity factor measures the total energy consumption in the sectoral production.

Considering the aggregate energy consumption of n sectors in Colombia (E), the IDA model or identity is defined as follows:

$$E = P\cdot A\cdot S\cdot I = \sum_{i=1}^{n} P\cdot\frac{Y}{P}\cdot\frac{Y_i}{Y}\cdot\frac{E_i}{Y_i} \quad (3)$$

where, E_i is the final energy consumption measured in teracalories of the economic sector i, Y_i is the gross value added production measured in thousands of millions of Colombian pesos of the economic sector i, Y is the GDP of the country in thousands of millions of pesos and P is the total Population measured in millions of inhabitants. The Agriculture, Mining, Industrial, Electricity, Gas and Water, Construction, Transport and Commercial and Public economic sectors are considered.

From equation (3), it is possible to express the additive decomposition change of the final energy consumption ΔE^T between two periods of time, t and t-1, in the following manner:

$$\Delta E^T = E_t - E_{t-1} = \Delta P^T + \Delta A^T + \Delta S^T + \Delta I^T \quad (4)$$

where ΔP^T is the Population effect (this measures the variations of energy consumption due to a variation of the population between period t and t-1); ΔA^T is the Activity effect (this measures the variations in energy consumption due to a change in the income per capita of the economy between period t and t-1); ΔS^T is the Structure effect (this measures the variations in energy consumption due to a change in the relative weight of the net production of the sectors in the national product between period t and t-1); and, ΔI^T is the Intensity effect (this measures the variations in energy consumption due to a change in the sectoral energy intensity, that is to say, due to a change in energy consumption per produced unit of each sector between period t and t-1). Following the LMDI-I method [29], the additive decomposition effects are defined as follows:

$$\Delta P^T = \sum_{i=1}^{n} w_i\cdot\ln\left(\frac{P_t}{P_{t-1}}\right) \quad (5)$$

$$\Delta A^T = \sum_{i=1}^{n} w_i\cdot\ln\left(\frac{A_t}{A_{t-1}}\right) \quad (6)$$

$$\Delta S^T = \sum_{i=1}^{n} w_i\cdot\ln\left(\frac{S_{i,t}}{S_{i,t-1}}\right) \quad (7)$$

$$\Delta I^T = \sum_{i=1}^{n} w_i\cdot\ln\left(\frac{I_{i,t}}{I_{i,t-1}}\right) \quad (8)$$

with w_i being the weighting factor used for the calculation of different effects, which is obtained from the logarithmic mean function that considers the variation between two periods of the final energy consumption, as expressed in equation (9):

$$w_i = \frac{E_{i,t} - E_{i,t-1}}{\ln E_{i,t} - \ln E_{i,t-1}} \tag{9}$$

When an effect takes positive values it acts as a driver of energy consumption, and when values become negative, then the effects act as a compensating factor of energy consumption.

2.3. Decoupling index based on LMDI effects

The Tapio decoupling elasticity allows us to give a rough measure of Colombia's performance in energy saving. Nonetheless, there is an important interest in knowing the effort needed to achieve decoupling [45]. In this paper, the effort is conceived as a general term referring to any kind of actions that directly or indirectly might induce a decrease in energy consumption, irrespective of the energy changes due to the economic activity. The term 'effort' includes energy efficiency enhancing measures, shifts towards less energy intensive activities, as well as changing consumption patterns among the population.

Thus, the efforts undertaken in Colombia during the period analysed are going to be summarised in the ΔEE_t effect. Accordingly, this effect only shows the energy consumption changes attributed to the population, structural and intensity effects, excluding those caused by the activity effect. Similarly to Jiang et al. [46]; reordering equation (4), the ΔEE_t effect is defined as follows:

$$\Delta EE_t = \Delta E^T - \Delta A^T = \Delta P^T + \Delta S^T + \Delta I^T \tag{10}$$

Hence, in order to assess the degree to which the efforts mentioned above are effective in terms of decoupling the economic growth from energy consumption changes, a new decoupling index μ_t, is calculated. Equation (11) is used when the activity effect is positive:

$$\mu_t = -\frac{\Delta EE_t}{\Delta A^T} = -\frac{\Delta P^T}{\Delta A^T} - \frac{\Delta S^T}{\Delta A^T} - \frac{\Delta I^T}{\Delta A^T} = \mu_{pop}^T + \mu_{str}^T + \mu_{int}^T \tag{11}$$

And equation (12) is used in the case of the activity effect being negative:

$$\mu_t = \frac{\Delta EE_t - \Delta A^T}{\Delta A^T} \tag{12}$$

Additionally, besides the total decoupling index μ_t, both equations (11) and (12) enable us to calculate three decoupling indices deriving from the different effects: μ_{pop}^T (population index), μ_{str}^T (structure index) and μ_{int}^T (energy intensity index).

The values of the decoupling indeces can be understood as follows. When energy policy efforts have been effective, the ΔEE_t effect shows negative values and, therefore, the index will provide positive values, using either equation (11) or (12). In this latter case, if the index value is $\mu_t \geq 1$, this denotes strong decoupling efforts, that is, the ΔEE_t effect is more significant than the activity effect. If the decoupling index is between $0 < \mu_t < 1$, this denotes weak decoupling efforts, that is, the ΔEE_t effect is weaker than the activity effect. When efforts carried out are not effective, the ΔEE_t effect will show positive values. In this latter case, the decoupling index will be $\mu_t \leq 0$, and this denotes that there have been no decoupling efforts [45] and [46].

3. Database

Three sources were mainly used to support this research. Firstly, the energy consumption is taken from the balances offered by the Mining and Energy Planning Unit (UPME in its Spanish acronym), which detail the necessary supply of final energy consumed by the main economic activities of the country. This dataset has been updated near to the end of 2016 offering detailed information until 2015 inluded in the Second revision of Colombian's energy balances 1975–2015 [65]. Secondly, the gross production was obtained from the annual report of the National Administrative Department of Statistics [83], which details the GDP at constant 2005 prices (Colombian currency) by branches of activity. Finally, the total population is taken from the "CO_2 Emissions from Fuel Combustion Highlights 2015", published by the International Energy Agency [9].

The sectoral analysis was determined for those sectors included in the energy balance. This required the aggregation of sectors that appear disaggregated in the GDP information. It is necessary to explain in detail how this aggregation was made.

Firstly, there was an in–depth study of the definitions offered by the Energy Statistics Manual provided by the Latin American Energy Organisation and which governs the UPME when classifying its data at the sectoral level. Also, an evaluation was made of the items of the Classification of Economic Activities produced by the National Directorate of Taxes and Customs [66], with which the DANE classifies the economic sectors it reports on.

