ENERGY SAVING AND EFFICIENCY ACTION PLAN

2011-2020

(2nd SPANISH ENERGY EFFICIENCY ACTION PLAN)

ANNEX

METHODS OF CALCULATING THE SAVINGS OBTAINED FROM THE ENERGY EFFICIENCY ACTION PLANS 2005-2007 AND 2008-2012.

ANALYSIS OF RESULTS

GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, TURISMO Y COMERCIO
IDAE Instituto para la Diversificación y Ahorro de la Energía
ahorra energía

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I. EXECUTIVE SUMMARY

1. Calculation of savings in 2010. Purpose and methods

Purpose

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on Energy End-Use Efficiency and Energy Services lays down in article 14 that Member States must present a second Energy Efficiency Action Plan (EEAP) before 30 June 2011. The Action Plan will include a thorough analysis and evaluation of the previous Plan, EEAP 2008-2012 (frist Action Plan for the purposes of Directive 2006/32/EC) together with the results in terms of meeting the energy savings targets given in article 4 for the third year of application of the Directive.

This Annex reflects the calculation methods and quantification of the energy savings obtained in 2010 with respect to the reference years 2007 and 2004. In addition, calculating the savings obtained in comparison with 2007 allows us to assess the progress made in meeting the savings targets set for 2016 and 2020. It also enables us to gauge the results of the *2005—2007 Action Plan,* approved as part of the *Energy Savings and Efficiency Strategy in Spain 2004—2012 (E4)*.

The scope of the study extends to the savings achieved in each of the sectors detailed in Action Plans 2005—2007 and 2008—2012 as a result of energy savings and efficiency measures using a variety of mechanisms implemented in the course of targeted programmes. The aforesaid programmes are usually combined with additional incentives (subsidies, tax incentives, etc.) to encourage alternative consumption patterns or changes to more efficient technologies.

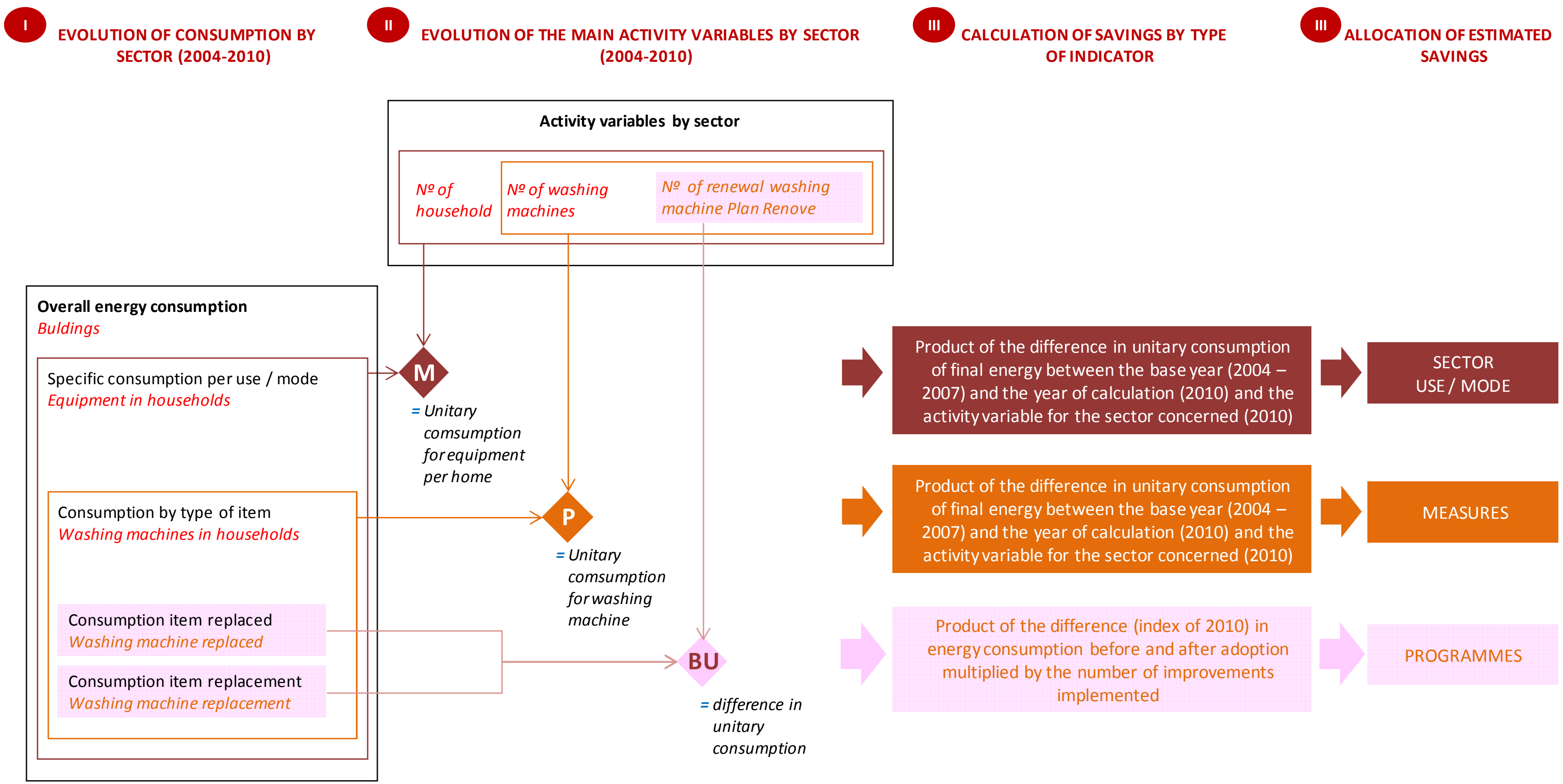
Method

Quantifying the savings obteined was achieved using the methods recommended by the European Commission in its document, "*Recommendations on Measurement and Verification Methods in the Framework of Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services*". This method (see for example the "Renewal of household appliances" in Figure 1) was the result of a combination of 'top-down' indicators and 'bottom-up' calculations.

- The top-down indicators (which the European Commission separates into *M* 'minimum' and *P* 'preferred' indicators), base on the differences between the year of reference or base year (2004 or 2007) and the year of calculation (2010). These indicators employ aggregate information on sector consumption, mode of transport or energy usage plus the statistical data pertaining to the different activity variables.

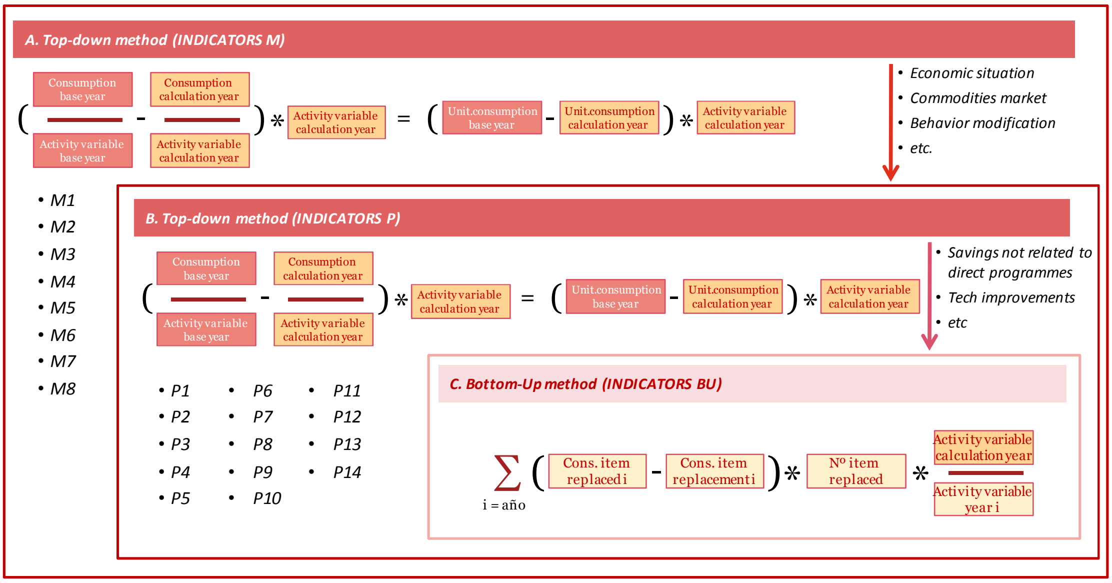
- Upward or *bottom-up* (BU) calculations are based on reliable information on each energy-saving measure adopted in the course of the period under analysis. The result is calculated multiplying of the difference in energy consumption before and after adoption by the number of improvements implemented.