Secondly, correspondences are established between the sectors aggregating and disaggregating some of them (Table A.1 of the Annex A), thus obtaining seven economic sectors: Agriculture, Mining, Industrial, Electricity, Gas and Water, Construction, Transport and Commercial and Public.

4. Results

4.1. Decoupling elasticity in Colombia

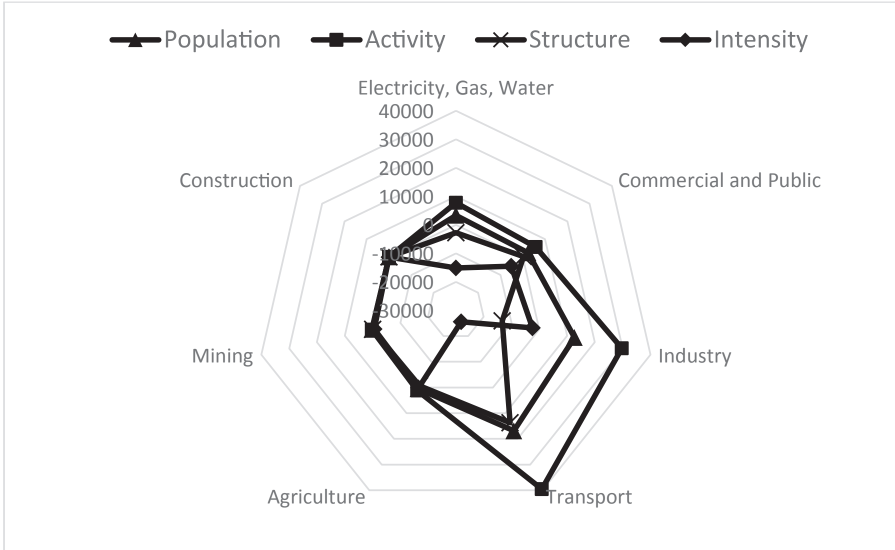
In order to explore the relationship between energy consumption and economic growth in Colombia between 2000 and 2015, equation (1) is used to calculate decoupling elasticity by using the economic growth measured by GDP at 2005 constant prices. The results of the decoupling elasticity index are shown in Table 2.

Only four subperiods clearly show a strong decoupling and two subperiods inform of weak decoupling. Considering that most of them are in the subperiod 2000–2007, it can be concluded that the economy moved towards a decoupling process. Notwithstanding, during the economic crisis period, 2007–2009, the energy consumption growth was considerably higher than the economic activity and that caused the decoupling elasticity to provide values informing about expansive negative decoupling and weak

Table 2
Decoupling elasticity in Colombia.

	E change	GDP change	Elasticity	Meaning
2000/2001	0.02	0.01	1.40	END
2001/2002	−0.02	0.03	−0.92	SD
2002/2003	0.00	0.04	0.03	WD
2003/2004	0.05	0.05	0.85	NC
2004/2005	−0.02	0.05	−0.48	SD
2005/2006	0.01	0.06	0.21	WD
2006/2007	−0.09	0.06	−1.38	SD
2007/2008	0.22	0.03	6.28	END
2008/2009	0.04	0.02	2.56	END
2009/2010	−0.07	0.04	−1.82	SD
2010/2011	0.05	0.06	0.82	NC
2011/2012	0.03	0.04	0.79	WD
2012/2013	0.02	0.05	0.47	WD
2013/2014	0.09	0.04	1.99	END
2014/2015	0.05	0.03	1.79	END

Source: Own elaboration.
(*) Expansive negative decoupling (END), Strong decoupling (SD), negative decoupling (ND) and weak decoupling (WD).



Source: Own elaboration

Fig. 1. Decomposition effects of energy consumption changes by sectors between 2000 and 2015 (Teracalories).

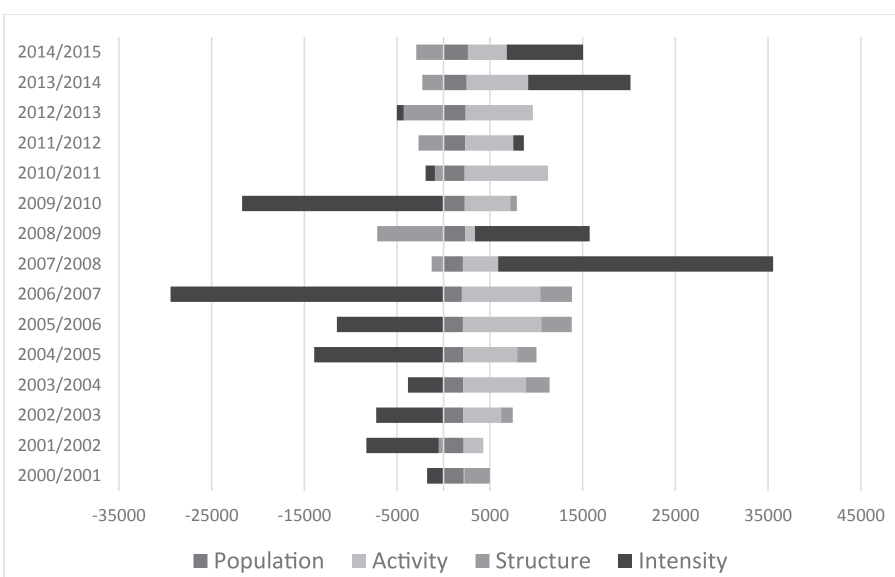
decoupling (in fact the subperiod of no coupling is close to weak decoupling). So, although there is not a regular path in the behaviour of energy consumption change and economic growth between 2008 and 2015, it should be highlighted that most of the sub-periods seem to be far from decoupling.

The first tool used warns that Colombia did not show a clear decoupling process. In any case, decoupling elasticity only gives a preliminary overview of possible decomposition processes. A decomposition analysis is needed to find more stylised results.

4.2. Additive LMDI decomposition effects: drivers of energy consumption in Colombia

Fig. 1 shows the energy consumption change for the period 2000–2015, detailed by productive sectors and decomposition effects.

During 2000–2015, the most important drivers of energy consumption changes are the activity and the population effects, mainly due to the Transport and the Industry sectors. The role of Agriculture, Mining and Construction are almost insignificant



Source: Own elaboration

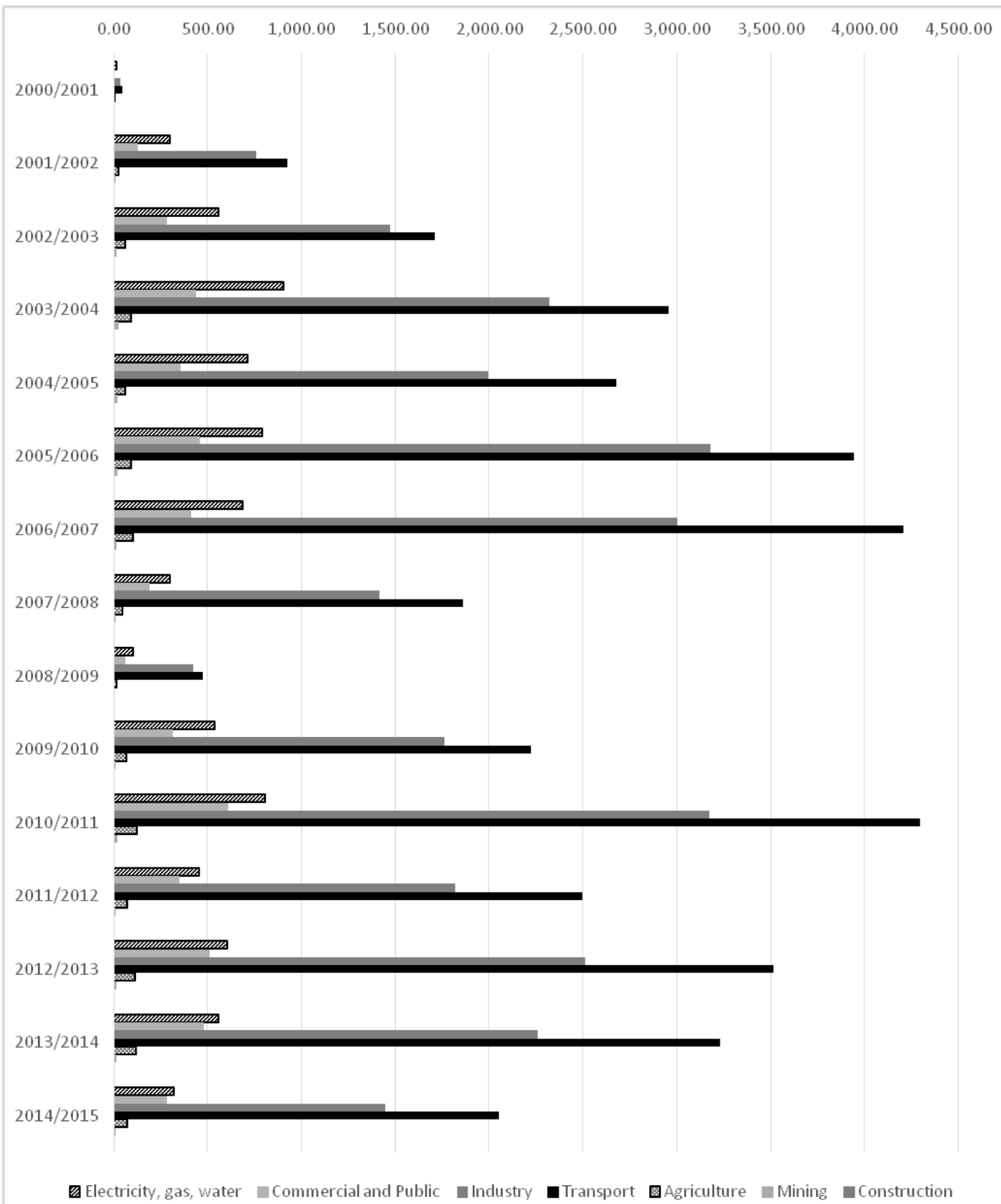
Fig. 2. Decomposition effects of energy consumption changes between 2000 and 2015 (teracalories).

considering the four effects. On the other hand, the intensity effect acts as an important inhibitor effect in the case of the Transport sector but also for the Electricity, Gas and Water sector. Finally, the structure effect drives energy consumption change in the Transport sector but reduces it in the Industry, Electricity, and Gas andWater sector.

Fig. 2 shows the main results of the decomposition analysis of Colombia's energy consumption from equation (4) for the period 2000–2015. The data of the additive chain linked decompositions effects for the period 2000–2015 is in Table A.2 in Annex A.

The activity effect (ΔA) is shown as the main driver of energy consumption and, although there are important changes in its magnitude, it never had a negative value in the period analysed. We can distinguish two subperiods when the results of the activity effect are considered (2000–2007; 2008–2015).

During the first subperiod, the activity effect drives energy consumption gradually upwards between 2000/2001 and 2006–2007 but from then there was a gradual decrease. Again, between 2008/2009 and 2010/2011, the activity effect drives the energy consumption, but from then, with some exceptions, there was a decrease. The data from DANE [83] revealed that the economic activity grew due to the financial establishments, insurances, buildings and services to companies by 5.8%, construction by 5.7% and manufacturing industries by 3.9% in



Source: Own elaboration

Fig. 3. Sectoral analysis of the Activity effect on the change of Energy Consumption in Colombia (Teracalories).

2011. These data show that the economic growth is still linked to energy consumption. As soon as the economic activity increases, the energy consumption also does so.

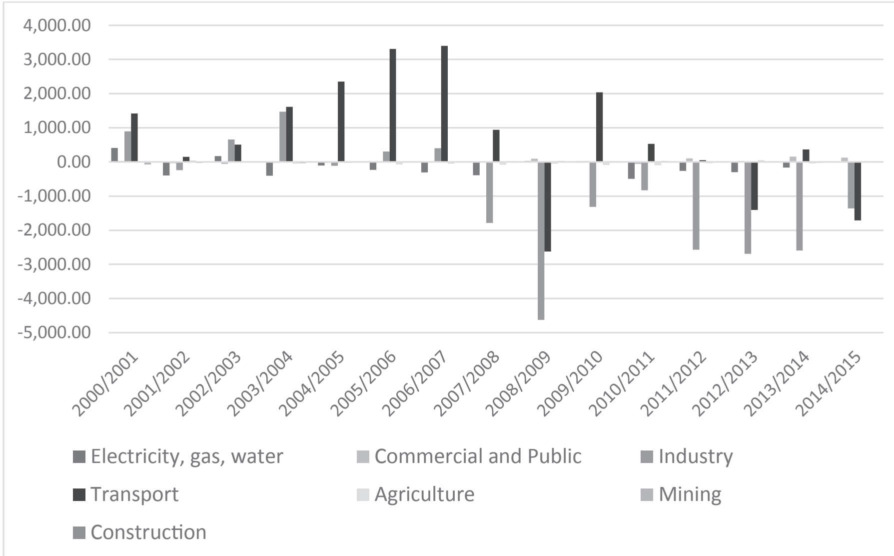
Fig. 3 gives details of the activity effect by sectors. The Transport and Industrial sectors drive the energy consumption changes due to the activity effect. Also Agriculture acted similarly to those sectors but had lower values in absolute terms. For example, in order to better understand the values of the ΔA, it is necessary to consider that, as of 2006, the Colombian monetary authority began a contractionary monetary policy to reduce the rate of inflation. The monetary restriction was centred on moderating the expansion of credit. Fig. 3 shows that the analysis conducted properly captured the economic impact of the monetary measures. For the same years, the construction sector also registered an important deceleration. This lower activity of the construction sector was due to the international financial crisis that began in 2008 and the increase of the price of some construction materials [67]. The Transport, Industrial and Electricity, Gas and Water sectors also confirm the effects of the crisis.