Figure 1. *Diagram of the methodology of calculation and allocation of energy savings by type of indicator (M, P and BU) to sector, size and performance, particularized as an example for "Renewal of household appliances"*



The differences in the results obtained by means of this dual approach (top-down — bottom-up) allow us to explain indirect and/or unquantifiable effects associated with structural or temporary changes, as shown in Figure 2. This analysis is made possible given that all savings are calculated for 2010 with respect to the same time base (2004 or 2007) while the activity variables present different sensitivities to temporary or structural variations in each of the sectors examined.

Figure 2. *Diagram of the methodology for energy savings calculation, which combines consistently top-down and bottom-up indicators*



The top-down indicators used in this study are mostly of the type *P* (preferred by the European Commission[1]), although in some cases we have settled for type *M* where insufficient good-quality statistical information was available. The majority of the *P*-type indicators allow economic factors unrelated to energy efficiency or savings to be factored out.

The positive or negative savings achieved depend on whether the value of the selected indicator falls — i.e., improves — between the base year and 2010. The actual amount of the savings is determined by the product of the difference in unitary consumption of final energy between the base year and the year of calculation, times the activity variable for the sector concerned.

Table 1 gives a list of the top-down indicators used for each sector, the means of transport or energy usage in the case of residential and services sectors (space heating, cooling, refrigeration, water heating, lighting and appliances). Once the savings are calculated they are assigned to each sector or measure detailed in the plan, taking special care when grouping or adding subtotals to calculate real overall savings without duplicating results.

Details of the calculations to be made for each of the sectors are provided in the different chapters of this Annex.

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[1] *"Recommendations on measurement and verification methods in the framework of Directive 2006/32/EC on energy end-use efficiency and energy services"* European Commission. Directorate-General for Energy.

Table 1. *Top-down indicators used to calculate the energy savings*

SECTOR			ENERGY INDICATOR		UNIT
INDUSTRY	Parametric Method Divisia 1 (LAS-PDM1)		$L_{Technological}$	PDM1 indicator of technological effect of industrial sub-sector	ktoe/10^6 €
			$L_{Structure}$	PDM2 indicator of structural effect of industrial sub-sector	ktoe/10^6 €
TRANSPORT	ROAD	PASSENGERS	BU_{rp}+BU_{cet}[2]	Unitary savings per vehicle replaced by type of replacement + unitary savings associated to Eco-driving courses	goe/pkm
			M53/PB	Energy consumption per buses fleet	toe/veq
		FREIGHT	M52/A2	Energy consumption of trucks and light vehicles per vehicle fleet equivalent	toe/veq
	RAILWAY	PASSENGERS	P10	Energy consumption of passengers rail transport per passenger traffic (passenger-km)	goe/pkm
		FREIGHT	P11	Energy consumption of freight rail transport per freight traffic (tonne-km)	goe/tkm
	MARÍTIME (FREIGHT)		M7	Energy consumption of freight sea transport (coastal and river) per freight traffic (tonne-km)	goe/tkm
	AIR (DOMESTIC PASSENGERS)		Mav	Energy consumption of passengers air transport in domestic flights per operations (number of flights)	goe/pkm
	MODAL SHIFT	PASSENGERS car to collective	P12	Transfer of passenger vehicle traffic to collective modes (bus, train and underground)	%
		FREIGHT road to railway/maritime	P13	Transfer of freight road traffic to rail and maritime modes	%
BUILDING	RESIDENTIAL	ENVELOPE AND THERMAL EQUIPMENT	P1	Energy consumption of households for space heating per floor area (adjusted for climatic conditions)	toe/m^2
			P2	Energy consumption of households for space cooling per floor area (adjusted for climatic conditions)	toe/m^2
			P3	Energy consumption of households for water heating per inhabitant	toe/inhabitant
		LIGHTING	P5	Electricity consumption of households for lighting per dwelling	toe/home
	SERVICE	ENVELOPE AND THERMAL EQUIPMENT	M311	Non-electric energy consumption in service sector for space heating per employee in full time equivalent (adjusted for climatic conditions)	toe/employee
			M411	Electric energy consumption in service sector for space heating per employee in full time equivalent (adjusted for climatic conditions)	toe/ employee
			M412	Electric energy consumption in service sector for space cooling per employee in full time equivalent (adjusted for climatic conditions)	toe/ employee
			M312	Non-electric energy consumption in service sector for water heating per employee in full time equivalent	toe/ employee
			M413	Electric energy consumption in service sector for water heating per employee in full time equivalent	toe/ employee
		LIGHTING	M42	Energy consumption in service sector for lighting per employee in full time equivalent	toe/employee
EQUIPMENT	RESIDENTIAL	APPLIANCES	P4	Domestic Energy consumption of electrical appliances per equipment unit	toe/equipment
			P41	Domestic energy consumption of cookers per equipment unit	toe/cooker
	SERVICE	APPLIANCES	M44	Electric energy consumption in service sector of appliances and office equipment per employee in full time equivalent	toe/ employee
		COOKERS	M43	Electric energy consumption in service sector of cookers per employee in full time equivalent	toe/ employee
			M32	Non-electric energy consumption in service sector of cookers per employee in full time equivalent	toe/ employee
PUBLIC SERVICES	STREET LIGHTING		MAP	Electric energy consumption of street lighting per dwelling	toe/ dwelling
	WATER DESALINATION		$MAG_{desalination}$	Energy consumption for desalination per volume of desalinated water	ktoe/hm^3 year
	WATER TREATMENT		$MAG_{treatment}$	Energy consumption for water treatment per inhabitant	toe/inhabitant
AGRICULTURE AND FISHERIES			M8'	Energy consumption in agriculture and fisheries per GVA unit	ktoe/10^6 €

[2] Given the quality of information available when assessing savings linked to passenger road transport, the *bottom-up* method has been used as a result of its accurateness instead of using more aggregated statistical data as with the other indicators.

2. Summary of energy saving results and emissions avoided

Table 2 shows the savings in final and primary energy plus the volume of CO_2 emissions avoided. These savings should not be confused with the accumulated savings within the period; they are the savings obtained in 2010 thanks to the improvement of energy efficiency with respect to the situation in the base year applicable (2004 or 2007).

Table 2. *Summary of savings in final and primary energy as well as CO_2 emissions avoided in all sectors, including energy*[3] *transformation in 2010 with respect to 2004 and 2007*