The population effect (ΔP) behaves as expected, acting as a driver of energy consumption for the whole period considered. According to the data from the Colombian Bank of the Republic [84], in 2012 the population of the country had increased by approximately 7.2% with respect to 2006. Comparatively, it is the second ranked determining factor of the increase of energy consumption. The sectoral analysis allows us a more stylised analysis in Fig. 4.

From Fig. 4, the Transport sector, followed by the Industrial sector, determined the population effect sign. These two sectors explain the role of the population as a clear driver of energy consumption changes. It must be noted that the energy consumption of the transport sector was especially increased by the expansion of

Source: Own elaboration

Fig. 4. Sectoral analysis of the Population effect on energy consumption changes in Colombia (Teracalories).



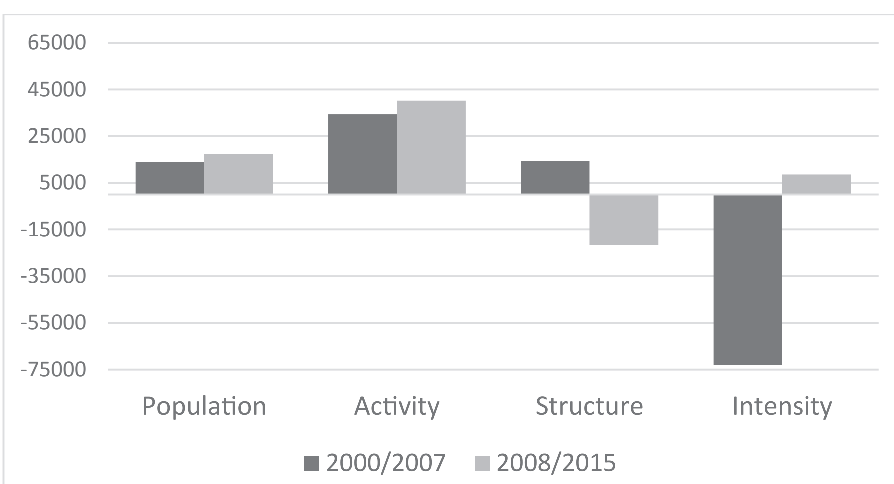
Source: Own elaboration

Fig. 5. Sectoral analysis of the Structure effect on the change of Energy Consumption in Colombia (Teracalories).

public transport in the cities and also of air transport [68]. Agriculture acted in the same way as the Transport and Industry sectors but had lower values in absolute terms. A stylised analysis shows that the trend in the other sectors is not the same for the period analysed. For example, the strong increase of the Commercial and Public services sector must be attributed to the important development of shopping centres or malls. Nevertheless, the small reduction in the contribution of the construction sector is due to the negative impact of the financial crisis on mortgage credit after 2008.

The data in Fig. 2 show that the results for the structure effect (ΔS) can be analysed considering again two subperiods, 2000–2007 and 2008–2015. During the first subperiod, the structure effect drives energy consumption changes. The data by sectors in Fig. 5 shows that the Transport and the Industry sectors are those with the greatest influence. Thus, those sectors are becoming more relevant in the economic structure of the Colombian economy. During the second subperiod, 2008–2015, the structure effect acts as an inhibitor of energy consumption changes. In this subperiod, the Industry sector and, to a lesser extent, the Transport sector are the most relevant ones. In these two sectors, the economic crisis reduced the energy consumption requirements.

Finally, the intensity effect (ΔI) is often used as a measure or aggregate proxy of the energy efficiency or technology level of a country's economy. It may be seen as a signal indicating the efficiency of the energy system, technology choices, energy prices, energy conservation techniques and investments for energy



Source: Own elaboration.

Fig. 6. Additive decomposition effects between two subperiods in Colombia (Teracalories).

saving [69,70]. Colombia achieved significant progress in energy efficiency for the period 2000–2007, approaching 9% on average, in comparison with the period 1975–1999 [71]. Most of the sectors contributed to this trend, those of Transport, Industry, Electricity, Gas and Water being relevant. For the period 2008–2010, the intensity effect showed an erratic trend, but after an important increase due to Industry, Electricity, Gas and Water at the beginning of the subperiod, the sign became positive because of the Industry and Transport sectors (see Table A.2 in Annex).

The results from the above chain-linked additive decomposition effects suggest that the analysis should be done distinguishing between two subperiods: 2000–2007 and 2008–2015. The additive decomposition results for these two subperiods are shown in Fig. 6. Firstly, during the first subperiod there was a decrease in the energy consumption due to the intensity effect that was partially compensated by the other three effects. During the second subperiod, there was an increase in energy consumption driven by the population, activity and intensity effects and only partially compensated by the structure effect.

4.3. *Decoupling index between energy consumption and economic growth. Drivers of the decoupling process*

The decoupling index calculated according to equation (11) is the third step conducted in this research. It determines the degree to which the energy consumption reduction effort outweighs the activity effect. This gives a measure of the real progress in decoupling economic growth from energy consumption in the path towards sustainability. The decoupling index shown in equation (12) is not needed from when the activity effect always gives positive values during the period analysed.

The decoupling index is based on the decomposition effects calculated in the previous LMDI analysis. Table 3 shows the main results not only for the global energy consumption change (μ_t) but also for the relative contribution of each effect in the decoupling process under analysis (μ_{pop}, μ_{str}, μ_{int}). Table A.3 in Annex A offers detailed sectoral information.

The data in Table 3 show the following. Firstly, the population decoupling effect is always negative. That means that the population effect does not overcome the activity effect and so there is no decoupling effort made in terms of population. Secondly, we can distinguish two subperiods when we analyse the structural effect, between 2000 and 2007 and 2008 and 2015. During the first subperiod, the structural effect shows negative values, no decoupling. Again, there is no success in the decoupling effort made related to the structural effect during this subperiod. However, between 2008 and 2015, with the exception of the subperiod 2013–2014, the structural effect acts as an inhibiting effect that overcomes the activity effect, although this mostly shows weak decoupling. Thirdly, the intensity effect does not show a clear pattern but we can also distinguish the two subperiods mentioned above. During the first subperiod, 2000–2007, the intensity effect shows positive values mostly higher than one, providing a strong decoupling. During this subperiod, the decoupling efforts with relation to the intensity effect were a success. Yet, between 2008 and 2015, the intensity effect shows negative values and positive values but most of them are lower than 1. In consequence, during this second subperiod the decoupling efforts were not notable in terms of the intensity effect.

Table 3
Drivers of the decoupling process (2000–2015).

	μ_{pop}	μ_{str}	μ_{int}	μ_t	Meaning of μ_t
2000/2001	−20.0	−24.7	16.3	−28.4	ND
2001/2002	−1.0	0.2	3.6	2.9	SD
2002/2003	−0.5	−0.3	1.8	1.0	SD
2003/2004	−0.3	−0.4	0.6	−0.1	ND
2004/2005	−0.4	−0.4	2.4	1.7	SD
2005/2006	−0.2	−0.4	1.4	0.7	WD
2006/2007	−0.2	−0.4	3.5	2.9	SD
2007/2008	−0.5	0.3	−7.8	−8.0	ND
2008/2009	−2.2	6.6	−11.5	−7.0	ND
2009/2010	−0.5	−0.1	4.4	3.8	SD
2010/2011	−0.3	0.1	0.1	0.0	ND
2011/2012	−0.5	0.5	−0.2	−0.2	ND
2012/2013	−0.3	0.6	0.1	0.4	WD
2013/2014	−0.4	0.4	−1.7	−1.7	ND
2014/2015	−0.6	0.7	−2.0	−1.9	ND
TOTAL	−0.4	0.0	0.6	3.8	SD

Source: Own elaboration
(*) Strong decoupling (SD), weak decoupling (WD) and No decoupling (ND).

If the total decoupling index and the two previously mentioned subperiods are considered, the values of the decoupling index $\mu_{t,}$ between 2001 and 2007 are, in most of the subperiods, positive and equal or higher than 1. They show that during this subperiod, the efforts to reduce energy consumption overcame the activity effect. The subperiod 2000–2001 has to be highlighted because the GDP growth was not significant and therefore the activity effect was not relevant.

From 2007 onwards, the total decoupling index (μ_t) showed negative values for most of the biannual periods. Hence, the increase in energy consumption due to the possible compensating effects were lower than that deriving from the activity effect.

5. Discussion

The activity and the population effects are the main drivers of Colombia's energy consumption. The results reported are consistent also across the scientific literature when this is focused on CO_2-eq emissions from fossil fuel combustion [44]. Malpede [43] as well found that the population effect acted as a driver for the Colombian case. For other countries and regions one can see Hatzigeorgiou et al. [16] for the case of Greece, Donglan et al. [72] for China's residential sector, Colinet and Román [19] for the South of Spain, Moutinho et al. [34] for Europe and, more recently, Mundaca and Markandya [73] give an exhaustive worldwide analysis. After controlling collinearity, these authors showed that the population and per capita GDP explained 98% of the variability of energy related CO_2 emissions for Latin America and Caribbean countries. The literature using alternative approaches, like the bootstrap panel Ganger causality test, also found a relationship between economic growth (activity or affluence effects) and energy consumption in Colombia. Destek and Aslan [40] noted a unidirectional causality between non-renewable energy consumption and economic growth using annual data from 1980 to 2012. Focusing on industrial total energy consumption, Narayan and Doytch [41] observed that economic growth had a positive and significant impact on this energy consumption for Colombia over the period 1971 to 2011.

Focusing on population and the importance of electricity consumption growth in Colombia, there is still room for implementing smart energy management systems deployment [74]. These types of systems should incorporate: a) Smart metres, b) the electricity self-consumption capacity and 3) storage systems to improve demand management. Also, other measures such as educational programmes and eco-labelling are suggested.

Energy intensity appears as the main compensating factor of the energy consumption increase in Colombia. This result is in line with that obtained by Theodoridis [75] and Timilsina and Shrestha [36]. Despite this finding, progress in energy intensity has failed to outpace the role played by drivers in energy consumption. Our finding coincides with the LMDI analysis conducted by Sheinbaum et al. [42]. When the global value of this effect is regarded from a sectoral perspective, the Industry sector shows better results in enhancing energy intensity. So, we can conclude that the recent measures approved by the Colombian Authorities in 2016, specifically oriented to industry (to improve technological change and energy efficiency), go in the right direction but no more.

From a sectoral point of view, the LMDI decomposition analysis shows that the key sectors from the perspective of energy consumption changes in Colombia are Transport, Industry, Electricity, Gas, Water and Commercial and Public services. Above all, the Transport sector required priority attention in order to increase the decoupling efforts. The role of the Transport sector was also highlighted for Colombia by Sheinbaum et al. [42]. As the decomposition effects show, the activity, structure and population effects drive energy consumption and they are just partially offset by the intensity effect. For this reason, although the Transport sector has improved energy efficiency, the economic growth still drives the energy consumption. This finding is in line with Timilsina and Shrestha [36]; although these authors found that energy intensity acted as a driver of energy related CO_2-eq emissions in Colombia's Transport sector.

These results are coherent with the trend of the energy consumption of these sectors in the last years. For example, the Transport sector increased the total energy consumption and represented more than 43% of this consumption in 2006, almost half of the energy consumed by the country in 2012. All the same, since 2008, the structure effect shows that the Transport sector was an inhibitor of energy consumption changes. The importance of this sector probably explains why the Energy and Technological Change project of the Transport sector 2012–2020 seems to be focused on this sector. The Colombian authorities might consider introducing labelling in vehicles in use as a way of increasing the visibility of those pollutant, less and zero emissions vehicles depending on the fuel they use. The experience in force in Spain since 2016 could be easily replicated [76].

Additionally, the Industrial, Commercial and Public services, and Electricity, Gas and Water sectors remarkably increased their energy consumption during the period analysed, demonstrating the insufficient attention to and regulation of these sectors. The recent literature shows that technological improvements need to be implemented in specific industries that are intensive in energy consumption. These are the cases of Alcántara et al. [26] for the lime industry, Herrera et al. [77] for the cement industry and Manrique et al. [78] for ceramics production.

The high energy consumption of the Commercial sector is mainly due to the growing number of shopping centres built in recent years in Colombia [26]. These buildings consume a great amount of energy (illumination and HVAC) and, therefore, they require regulations adapted to aspects such as insulation and self-consumption (e.g., the installation of solar panels). Among the measures aimed at improving efficiency in the Commercial sector are rational lighting, cooling and heating systems, double glazing, and solar-heated water for household use [79]. The first results after putting in force the Colombian National Energy Plan (2006–2025) show that some changes were recorded in the Commercial and Public sector. This consumed 31.2% of final energy in 2006 and was reduced to 23.6% in 2012 [65].