	Indicators used	Final energy saving 2010 [ktoe] Base 2004	Final energy saving 2010 [ktoe] Base 2007	Primary energy saving 2010 [ktoe] Base 2004	Primary energy saving 2010 [ktoe] Base 2007	CO_2 Emissions avoided 2010 [ktCO_2] Base 2004	CO_2 Emissions avoided 2010 [ktCO_2] Base 2007
INDUSTRY	$L_{technological} + L_{structurre}$	**-798.6**	**-2,865.6**	**-2,695.7**	**-5,717.4**	**-5,281.8**	**-12,416.8**
TRANSPORT		**6,451.1**	**4,561.1**	**6,874.1**	**4,909.2**	**21,471.2**	**13,330.1**
Road	BU_{RP}+BU_{cet}+M53+M52+P12+P13	6,784.1	4,916.1	7,569.4	5,494.4	23,001.2	14,788.7
Railway	P10+P11	-317.4	-206.7	-677.8	-419.2	-1,468.0	-953.9
Maritime	M7	52.3	-99.9	58.6	-111.9	166.8	-342.1
Air	Mav	-68.0	-48.3	-76.1	-54.1	-228.8	-162.5
BUILDING AND EQUIPMENT		**2,232.5**	**2,529.1**	**3,165.0**	**4,189.1**	**6,982.8**	**9.269.0**
Residential		354.9	751.9	724.4	1,160.3	1,504.0	2.587.7
Envelope & ther. equipment	P1+P2+P3	273.9	698.6	521.8	1,034.5	1,094.3	2.318.6
Lighting	P5	81.0	53.3	202.6	125.7	409.6	269.2
Services		2,076.7	1,569.9	3,149.9	2,631.0	6,861.9	5.814.1
Envelope & ther. equipment	M311+M411+M412+M312+M413	1,363.7	1,322.0	1,365.5	2,046.9	3,254.4	4.563.4
Lighting	M42	713.0	247.9	1,784.4	584.1	3,607.4	1.250.7
Equipment	P4+P41+M44+M43+M32	-199.1	207.3	-709.2	397.8	-1,383.0	867.1
PUBLIC SERVICES		**31.8**	**28.6**	**79.6**	**67.4**	**161.0**	**144.3**
Street lighting	MAP	4.6	11.3	11.5	26.5	23.2	56.8
Water	$MAG_{desolation}$ +$MAG_{treatment}$	27.2	17.3	68.2	40.9	137.8	87.5
AGRICULTURE AND FISHING	M8'	**425.5**	**466.7**	**535.5**	**580.4**	**1,526.3**	**1.673.2**
TOTAL END-USE SECTORS		**8,342.3**	**4,719.9**	**7,958.5**	**4,028.7**	**24,859.4**	**11,999.8**
ENERGY TRANSFORMATION		**N/A**	**N/A**	**9,766.9**	**7,018.5**	**51,796.9**	**53,252.8**
Electric power generation	$AEP_{generation}$	N/A	N/A	9,481.8	6,909.1	51,465.8	52,946.6
Oil refining	$AEP_{refining}$	N/A	N/A	71.9	38.6	38.4	185.5
Encouraging co-generation	$AEP_{cogeneration}$	N/A	N/A	213.2	70.8	292.7	120.6
TOTAL END-USE SECTORS AND ENERGY TRANSFORMATIÓN		**8,342.3**	**4,719.9**	**17,725.4**	**11,047.2**	**76,656.4**	**65,252.6**

It should be underlined that these results do not show all the savings in final energy in the period, only those resulting from an improvement in efficiency, for example through a technological advance or as the result of administrations action. This being the case, quantifying the effects of the present economic situation was kept to a minimum.

The total savings obtained in 2010 with respect to 2004 was 8,342.3 ktoe; 4,719.9 ktoe with respect to 2007. These results show that the consumption of final energy in

[3] The means of calculating the savings achieved in the energy transformation sector are given in Section VII of this Annex.

the year of calculation (93,423 ktoe) provided an energy saving of 8.2% and 4.8% respectively.

The main savings in terms of final energy are as follows:

- With respect to the industrial sector, in 2010 its contribution was negative with respect to both base years. Using 2004 as base, negative savings of -798.6 ktoe in terms of final energy were obtained, while the figure with respect to 2007 was -2,865.6 ktoe. Unitary consumption in the sector has risen over the last few years, mainly as the result of lower use of productive capacity and of having to maintain fixed energy consumptions.

- The main savings in final energy were obtained in the transport sector: 6,451.1 ktoe v. 2004 and 4,561.1 ktoe v. 2007. Most of these savings were obtained in road haulage (6,784.1 ktoe), which offset the negative savings pertaining to rail transportation. The rise in rail consumption resulted from the downturn in freight transportation — a consequence of the present economic downturn — and the resulting decline in load factor (the increase in fuel consumption per tonne-kilometre hauled).

- The buildings segment — which includes the energy uses of the building envelope, heating installations, interior lighting and appliances — managed to contribute a total saving of 2,232.5 ktoe v. 2004 and of 2,529.1 ktoe v. 2007. These results were largely due to improvements in the energy efficiency of the building envelope and heating equipment, and occurred mainly in the services sector (approximately 61% of total savings in 2010 related to the provision of space heating, cooling and domestic hot water in the services sector).

- The public services sector — which includes street lighting and the water supply or water cycle — contributed 31.8 ktoe v. 2004 and 28.6 ktoe v. 2007. With respect to street lighting, the increase in household electricity consumption as a consequence of urban development and the multiplication of power sockets largely offset the improvements resulting from energy efficiency and technological renewal.

- The agriculture and fisheries sector increased its contribution from 425.5 ktoe in 2004—2010 to 466.7 ktoe in 2007—2010. This was principally due to the growth of the subsector that uses the least amount of energy, i.e., crop, livestock and fruit and vegetable farming, as opposed to fisheries. Crop, livestock and fruit and vegetable farming accounted for 95% of the added value and 85% of energy consumption of the combined agriculture and fisheries sector.

Table 3 shows the savings obtained by tracking bottom-up indicators to locate the direct savings resulting from the various mechanisms introduced, accompanied by a description of each[4].

[4] Chapter 3 of the Energy Efficiency Action Plan 2011-2020 describes in detail each of the programmes referred to.

Table 3. *Summary of savings in final and primary energy as well as C02 emissions avoided in 2010 due to the diferents mechanisms of action*

	Final Energy Savings 2010 [ktoe]	**Primary Energy Savings 2010 [ktoe]**	**CO_2 Emissions avoided 2010 [$ktCO_2$]**
IDAE- REGIONAL ADMINISTRATIONS PROGRAMME *(1)*	2,304.5	3,221.2	7,843.9
PROGRAMME FOR STRATEGIC PROJECTS ON ENERGY EFFICIENCY	199.9	337.0	722.5
CAMPAIGNS CONDUCTED DIRECTLY BY THE IDAE	140.5	302.2	653.8
Eco-driving for cars and vans	1.1	1.2	3.7
Eco-driving for trucks and buses	30.7	34.4	105.0
MOVELE project	2.1	1.2	6.0
Low energy bulb distribution programme	84.9	212.5	429.5
2x1 low energy bulb programme	13.0	32.5	65.8
Traffic-light replacement programme	8.7	20.4	43.7
OTHER PROGRAMMES (Plan Prever, VIVE, 2000 E)	**730.1**	**813.1**	**2,328.5**
TOTAL	**3,375.0**	**4,673.2**	**11,547.3**

(1) The savings made by this mechanism are detailed in Table 4 *Source: IDAE*

- **IDAE—Regional Administrations Programme**

  Since 2005 Spain's regional administrations have conducted the campaigns announced in the 2005—2007 and 2008—2012 action plans. Through agreements signed with the IDAE (Institute for the Diversification and Saving of Energy) they have determined how the plans are to be implemented, i.e., the conditions to be met by beneficiaries of the subsidies and what ceilings are set on the subsidies available. The agreements signed to implement the 2008—2012 campaign are rolled over each year and will remain in force until 2012.

  As a result the regional administrations have been administering approximately 75% of the total sum budgeted for the 2005—2007 and 2008—2012 campaigns, with the Ministry of Industry, Tourism and Trade, via the IDAE, managing the remaining 25% directly. Thanks to these subsidies a direct energy saving of 2,304.5 ktoe was obtained in 2010, spread over the various sectors affected.

Table 4. *Summary of savings achieved in 2010 (base 2004) for IDEA - Regional Administrations programmes (2005-2010)*