In these same years, the Environment Ministry and the UPME, through the Institute of Hydrology, Meteorology and Environmental Studies [80], developed the so-called Plans of Technological Change. The objective of these projects was for Colombia to achieve decoupling between energy consumption, economic growth and GHG emissions. Yet the results obtained in this research reveal that the efforts have not been sufficient, although they are headed in the right direction.

Focusing on the decoupling analysis when comparing the figures from Table 3 with those included in Table 1, we can conclude that for most of the years the meaning of Tapio's index values and the decoupling index values are not so dissimilar. In fact, both calculations coincide when identifying the strong decoupling subperiods. Additionally, they both show that between 2000 and 2007, the Colombian economy was closer to achieving a decoupling of energy consumption from economic growth, but after 2008, the trend was against decoupling. The results from 2014 could warn about the so-called "rebound effect". Mundaca and Markandya [73] confirm this for the Latin America and Caribbean countries after the global financial crisis. Despite these authors focusing on CO_2-eq emissions change, they detected an exceptional increase in these emissions (derived from fossil fuel combustion) explained by various factors. Above all, it derives from the increases in economic activity and energy use, including a lack of progress in reducing energy intensity.

Regarding the decoupling index, Colombia's efforts to achieve decoupling energy consumption from economic growth by effects allow a more stylised discussion. The structural decoupling index shows that the energy consumption of productive sectors increased during the Colombian economy's expansion (2000–2007). Hence, the apparent decoupling process was in fact due to the intensity effect. That is what the LMDI decomposition and the intensity decoupling index corroborate. As soon as the economy growth declined from 2008, the structure effect in the LMDI analysis and the structure decoupling index show that there was a decrease of energy consumption of the productive sectors besides an increase due to the intensity effect.

6. Conclusions and policy implications

Decomposition analysis, in addition to being a powerful explanatory tool, offers valuable assistance in assessing and analysing the progress in decoupling energy consumption from economic growth, supplemented by the decoupling index and elasticiy.

For the whole period analysed, 2000–2015, the results let us conclude that efforts made to achieve decoupling energy consumption from economic growth were not at all effective in Colombia. The activity (or affluence) and population effects acted as the main drivers of energy consumption. Strong measures might be oriented to them as both played a negative role in curbing energy consumption in Colombia.

The three methodology approaches applied suggest that the conclusions have to be displayed in two subperiods, 2000–2007 and 2008–2015. During the first subperiod, the diminishing of the energy consumption was mainly due to the energy intensity effect driven by the Industry and Transport sectors. Additionally the decoupling index informed about a strong decoupling effort.

Nonetheless, from 2008, the main drivers of energy consumption growth were the activity and population effects. The risk of a rebound effect was detected after the two decoupling analyses conducted warned of a lack of progress in reducing energy intensity.

Regarding Colombia's current measures in force, they seem to be well oriented, so there is room for some optimism with respect to the decoupling process. Notwithstanding, the results enable us to conclude that efficiency and energy consumption saving policies should be implemented. We suggest a list of policy recommendations addressing the decoupling pathway between economic growth and energy consumption. We group our recommendations following the taxonomy of policy instruments available in Mundaca and Markandya [73] but focused on Colombia.

Economic incentives. As the literature showed a technological gap in a set of energy intensity industries, investment in these technologies might be promoted. We recommend that investment spending benefit from fiscal incentives in companies' tax obligations. Investments need to be supervised by the authorities and properly certified. Swedish corporate tax is a good example of how to implement this type of fiscal incentives.

Regulatory approaches. It might be mandatory for energy utilities and facilities companies to deploy a smart energy system incorporating a) Smart metres, b) the electricity self-consumption capacity and 3) storage systems to improve demand management. The smart energy system will led to a lower energy demand. The cost of the transition to a smart energy system could be totally or partially passed on to the final consumer through final prices or be subsidised by the government. Energy audits might be mandatory for those firms interested in working with Colombia's authorities. At a sectoral level, due to the role played by the Transport sector, we recommend introducing labelling in vehicles in use as a way of increasing the visibility of their energy efficiency level. The enhancing of building codes, including requirements for materials and small-scale technologies needs to be included in this regulatory approach.

Information schemes. Measures such as educational programmes, professional training, technical assistance and eco-efficiency labelling are suggested. There exists a great misunderstanding among citizens concerning potential energy saving in efficient vehicles or domestic appliances. These types of misunderstanding make educational programmes useful for the decoupling between economic growth and energy consumption. This degree of misperception decreases in line with the educational level. Our recommendation is therefore to strengthen educational programmes that are energy saving oriented.

Voluntary agreements. These measures use the results of negotiations between governments and the industrial sector that are committed to achieving an energy efficiency improvement objective.

Although expectations should be moderate, the decoupling between economic growth and energy consumption is a crucial part of a right road map in the fight against Climate Change.

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ANNEX

Table A.1
Grouping of Economic Sectors

Productive sectors		Aggregation
Agriculture, livestock industry, hunting, forestry and fishing	Crops - Livestock industry - Fishing – Forestry	Agriculture
Operation of mines and quarries	Extraction of coal - Extraction of oil and gas - Extraction of ores - Extraction from mines and quarries	Mining
Manufacturing industries	Food - Drink - Tobacco - Textiles and preparations - Footwear and leather - Transformation of wood - Manufacture of paper - Printing - Oil refining - Rubber and plastics - Manufacture of chemical products - Metallurgy - Mineral products (cement, glass and ceramics) - Machinery - Furniture - Vehicles	Industry
Provision of electricity, gas and water	Generation and distribution of electrical energy - Production of gas - Capture, treatment and distribution of water	Electricity, gas and water
Construction	Buildings - Civil Engineering - Special activities	Construction
Commerce, repair, restaurants and hotels	Wholesale and retail trade - Motorcycle and Motor vehicle repair - Accommodation – Food services	Commercial and Public services sector
Financial establishments, insurance, real estate activities and services to companies	Financial and insurance activities - Real estate activities - Professional activities	
Social services, communal and personal activities	Administrative services and support activities - Public administration and defence - Education - Social assistance - Entertainment and recreation	
Transport, storage and communications	Terrestrial (with rail transport) - Aquatic - Aerial – Messaging Services - Storage	Transport

Source: Own elaboration from DIAN (Resolution 139) and the Latin American Energy Organisation [81] Statistics Handbook.
Note: The Agriculture sector includes the productive activity that humankind makes directly in nature, such as cultivation, hunting and forestry. The Mining sector refers to the extraction of coal, oil and minerals in general. The Industrial sector has a wider definition, as it includes transformation activities that are important for the country, such as the textile, drinks, food, metallurgy, rubber and plastics, wood transformation, footwear and mineral products manufacturing sectors. The Electricity, Gas and Water sector includes the generation and provision of primary energy from any source (natural gas, oil, electricity, etc.) for the use of final energy generating companies. The activity of the Construction sector is defined as the construction of industrial establishments, highways and buildings of any type. The Transport sector refers to any means of terrestrial, maritime and aerial transport, as well as mail and storage services. The Commercial and Public services sector includes a large part of the activity of the tertiary sector (or services), including trade, restaurants and hotels, financial establishments, real estate activities, services to companies and social activities, among others.