	Final E. savings [ktoe]	**Primay E. Savings [ktoe]**	**CO_2 Emissions avoided [$ktCO_2$]**
INDUSTRY	**1,068.6**	**1,585.8**	**3,468.6**
Energy audits	N/C	N/C	N/C
Publics aids programmes	1,068.6	1,585.8	3,468.6
TRANSPORT	**947.8**	**944.1**	**2,978.1**
Urban mobility plans and Mobility plans for companies and activity centres	860.0	846.4	2,683.8
Increased participation of collectives by road transport	N/C	N/C	N/C
Fleet management of road transport	1.3	1.5	5.0
Eco-driving for cars and vans	52.4	58.1	173.1
Eco-driving for trucks and buses	30.0	33.5	102.5
Replacing car fleets	2.7	3.0	8.6
Renovarion of road transport fleets	1.5	1.6	5.0
BUILDING AND AND EQUIPMENT	**195.5**	**438.5**	**898.8**
Rehabilitation of thermal envelope and improvements to the thermal installations of existing buildings	22.3	42.5	89.1
Improved energy efficiency in heating systems of existing buildings	61.1	116.4	244.2
Improved energy efficiency in the interior lighting installations of existing buildings	29.7	74.4	150.4
Construction of new buildings and rehabilitation of existing with a high energy rating	0.9	1.5	3.3
Improved energy efficiency in appliances equipment	81.4	203.7	411.8
PUBLIC SERVICES	**84.7**	**211.9**	**428.4**
Renewal of existing public street lighting installations	77.7	194.3	392.9
Studies, feasibility analysis and audits of existing street lighting installations	N/C	N/C	N/C
Training of municipal energy managers	N/C	N/C	N/C
Improvement of installations for the treatment and supply of drinking water and the desalinisation and de-sludging of waste water	7.0	17.6	35.5
AGRICULTURE AND FISHING	**8.0**	**11.6**	**30.4**
Promotion and training techniques for efficient use of energy in agriculture and fishing sector	N/C	N/C	N/C
Switch from sprinkler irrigation to drip irrigation	2.1	4.5	9.8
Improvements in energy savings and efficiency in the fisheries sector	4.1	4.6	14.1
Energy audits and action plans for improvements on farms	1.6	2.2	6.0
Support for conservation agriculture	0.2	0.2	0.6
TOTAL END-USE SECTOR	**2,304.5**	**3,191.9**	**7,804.3**
ENERGY TRANSFORMATION	N/C	29.3	39.6
Feasibility studies for co-generation plants	N/C	N/C	N/C
Energy audits for co-generation plants	N/C	N/C	N/C
Promotion of cogeneration plants in non-industrial activities	N/C	9.5	12.1
Promotion of low power cogeneration plants	N/C	0.8	1.4
Promotion of co-generation plants in industrial activities	N/C	19.0	26.1
TOTAL END-USE SECTORS + ENERGY TRANSFORMATION	**2,304.5**	**3,221.2**	**7,843.9**

(N/C) The savings produced by these actions have not been quantified. *Source: IDAE*

- **Campaigns conducted directly by the IDAE**

  The public funds managed directly by the IDAE as part of the 2005—2007 and 2008—2012 Action Plans were employed directly in nationwide campaigns and programmes aimed at final consumers not eligible for the aid, training or information services funded by regional administrations.

  A notable instance of such campaigns was the support provided for strategic projects, the aim of which was to encourage original, innovative initiatives at the sector level in support of energy savings and efficiency. The savings obtained by this mechanism by the end of 2010 were estimated at 199.9 ktoe of final energy.

  Other programmes managed directly by the IDAE were focused mainly on: the transport sector by means of training courses on Eco-driving and the MOVELE project; households via distribution of low-consumption compact fluorescent light bulbs; and the public service sector by means of a programme to replace conventional traffic lights with those employing LED technology. In all, these programmes accounted for a total of 140.5 ktoe of final energy at the end of 2010.

- **Other programmes**, such as vehicle replacement schemes (Plan PREVER 1997—2007, Plan VIVE 2008—2010) and Plan 2000E in 2010) focusing on the transport sector, achieved a final energy saving of 867.8 ktoe in 2010.

3. Conclusions on the sectors under study

For the different sectors under study it is worth noting the following points with regard to the economic effort undertaken by the central administration:

Industry

The industrial sector failed to achieve final energy savings in either of the two periods examined, 2004—2010 (—798.6 ktoe), 2007—2010 (—2,865.6 ktoe), due mainly to the decline in output ratios in various sub-sectors.

The economic crisis distorts any analysis of the results corresponding to the energy efficiency measures aimed at this sector. On the one hand, per unit energy consumption rose in the last few years, largely as the result of productive capacity being under-utilised while fixed costs still had to be met, resulting in negative savings. On the other hand, the contraction of the building industry in comparison with other industries produced positive results in terms of achieving energy savings by means of structural change.

It is worth noting the effort made to offset these consequences by measures designed to improve the efficiency of industrial equipment. The administrations initiated and funded the moves proposed in the both Energy Savings and Efficiency Plan 2005-2007 and 2008-2012, articulated through cooperation agreements between the IDAE and regional administrations (1,068.6 ktoe in 2010 v. 2004), together with aid program IDAE for strategic projects.

Table 5. *Public aids managed directly by IDAE, or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Industrial Sector in the period 2006-2010*[5]

	2006	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**28,327**	**28,839**	**29,614**	**29,351**	**28,456**
Energy audits and other studies [k€]	1,888	1,610	2,556	2,385	1,981
Public aids programmes [k€]]	24,633	27,119	26,059	26,853	25,149
Strategic projects [k€]			**15,100**	**65,700**	**68,800**

Source: IDAE

Transport

The savings obtained by this sector (6,451.1 ktoe in 2010 versus 2004 and 4,561.1 ktoe versus 2007) present varying degrees of success depending on the mode of transport concerned, road, rail, sea or air. In general all four modes show a downward trend in total traffic and consumption in the latter part of the period under study as a consequence of the recession. This factor is particularly pronounced with respect to freight transport, where the sharp decline in industrial activity has resulted in falling consumption and a much reduced traffic in trucks and light vehicles, while fleet sizes remain constant.

Most of the savings achieved were in road transport (6,784.1 ktoe and 4,916.1 ktoe), mainly in freight haulage.

Rail transport presented negative savings in both periods of analysis (—317.4 ktoe and —206.7 ktoe) as a consequence of the reduction in freight haulage as a result of the recession and the subsequent reduction in load factor. Broadly speaking, energy consumption remains flat, while load volumes fall.

On the other hand the negative savings recorded for air transport (—68.0 ktoe and — 48.3 ktoe) are the result of a relatively higher consumption of energy per journey in the period under study.

The measures contained in both action plans 2005-2007 and 2008-2012 relating to the sector and articulated by means of cooperation agreements between the IDAE and the regional administrations (947.8 ktoe in 2010 with respect to 2004) promoted, among others, fleet renewals and a changeover to more fuel-efficient modes of transport. The support afforded the Sustainable Mobility Plans and associated communication and awareness campaigns also contributed to improving energy efficiency in the transport sector.

In addition to the measures undertaken in harness with regional administrations, other initiatives, also articulated by the IDAE, in the form of subsidies for strategic projects, were set in train. They include the MOVELE Project, the programmes on Eco-driving techniques, and the various programmes designed to replace vehicles (PREVER, VIVE and 2000E). These measures were further reinforced by legal moves such as favourable vehicle registration rates and by EC Regulation 443/2009/EC laying down limits on the CO_2 emissions of new cars. These legislative initiatives contributed significantly to renovating the stock of cars.

[5] The total number of subsidies aimed at the IDAE-Regional Government Programme does not relate to the total measures identified in the table, as in addition, the table includes subsidies aimed at "training and dissemination activities in the industry sector" and the "efficiency improvement and promotion of energy research programme".

Table 6. *Public aid managed directly by IDAE or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Transport Sector in the period 2006-2010*[6]

	2006	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**17,137**	**19,039**	**32,289**	**28,646**	**24,365**
Urban mobility plans and Mobility plans for companies and activity centres [k€]	8,182	9,621	17,048	11,589	8,962
Increased participation of collectives by road transport [[k€]	4,321	1,539	1,972	1,148	367
Fleet management of road transport [k€]	200	597	1,580	1,847	2,355
Eco-driving for cars and vans [k€]	1,025	2,172	3,368	4,117	3,324
Eco-driving for trucks and buses [k€]	1,206	2,215	2,594	3,465	2,919
Replacing car fleets [k€]	259	1,133	4,120	4,614	4,809
Renovarion of road transport fleets [k€]	1,924	1,695	1,575	1,582	1,605
Strategic projects [k€]			**4,222**	**10,917**	**10,527**

Source: IDAE

Buildings and installations

Of the energy savings achieved in both periods in buildings and building installations (2,232.5 ktoe v. 2004 and 2,529.1 ktoe v. 2007) approximately two thirds relate to building envelope and their thermal installations, mainly in the services sector (approximately 61% of savings in 2010 relate to reductions in the cost of space heating, air conditioning and the supply of hot water in this sector).

Most of the other savings arose from fitting more efficient interior lighting, given that other installations generated few if any savings due to the pre-existing level of market penetration and relatively higher energy requirements.

The sector made good progress in applying the measures proposed in the Energy Savings and Efficiency Plans 2005-2007 and 2008-2012, aided by a number of legal reforms designed to foster more efficient energy use in building and architecture.