Table A.2
Additive decomposition LMDI by sectors and effects (Teracalories).

	SECTOR	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2014/2015
Population	Electricity, Gas and Water	292.20	296.40	286.20	285.31	260.04	192.56	161.68	162.07	226.38	250.30	200.21	201.60	197.10	207.09	198.67	3308.25
	Commercial and Public	134.21	127.94	145.55	138.71	130.15	111.76	96.65	103.35	126.10	146.76	151.34	157.09	165.61	176.58	178.22	2441.12
	Indutry	750.96	752.79	753.79	729.94	725.66	775.67	705.49	767.54	913.56	817.88	790.64	809.77	817.34	836.22	903.32	12665.46
	Transport	961.95	916.51	875.47	931.22	974.00	962.64	987.65	1010.32	1016.46	1029.83	1070.09	1112.74	1144.12	1194.12	1281.37	16863.59
	Agriculture	27.26	27.75	32.81	29.80	23.10	23.29	24.84	26.10	28.25	30.33	30.81	32.83	36.32	44.93	46.10	496.89
	Minning	10.05	9.91	8.45	7.76	6.75	4.55	3.99	4.08	4.32	4.48	4.47	4.68	5.06	5.43	5.56	111.93
	Construction	0.45	0.46	0.42	0.43	0.47	0.31	0.25	0.44	0.61	0.58	0.48	0.49	0.59	0.89	1.03	9.31
	TOTAL	**2177.08**	**2131.76**	**2102.69**	**2123.16**	**2120.17**	**2070.78**	**1980.54**	**2073.90**	**2315.67**	**2280.17**	**2248.04**	**2319.20**	**2366.13**	**2465.27**	**2614.26**	**35896.56**
Activity	Electricity, Gas and Water	14.6190407	299.05239	558.63784	906.638816	714.687325	789.046431	688.437052	298.710494	105.222986	539.772276	804.015611	452.647518	605.772837	559.924263	318.482367	7761.18666
	Commercial and Public	6.71475027	129.086211	284.112008	440.782545	357.70516	457.976859	411.536245	190.484263	58.6111726	316.484501	607.767612	352.717429	508.979925	477.439559	285.69603	5726.87793
	Indutry	37.5711818	759.538117	1471.35	2319.5749	1994.39075	3178.47307	3003.96199	1414.63903	424.629498	1763.7476	3175.03853	1818.17964	2512.05524	2260.94875	1448.10072	29713.261
	Transport	48.1276043	924.720505	1708.86947	2959.1936	2676.95112	3944.64117	4205.40594	1862.10932	472.458165	2220.80132	4297.23934	2498.42804	3516.39899	3228.6347	2054.14187	39562.1001
	Agriculture	1.36398811	27.9965688	64.0446333	94.6903111	63.4918527	95.4446092	105.776916	48.1071542	13.1318521	65.4137576	123.722118	73.7196652	111.613082	121.49134	73.9101443	1165.7182
	Minning	0.50262202	10.0012677	16.494549	24.6668705	18.5458147	18.662722	16.9682054	7.52127432	2.00890556	9.66814235	17.9516918	10.498469	15.5599539	14.6879374	8.90936278	262.583089
	Construction	0.02264914	0.46153455	0.8170732	1.37015057	1.29071331	1.26752523	1.06805889	0.80833298	0.2845528	1.26126007	1.91816655	1.10027609	1.8215596	2.39479589	1.64467742	21.8307627
	TOTAL	**108.921836**	**2150.85659**	**4104.32557**	**6746.91719**	**5827.06274**	**8485.51238**	**8433.15441**	**3822.37987**	**1076.34713**	**4917.14886**	**9027.65306**	**5207.29105**	**7272.20158**	**6665.52134**	**4190.88517**	**84213.5577**
Structure	Electricity, Gas and Water	409.372604	−398.465884	170.48834	−406.419758	−108.287322	−234.890796	−307.231603	−393.412962	25.6493782	19.3919941	−493.520996	−259.564251	−298.953168	−167.108053	−12.1443267	−2754.09942
	Commercial and Public	30.2474577	−37.2181578	−63.015358	−26.6816755	−20.0808377	−17.5215597	9.08061946	7.7820037	95.2708773	29.3863359	−62.6565815	101.446899	28.5062391	157.722292	125.174757	322.932643
	Indutry	899.13021	−241.948597	656.672332	1469.19492	−111.363075	306.287879	402.030996	−1786.7492	−4622.6417	−1314.75994	−828.816717	−2571.24825	−2687.95274	−2590.78666	−1360.21673	−13344.1791
	Transport	1421.72449	148.873925	509.95875	1612.42406	2354.06972	3307.5506	3401.58942	937.03134	−2620.26476	2035.4782	527.375317	52.7445571	−1407.23471	365.332378	−1710.48872	13710.5304
	Agriculture	8.77156709	42.7325878	−16.9968969	−53.6971508	−34.0575376	−73.1918132	−50.7540101	−82.4759291	−57.1009471	−90.8010678	−100.409579	−36.37726	50.9640747	−46.4995804	14.0947716	−623.685228
	Minning	−78.4144737	−34.0977088	−13.6006108	−38.1566986	−3.30103823	−14.0969508	−16.0009569	19.2640821	31.7255785	24.3190638	29.3907479	5.55214542	0.7800266	−25.5191361	−11.3816969	−57.8802384
	Construction	1.42272762	3.32334075	1.43419386	1.76170747	0.7999083	1.3830115	0.36494908	1.87320936	1.77491667	−1.89725919	0.83985383	0.84681816	3.16280671	4.44611732	0.84533541	27.6116951
	TOTAL	**2692.25458**	**−516.800494**	**1244.94075**	**2558.4254**	**2077.77982**	**3275.52037**	**3439.07942**	**−1296.68745**	**−7145.58665**	**701.117325**	**−927.797955**	**−2706.59934**	**−4310.72747**	**−2302.41264**	**−2954.11661**	**−2718.76927**
Intensity	Electricity, Gas and Water	916.809843	−326.98377	−2368.32291	1005.47466	−6043.43774	−5988.71269	−623.886255	195.632022	11781.7488	−9404.46683	−881.708668	493.318783	−1950.91819	3100.09357	−5321.00631	−15113.3419
	Commercial and Public	−3075.17348	2024.19182	187.349431	−1901.80884	−270.774721	−3299.21891	−358.266968	757.383265	2786.0207	−91.6306515	−206.455874	98.7440986	230.908536	521.255223	−1407.08704	−5161.92832
	Indutry	−547.65651	75.6158965	−3727.81222	−6023.70688	−337.683274	4128.57186	−22900.4794	30860.5738	−4530.54421	−9087.87059	496.137655	653.296599	804.55749	3019.61699	8643.79548	−2458.54634
	Transport	1024.19598	−9775.10484	−1587.30213	3961.1664	−6788.02483	−6442.83284	−5477.64328	−2419.45965	2152.35064	−3297.10686	−202.702966	−587.910334	273.715336	2820.9095	7846.97984	−25612.2246
	Agriculture	−165.398308	191.522841	465.141446	−997.790848	−220.535715	226.455123	−81.8648243	244.267422	177.716965	209.053721	−167.121526	448.824689	−94.892376	1467.07418	−1485.10982	201.072307
	Minning	68.865679	21.1839693	−235.344289	126.727517	−277.992639	−114.120179	3.04773486	−19.8661514	−2.0564837	−44.4705056	−44.8127272	14.2736285	15.5973231	43.3988064	−12.0852974	−615.630545
	Construction	3.10192289	−7.24231212	−5.66986327	2.43697516	−1.56024539	−25.9598606	9.31615629	18.8798829	3.32833793	−9.94887089	−11.2356776	8.56287014	1.42295821	43.273362	−32.5159573	−14.7479577
	TOTAL	**−1775.25488**	**−7796.81639**	**−7271.96053**	**−3827.50101**	**−13940.0092**	**−11515.8175**	**−29429.7769**	**29637.4105**	**12368.5648**	**−21726.4406**	**−1017.89978**	**1129.11033**	**−719.608926**	**11015.6216**	**8232.9709**	**−48775.3473**
TOTAL		**3203.00**	**−4031.00**	**180.00**	**7601.00**	**−3915.00**	**2316.00**	**−15577.00**	**34237.00**	**8615.00**	**−13828.00**	**9330.00**	**5949.00**	**4608.00**	**17844.00**	**12084.00**	**68616.00**