The four measures of the Action Plan aimed at this sector and given material form in cooperation agreements between the IDAE and regional administrations (195.5 ktoe in 2010 v. 2004) sought to encourage major upgrades of building envelope, improvements in thermal installations, better lighting systems and more modern household appliances. The Energy Savings and Efficiency Activation Plans .The 2 for1 programme and the programme to distribute free of charge high-efficiency light bulbs, combined with the strategic project programme and the communication and awareness programmes, also contributed significantly to improving energy efficiency in the buildings sector.

These measures were aided by a concerted effort at the regulatory level, in particular by publication of the Technical Building Code (decree Law 314/2006), introducing more efficient requirements for building envelope and thermal systems. Also of note were the new Regulations on Thermal Installations in Buildings (decree law 1027/2007), under which the energy performance of such installations has to be

[6] The total number of subsidies aimed at the IDAE-Regional Government Programme does not relate to the total measures identified in the table, as in addition, the table includes subsidies aimed at “training and dissemination activities in the transport sector”, “greater maritime participation in the transporting of goods” and “greater rail participation in inter-urban transport”.

reviewed periodically, and developers are obliged to obtain building energy compliance certificates, as per Decree Law 47/2007.

Table 7. *Public aid directly managed by IDAE or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Building and Equipment Sector in the period 2006-2010*[7]

	2006	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**87,785**	**78,735**	**139,210**	**143,157**	**148,268**
Rehabilitation of thermal envelope and improvements to the thermal installations of existing buildings [k€]	15,330	8,245	23,968	27,381	36,577
Improved energy efficiency in heating systems of existing buildings [k€]	13,523	12,869	41,512	38,820	38,803
Improved energy efficiency in the interior lighting installations of existing buildings [k€]	1,782	1,860	4,058	7,421	7,400
Construction of new buildings and rehabilitation of existing with a high energy rating [k€]			2,008	2,172	2,028
Improved energy efficiency in appliances equipment [k€]	55,231	51,280	61,100	59,395	55,333
Strategic projects [k€]			**25,158**	**32,553**	**38,835**
Campaigns conducted directly by the IDAE [k€]			**3,130**	**27,848**	**13,693**
Distribution of low-consumption light bulbs [k€]				27,848	13,693
"2 for 1" distribution of low-consumption light bulbs [k€]			3,130		

Source: IDAE

Public services

The public service sector has achieved positive savings in the period 2004—2010 (31.8 ktoe) thanks mainly to improving the use efficiency of the water supply or water cycle, specifically in the desalination process. Also, in the savings obtained in the second period of the 2007—2010 report (28.6 ktoe) the contribution of street lighting rose significantly.

Both the use and the geographical density of street lighting have increased notably in recent times as a consequence of the volume of urban development. The adoption of rules on energy efficiency and street lighting formulated in decree law 1890/2008, the efficiency of this segment has improved the efficiency of the sector..

The Energy Efficient Savings Plan 2005-2007 and 2008-2012 has fostered a more efficient use of energy in the public sector in a number of ways. The initiatives adopted were articulated mainly by the IDAE, working in harness with regional administrations (84.7 ktoe in 2010 v. 2004). The areas covered were street lighting, water supply, sewage works and desalination. Most of the savings achieved in this sector resulted from the initiative of the renovation of street lighting, wich must be added those resulting from other programmes, e.g. traffic-light renewal programme.

[7] The total number of subsidies aimed at the IDAE-Regional Government Programme does not relate to the total measures identified in the table, as in addition, the table includes subsidies aimed at activities including those linked to audits, training, dissemination, replacing metres, inspections and improving the efficiency of lifts.

Table 8. *Public aid directly managed by IDAE or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Public Services Sector in the period 2006-2010*

	2006	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**21,409**	**22,596**	**30,090**	**33,723**	**29,173**
Renewal of existing public street lighting installations [k€]	17,185	17,893	26,321	28,901	25,623
Studies, feasibility analysis and audits of existing street lighting installations [k€]	1,393	2,544	1,672	2,052	1,714
Training of municipal energy managers [k€]	112	0	177	345	265
Improvement of installations for the treatment and supply and the desalinisation and de-sludging of waste water [k€]	2,719	2,159	1,920	2,426	1,572
Strategic plans [k€]					**356**
Campaigns conducted directly by the IDAE [k€]				**31,794**	
Replace existing traffic lights with LED [k€]				31,794	

Source: IDAE

Agriculture and Fisheries

According to the indicators examined, end-use energy savings were achieved in the Agriculture and Fisheries sector in both assessment periods: 425.5 ktoe in 2010 v. 2004 and 466.7 ktoe in 2010 v. 2007. This was due in part to a downturn in production and in part to technological improvements.

In the subsector of agriculture, positive energy savings were achieved thanks to improvements in farm machinery and more efficient irrigation methods. However, the increase in the use of air-conditioning in livestock and fruit and vegetable farms resulted in increased energy usage, generating negative savings.

The savings achieved in the subsector of fisheries and aquiculture were the consequence of direct action by the administrations to reduce energy consumption in various types of fishing vessels, the downturn in the economy and the natural technological evolution of the fishing fleet.

Table 9. *Public aid directly managed by IDAE or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Agriculture Sector in the period 2006-2010*[8]

	2006	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**1,378**	**4,540**	**3,980**	**3,657**	**4,581**
Promotion and training techniques for efficient use of energy in agriculture and fishing sector [k€]	935	1,355	956	899	808
Switch from sprinkler irrigation to drip irrigation [k€]		2,800	946	1,391	1,749
Improvements in energy savings and efficiency in the fisheries sector [k€]			1,003	459	611
Energy audits and action plans for improvements on farms [k€]	362	308	982	839	1,179
Support for conservation agriculture [k€]			93	69	235

Source: IDAE

[8] The total number of subsidies aimed at the IDAE-Regional Government Programme does not relate to the total measures identified in the table, as in addition, the table includes subsidies aimed at the "RENOVE plan for tractors and improved energy efficiency using vehicle inspections".

Energy conversion

The primary energy conversion, i.e. generating of electricity, refining oil, and power co-generation, were all examined.

In 2010, of a total consumption of primary energy of 131,927 ktoe, 62,358 ktoe (47%) was in the form of oil, most of it processed at Spanish refineries, and 49,249 ktoe (37%) were consumed generating electricity for national consumption. These figures show the strategic importance of efficiency in the energy transformation industry.

In the period examined, almost all the savings correspond to the improvement in the overall yield of the country's electricity generating plant (9,482 ktoe of primary energy in 2010 v. 2004, 6,909 ktoe v. 2007), including reductions in transmission losses. This was achieved in the main by the significant increase in renewables and combined-cycle natural-gas components of Spain's power generation mix.

Co-generation also played a significant role in primary energy savings (213 ktoe in 2010 v. 2004 and 71 ktoe v. 2007) thanks to the higher efficiency ratio of simultaneous production of heat and electricity in comparison with the production of these two energy flows separately.

Meanwhile oil refining also generated savings (72 ktoe in 2010 v. 2004 and 39 ktoe v. 2007), thanks in the main to smaller losses in the refining process.

Table 10. *Public aid directly managed by IDAE or IDAE in collaboration with the Regional Administrations, applied to measures relating to the Energy Transformation Sector in the period 2006-2010*

	2004	2007	2008	2009	2010
IDAE- Regional Administrations Programme [k€]	**2,467**	**4,427**	**3,484**	**1,424**	**1,516**
Feasibility studies for co-generation [k€]	444	348	416	281	316
Energy audits for co-generation [k€]	177	274	186	90	156
Promotion of co-generation plants in non-industrial activities [k€]	426	629	496	952	866
Promotion of low power co-generation plants [k€]		132	130	102	178
Promotion of cogeneration plants in industrial activities [k€]	1,420	3,044	2,257		
Strategic projects[k€]				80	

Source: IDAE

II. INDUSTRY

1. Summary of savings in the industrial sector

INDUSTRIA

The industrial sector achieved no final energy savings in either of the periods under analysis 2004—2010 and 2007—2010 mainly due to the decline in production ratios in some industry branches. Final energy consumption in this sector in 2010 was 28,209.4 ktoe, 28% of the national total.

Breakdown of savings

The relative savings in the industrial sector are structured according to origin: technological or structural:

Industry [*L*] = **-798.6 ktep** $_{2010(Base\ 2004)}$

Structural effect	Technology effect	
[*LE*] = **1,655.1 ktep** $_{2010(Base\ 2004)}$	[*LT*] = **-2,454.1 ktep** $_{2010(Base\ 2004)}$	
	Cooperation agreements [BUin$_1$] = **1,068.6 ktep** $_{2010(B\ 2004)}$	Strategic Projects [BUin$_2$] = **131,5 ktep** $_{2010(B\ 2004)}$

Sector consumption

	Final Energy 2010 [ktoe]
TOTAL CONSUMPTION INDUSTRY SECTOR	28,209.4
Wood, cork, furniture	705.0
Food, beverages and tobacco	2,352.2
Textiles, leather and footwear	597.3
Pulp, paper and printing	2,534.5
Chemistry	4,943.7
Non-metallic Minerals	6,093.1
Metallurgy and metal products	5,944.2
Machinery and mechanic equipment	320.9
Transport equipment	851.7
Electrical, electronic and optical equipment	345.1
Rest of the manufacturing industry	3,521.7

Savings obtained

	Final Energy Savings 2010 [ktoe]		Primary Energy Savings 2010 [ktoe]		CO_2 Emissions Avoided 2010 [ktCO_2]	
	Base 2004	Base 2007	Base 2004	Base 2007	Base 2004	Base 2007
TOTAL SECTOR SAVINGS	-798.6	-2,865.6	-2.,695.7	-5,717.4	-5,281.8	-12,416.8
Wood, cork, furniture	86.8	-120.9	105.7	-145.4	240.5	-334.9
Food, beverages and tobacco	436.7	-194.0	748.9	-319.9	1,597.0	-708.2
Textiles, leather and footwear	319.8	40.8	527.4	64.8	1,132.1	144.1
Pulp, paper and printing	-407.1	-428.5	-559.0	-575.1	-1,240.9	-1,305.0
Chemistry	-1,071.1	-41.7	-2,076.6	-77.1	-4,343.8	-168.7
Non-metallic Minerals	-212.6	325.2	-242.1	368.1	-559.5	855.4
Metallurgy and metal products	1,283.1	-281.4	1,747.6	-374.9	3,886.0	-851.6
Machinery and mechanic equipment	12.8	-21.3	28.3	-44.5	58.1	-96.3
Transport equipment	69.1	-196.3	109.5	-301.0	236.7	-671.9
Electrical, electronic and optical equipment	-5.4	-40.9	-12.6	-90.5	-25.6	-194.7
Rest of the manufacturing industry	-1,310.8	-1,906.5	-3,072.9	-4,221.8	-6,262.4	-9,085.1

Conclusions

The industrial sector achieved global final energy savings of —798.6 ktoe in the period 2004—2010. These negative savings were due in the main to the performance of the structure of industry itself, 1,655.1 ktoe being attributable to this cause. At the same time, negative savings of —2,454.1 ktoe were due to the decline in the production ratios of certain branches having a negative impact on the energy efficiency of certain industrial processes.

With respect to the structure of the sector, it should be noted that whereas those industries having reduced energy-intensive ratios (Wood, cork and furniture, Textiles, leather & footwear, Electrical, Electronic and Optical Equipment and Transport Equipment), together with Metallurgy and Metal Products and Non-Metallic Minerals reduced their weighting with respect to the total sector, others having a higher ratio increased their gross value added (Pulp, paper and printing/cardboard and Chemicals), as did the Rest of manufacturing industry and Food, drink and tobacco.

As the main activity variable GVA (gross value added) was used both for the sector as a whole and for each of the activity branches, the overall decline of which, up to 2009, moved in parallel with the present economic climate.

Part of these global savings were obtained thanks to the improvements in the efficiency of the equipment (1,194.8 ktoe) as a result of the measures adopted in the both Energy Savings and Efficiency Plan 2005-2007 and 2008-2012, articulated by means of the cooperation agreements between the IDAE and regional administrations (1,068.6 ktoe) together with the IDAE subsidies for Strategic Projects (131.5 ktoe).

2. External perimeters

Industry has reduced its percentage weighting in national energy consumption from 36% in 2004 to 28% in 2010 and obtained savings in energy consumption thanks to changes in the structure of consumption favouring those sectors using less energy.

The detail of energy savings in industry is provided in Figure 3, which gives the volumes obtained in 2010 v. 2004, plus the main perimeters. Gross savings in the sector were –798.6 ktoe, of which 1,655.1 ktoe are attributable to the improvements in the structure of the sector while the negative savings of –2,451.1 ktoe were the result of efficiency losses caused by the decline in production in some branches of industry.

Figure 3. *Breakdown of energy saving in the industrial sector in 2010 with respect to 2004*

Industry			[*L*] = **-798.6 ktep** $_{2010(\text{Base } 2004)}$
Structural effect [*LE*] = **1,655.1 ktep** $_{2010(\text{Base } 2004)}$	Technology effect [*LT*] = **-2,454.1 ktep** $_{2010(\text{Base } 2004)}$		
	Cooperation agreements [$BUin_1$] = **1,068.6 ktep** $_{2010(\text{B } 2004)}$	Strategic Projects [$BUin_2$] = **131,5 ktep** $_{2010(\text{B } 2004)}$	

The different subsectors of industrial activity referred to in this analysis are:

1. Wood, cork and furniture
2. Food, drink and tobacco
3. Textiles, leather and footwear
4. Pulp, paper and printing/cardboard
5. Chemicals
6. Non-metallic minerals
7. Metallurgy and metal products
8. Mechanical machinery and equipment
9. Transport equipment
10. Electrical, electronic and optical equipment
11. Rest of the manufacturing industry, including: processing of rubber and plastic materials, non-energy excavations, building, recycling, other manufacturing industries.

With respect to the activity ratios of the sector, the Industrial Production Index (IPI) shows an increase in the period for some subsectors (2 and 5), whereas the rest post downturns in activity, as detailed below. This circumstance has a direct bearing on the level of energy consumption.

Method used

To determine the total savings achieved in the end-use energy consumption of industrial sector as a whole and its various subsectors we used the *Divisia measurement method 1 (DMM1)*. This is calculated as the sum of partials that are sub-indexed, i.e. adjusted, to take into account the technological and structural condition of the sector, both as a unit and as the sum of its component activities.

Technology effect per branch of activity

$$LT_{R2010} = C_{R2004} + R \cdot (C_{R2010} - C_{R2004}) \cdot Ln\left(\frac{C_{R2010} / GVA_{R2010}}{C_{R2004} / GVA_{R2004}}\right)$$

where:

- C_{Ri}: Consumption of final energy by the branch of activity in the year i
- *R* : Remainder
- GVA_i: Gross Value Added of the branch in the year i

Structural effect per branch of activity

$$LE_{R2010} = \left[C_{R2004} + R \cdot (C_{R2010} - C_{R2004})\right] \cdot Ln\left(\frac{GVA_{R2010} / GVA_{I2010}}{GVA_{R2004} / GVA_{I2004}}\right)$$

where:

- C_{Ri}: Consumption of final energy by the branch of activity in the year i
- *R* : Remainder
- GVA_{Ri} : Gross Value Added of the branch of activity in year i
- GVA_{Ii} : Gross Value Added of the industrial sector in year i

To calculate the R factor the following expression is used:

$$R = \frac{1}{Ln\left(C_{R2010} / C_{R2004}\right)} - \left(\frac{C_{R2004}}{C_{R2004} - C_{R2010}}\right)$$

where:

C_{Ri}: Consumption of final energy by the branch of activity in year i

Consequently, the specific savings obtained by each subsector in the period 2004—2010 are the sum of the individual effects of its specific technology and structure in 2010.

Savings by activity subsector

$$L_R = LT_R + LE_R$$

where:

- LT_R : Result of the technological indicator of PDM1 for the branch of activity in the period 2004-2010
- LE_R : Result of the structural indicator of PDM1 for the branch of activity R in the period 2004-2010

To calculate the total savings achieved in 2010 in the industrial sector as a whole we can add together the partial savings obtained by each industrial subsector thanks to the ability of the *Divisia Measurement Method 1* to accept additions.

Industry sector savings

$$L_I = \sum L_R = \sum (LT_R + LE_R)$$

where:

- L_R : Result of the indicator of PDM1 for the branch of activity R in the period 2004-2010

Key variables in the industrial sector

Table 11 gives all the variables having a direct bearing on calculating the savings made in the *Industry* Sector as a whole and in its component parts.