Table A.3
Drivers of the decoupling process by sectors (2000–2015).

		2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	TOTAL
Pop	Selfconsump.	−2.68	−0.14	−0.07	−0.04	−0.04	−0.02	−0.02	−0.04	−0.21	−0.05	−0.02	−0.04	−0.03	−0.03	−0.05	−0.04
	Commercial and Public	−1.23	−0.06	−0.04	−0.02	−0.02	−0.01	−0.01	−0.03	−0.12	−0.03	−0.02	−0.03	−0.02	−0.03	−0.04	−0.03
	Industry	−6.89	−0.35	−0.18	−0.11	−0.12	−0.09	−0.08	−0.20	−0.85	−0.17	−0.09	−0.16	−0.11	−0.13	−0.22	−0.15
	Transport	−8.83	−0.43	−0.21	−0.14	−0.17	−0.11	−0.12	−0.26	−0.94	−0.21	−0.12	−0.21	−0.16	−0.18	−0.31	−0.20
	Agriculture	−0.25	−0.01	−0.01	0.00	0.00	0.00	0.00	−0.01	−0.03	−0.01	0.00	−0.01	0.00	−0.01	−0.01	−0.01
	Mining	−0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	−19.99	−0.99	−0.51	−0.31	−0.36	−0.24	−0.23	−0.54	−2.15	−0.46	−0.25	−0.45	−0.33	−0.37	−0.62	−0.43
Str	Selfconsump.	−3.76	0.19	−0.04	0.06	0.02	0.03	0.04	0.10	−0.02	0.00	0.05	0.05	0.04	0.03	0.00	0.03
	Commercial and Public	−0.28	0.02	0.02	0.00	0.00	0.00	0.00	0.00	−0.09	−0.01	0.01	−0.02	0.00	−0.02	−0.03	0.00
	Industry	−8.25	0.11	−0.16	−0.22	0.02	−0.04	−0.05	0.47	4.29	0.27	0.09	0.49	0.37	0.39	0.32	0.16
	Transport	−13.05	−0.07	−0.12	−0.24	−0.40	−0.39	−0.40	−0.25	2.43	−0.41	−0.06	−0.01	0.19	−0.05	0.41	−0.16
	Agriculture	−0.08	−0.02	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.02	0.01	0.01	−0.01	0.01	0.00	0.01
	Mining	0.72	0.02	0.00	0.01	0.00	0.00	0.00	−0.01	−0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	−24.72	0.24	−0.30	−0.38	−0.36	−0.39	−0.41	0.34	6.64	−0.14	0.10	0.52	0.59	0.35	0.70	0.03
Int	Selfconsump.	−8.42	0.15	0.58	−0.15	1.04	0.71	0.07	−0.05	−10.95	1.91	0.10	−0.09	0.27	−0.47	1.27	0.18
	Commercial and Public	28.23	−0.94	−0.05	0.28	0.05	0.39	0.04	−0.20	−2.59	0.02	0.02	−0.02	−0.03	−0.08	0.34	0.06
	Industry	5.03	−0.04	0.91	0.89	0.06	−0.49	2.72	−8.07	4.21	1.85	−0.05	−0.13	−0.11	−0.45	−2.06	0.03
	Transport	−9.40	4.54	0.39	−0.59	1.16	0.76	0.65	0.63	−2.00	0.67	0.02	0.11	−0.04	−0.42	−1.87	0.30
	Agriculture	1.52	−0.09	−0.11	0.15	0.04	−0.03	0.01	−0.06	−0.17	−0.04	0.02	−0.09	0.01	−0.22	0.35	0.00
	Mining	−0.63	−0.01	0.06	−0.02	0.05	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	−0.01	0.00	0.01
	Construction	−0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	0.01	0.00
	TOTAL	16.30	3.62	1.77	0.57	2.39	1.36	3.49	−7.75	−11.49	4.42	0.11	−0.22	0.10	−1.65	−1.96	0.58
μt		−28.41	2.87	0.96	−0.13	1.67	0.73	2.85	−7.96	−7.00	3.81	−0.03	−0.14	0.37	−1.68	−1.88	3.82

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