Table 11. *Evolution of final energy consumption in the industrial sector and industrial branches in the period 2004-2010*

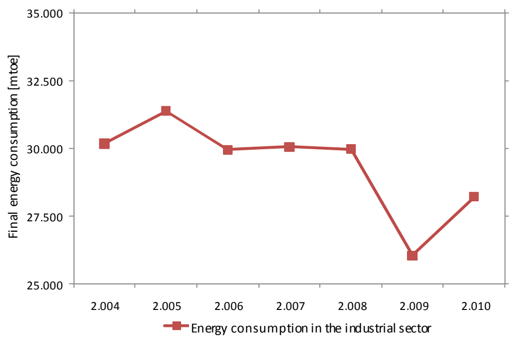
	2004	2007	2008	2009	2010
Energy consumption [ktoe]	**30,174.8**	**30,055.5**	**29,971.1**	**26,040.2**	**28,209.4**
Wood, cork and furniture	866.2	697.9	751.1	706.5	705.0
Food, beverages and tobacco	3,044.0	2,556.5	2,428.1	2,184.6	2,352.2
Textiles, leather and footwear	991.0	746.7	593.6	524.9	597.3
Pulp, paper and printing	2,360.0	2,516.0	2,500.5	2,290.4	2,534.5
Chemistry	4,312.0	5,770.1	5,201.2	4,381.3	4,943.7
Non-metallic Minerals	6,477.9	7,519.3	6,959.6	5,900.5	6,093.1
Metallurgy and metal products	7,880.2	6,687.0	6,437.0	5,615.3	5,944.2
Machinery and mechanic equipment	366.3	354.3	362.9	318.3	320.9
Transport equipment	1,009.0	788.4	860.1	751.0	851.7
Electrical, electronic and optical equipment	373.9	361.7	370.4	325.0	345.1
Rest of the manufacturing industry	2,494.2	2,057.6	3,506.6	3,042.4	3,521.7

Source: IDAE

Energy consumption in industry shows — as seen in Figure 4 — a downward trend between 2004 and 2010 (—6.5%) due in the main to the present state of the economy.

The branches of industrial activity most affected by the crisis were: Textiles, Leather and Footwear, hit by a downturn in consumption during the period of —39.7%; Metalwork and Metal products with a fall of —24.6%; and Food, Drink and Tobacco, with a decline of —22.7%.

Figure 4. *Evolution of final energy consumption in the industrial sector in the period 2004-2010*



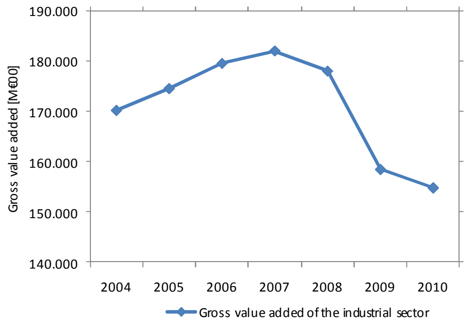
The Gross Value Added of the Industry Sector rose by 7% between 2004 and 2007 but fell by —15% in the period between 2007 and 2010 (Table 12). In the full period 2004—2010 the decline was —9.1%. The sub-sectors worst hit by the recent economic conditions were wood, cork and furniture (—36.6%), textiles, leather and footwear (—34.2%), non-metallic minerals (—33.4%) and transport equipment (—22.4%).

Table 12. *Evolution of Gross Value Added (GVA) in the industrial sector and industrial branches in the period 2004-2010*

	2004	2007	2008	2009	2010
Gross Value Added [M€00]	**170,192.6**	**182,037.9**	**177,994.7**	**158,428.7**	**154,756.1**
Wood, cork, furniture	5,962.4	5,881.2	5,461.2	4,118.7	3,782.5
Food, beverages and tobacco	14,249.2	15,247.3	15,084.2	15,000.7	15,315.4
Textiles, leather and footwear	6,401.0	5,603.1	5,481.8	4,439.7	4,213.5
Pulp, paper and printing	10,116.4	10,618.7	10,121.0	9,393.9	9,211.1
Chemistry	10,362.1	10,752.6	10,640.8	10,646.9	11,554.7
Non-metallic Minerals	8,948.3	9,355.7	8,836.4	6,689.2	5,959.6
Metallurgy and metal products	17,786.3	19,024.6	18,252.7	14,574.2	14,841.1
Machinery and mechanic equipment	8,268.5	8,554.8	8,673.9	7,408.0	7,735.5
Transport equipment	12,302.7	13,160.0	12,255.7	9,620.3	9,552.8
Electrical, electronic and optical equipment	6,897.8	7,353.3	7,265.4	5,854.0	6,041.1
Rest of the manufacturing industry	68,897.8	76,486.4	75,921.5	70,683.0	66,548.9

Source: IDAE

Figure 5. *Evolution of Gross Value Added (GVA) in the industrial sector in the period 2004-2010*



Total savings in the industry sector

To calculate the energy savings obtained in the period we applied the indicators described above using the sector-specific variables and the economic variables shown in Tables 11 and 12. The results in terms of energy savings over final consumption are given in Table 13.

Table 13. *Energy saving in the industry sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total Industrial sector**	***LT+LE***	**2,131.1**	**-798.6**
	Technological effect	*LT*	285.2	-2,454.1
	Structural effect	*LE*	1,845.9	1,655.5
Base 2007 [ktoe]	**Total Industrial sector**	***LT+LE***	**136.7**	**-2,865.6**
	Technological effect	*LT*	-1,205.5	-3,987.7
	Structural effect	*LE*	1,342.2	1,122.1

On the basis of the indicators proposed, the industrial sector generated negative savings of —798.6 ktoe in the period under study. These were smaller than they otherwise might have been due to the change in the relative levels of consumption of the different subsectors. As for the technology effect, this resulted in significant negative savings, which indicates that the production ratios in some sectors had a negative impact on the energy efficiency of the industrial processes employed.

To show in detail the energy performance of each of the sector branches, Table 14 presents the technological results while Table 15 gives the structural results. As can be seen in Figure 6, the sub-sector of non-metallic minerals, with a relative weighting in terms of the consumption of end-use energy in the sector in 2010 of 22%, suffered the greatest penalties with respect to the DMM1 technology indicator. This is due to the downward trend in 2009 and 2010 of the ratio of energy consumption to Gross Value Added in this subsector.

Figure 6. *Evolution of final energy consumption and Gross Value Added in the "Non-metallic minerals" activity in the period 2004-2010*

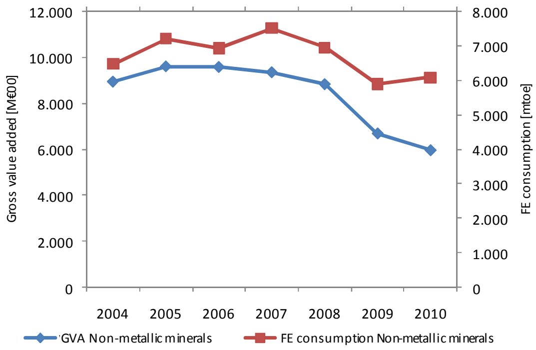


Table 14. *Energy savings according to PDM1 indicator in each branch industry activity in 2009 and 2010 with respect to 2004 and 2007*

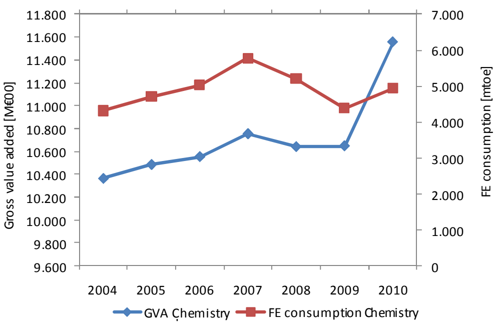
		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total industrial sector**	*∑LTi*	**285.2**	**-2,454.1**
	Wood, cork and furniture	*LT*	-130.2	-195.0
	Food, beverages and tobacco		992.5	885.4
	Textiles, leather and footwear		197.7	68.6
	Pulp, paper and printing		-102.7	-403.9
	Chemistry		48.6	-128.4
	Non-metallic Minerals		-1,222.0	-2,169.1
	Metallurgy and metal products		933.6	692.9
	Machinery and mechanic equipment		10.4	22.6
	Transport equipment		43.1	-77.5
	Electrical, electronic and optical equipment		-8.3	-18.9
	Rest of the manufacturing industry		-477.6	-1,130.9
Base 2007 [ktoe]	**Total industrial sector**	*∑LTi*	**-1,205.5**	**-3,987.7**
	Wood, cork and furniture	*LT*	-258.7	-316.7
	Food, beverages and tobacco		333.2	215.2
	Textiles, leather and footwear		75.3	-41.3
	Pulp, paper and printing		-68.7	-377.6
	Chemistry		1,339.0	1,211.0
	Non-metallic Minerals		-621.3	-1,632.0
	Metallurgy and metal products		-563.3	-823.8
	Machinery and mechanic equipment		-12.4	-0.5
	Transport equipment		-203.7	-325.8
	Electrical, electronic and optical equipment		-41.5	-52.9
	Rest of the manufacturing industry		-1,183.4	-1,843.3

Table 15. *Energy savings according to LEi indicator in each branch industry activity in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total industrial sector**	*∑LEi*	**1,845.9**	**1,655.5**
	Wood, cork and furniture	*LE*	233.8	281.8
	Food, beverages and tobacco		-318.7	-448.7
	Textiles, leather and footwear		215.8	251.2
	Pulp, paper and printing		5.8	-3.2
	Chemistry		-429.2	-942.7
	Non-metallic Minerals		1,356.5	1,956.5
	Metallurgy and metal products		852.5	590.2
	Machinery and mechanic equipment		13.1	-9.8
	Transport equipment		152.3	146.6
	Electrical, electronic and optical equipment		32.3	13.5
	Rest of the manufacturing industry		-268.2	-179.9
Base 2007 [ktoe]	**Total industrial sector**	*∑LEi*	**1,342.2**	**1,122.1**
	Wood, cork and furniture	*LE*	152.6	195.7
	Food, beverages and tobacco		-290.0	-409.2
	Textiles, leather and footwear		59.0	82.1
	Pulp, paper and printing		-39.3	-50.9
	Chemistry		-650.8	-1,252.7
	Non-metallic Minerals		1,312.6	1,957.1
	Metallurgy and metal products		782.7	542.3
	Machinery and mechanic equipment		1.7	-20.8
	Transport equipment		134.2	129.5
	Electrical, electronic and optical equipment		30.6	12.1
	Rest of the manufacturing industry		-151.1	-63.2

On the other hand the chemicals subsector, with a relative weighting in final energy consumption of 18% in 2010, suffers the highest penalties with respect to the DMM1 structural indicator as a result of the increasing delinkage after 2008 between energy consumption and Gross Value Added, as shown in Figure 7.

Figure 7. *Evolution of final energy consumption and Gross Value Added for the "Chemistry" activity in the period 2004-2010*



Furthermore, we decided it would be interesting to check the calculation shown against the DMM1 formula corresponding to the downward indicator proposed by the European Commission, the *M8*, as a means of testing the robustness of the conclusions reached. The *M8* indicator is defined as the ratio between the final energy consumed and the gross value added of this industrial subsector.

$$M8 = \left(\frac{E^I}{GVA^I} \right)$$

where:
- E^I : Energy consumption of the industrial sector
- GVA^I : Gross Value Added of the industrial sector

The savings with respect to the external perimeter of the sector using the *M8* indicator are obtained by multiplying the difference in this value as at the base year (2004 or 2007) and the calculation year (2010) by the gross aggregate value of the sector and by a parameter *K* which corresponds to the percentage of consumption of final energy by the industrial sector concerned not affected by European Commission Directive 32/2006 (ETS).

$$\text{Energy savings } M8 = \left[\left(\frac{E_{04}{}^I}{GVA_{04}{}^I} \right) - \left(\frac{E_{10}{}^I}{GVA_{10}{}^I} \right) \right] \cdot VA_{2010} \cdot K_{2004}$$

where:
- E^I : Energy consumption of the industrial sector
- *K:* Percentage of final energy consumed not affected by Directive CE/32/2006
- GVA^I : Gross Value Added of the industrial sector

The total savings obtained in the industry sector as measured by means of the *M8* indicator include both direct and indirect savings.

Table 16. *Energy savings according to M8 indicator in the industrial sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Industrial Sector	*M8*	**2,048.8**	**-771.5**
Base 2007 [ktoe]	Industrial Sector	*M8*	**117.3**	**-2,658.2**

As we can see, the results obtained using DMM1 and the *M8* indicator are broadly in line, showing a difference of approximately 7%.

3. Improving the energy efficiency of industrial equipment

Technological advances in equipment items facilitate improved consumption ratios in industrial processes. While signifying reduced operating costs for companies, acquiring such items usually entails substantial investments, with the result that the decision to introduce improvements in energy efficiency is rarely immediate.

Consequently, the Energy Efficiency Action Plan 2005-2007 and 2008-2012 set out a way of encouraging the use of more efficient equipment by means of a number of initiatives set in train by the IDAE:

- Cooperation agreements between the IDAE and regional administrations in the period 2005—2012 on publicly funded subsidies for acquiring equipment items designed to improve energy efficiency.

- Aids programm IDAE Strategic Projects in the period 2008—2010 based on publicly funded programmes providing finance for strategic investment projects of savings and energy efficiency.

3.1. Cooperation agreements between the IDAE and regional administrations

Cooperation agreements between public bodies allow for a broad range of initiatives in the form of subsidies or training courses. Individuals and companies, the latter privately or publicly owned, may benefit from these arrangements. In the case of investment in new equipment, the amount of the subsidy conferred covers up to 22% of the cost.

To gauge the savings from support programms approved under these cooperation agreements, we used the annual reports drawn up by regional administrations on the savings achieved through publicly funded programmes, energy audits, training activities and the energy research programme.

The useful life of this kind of aid usually extends well beyond the accounting period, for which reason the savings achieved thereby as at year 2010 are calculated as the quotient between the cash saving obtained in year n and the Gross Value Added accruing therefrom as per the activity index of 2008.

$$BU_{inC\,1} = \sum_{t=2004-2007}^{2010} Ah_{in\,1} \cdot \frac{GVA_{2010}}{GVA_{2004}}$$

where:

- Ah_{et}: Annual savings reported by the regional administrations with respect to:
  - Public aid programmes
  - Energy audits and other studies
  - Training and promotion studies
  - Programme for improving efficiency and fostering research
- GVA_i: Gross Value Added of the industry in year i.

3.2. IDAE Grants for Strategic Projects

This initiative aims at complementing and reinforcing the efforts made by various administrations bodies to encourage companies to undertake investment programmes in energy savings and efficiency extending over several years.

The thinking behind this is to encourage projects that lack adequate backing from existing sources in order to provide consistent ongoing open-ended support (with direct and indirect beneficiaries across all sectors).

In order to calculate the effects of these strategic projects the promoters used the annual reports drawn up by the IDAE on the savings achieved thanks to the associated investment in energy efficiency.

It is felt that the useful life of this kind of grant is longer than the period of analysis, with the result that the savings obtained in 2010 are in fact the sum of the concrete savings reported since 2008 as adjusted by the activity index of 2010.

$$BU = \sum_{t=2008}^{2010} Ah_{it}$$

where:

- Ah_t : Annual savings reported by the regional administrations with respect to the strategic projects promoted by the IDAE

3.3. Summary of direct savings in the industry sector

Savings regarded as direct are those resulting from the introduction of specific measures to upgrade assets with a view to reducing consumption by means of funding mechanisms set up by official bodies.

Table 17. *Energy savings of the measure "Improvement of equipment in the industry sector" in the period 2004-2010*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Improvement of equipment	$BU_{indC} + BU_{indC}$	**952.2**	**1,200.1**
	C. agreements IDAE- regional administrations	BU_{indC}	854.8	1,068.6
	Strategic Projects	BU_{indC}	97.3	131.5
Base 2007 [ktoe]	Improvement of equipment	$BU_{indC} + BU_{indC}$	**550.4**	**803.9**
	C. agreements IDAE- regional administrations	BU_{indC}	453.0	672.5
	Strategic Projects	BU_{indC}	97.3	131.5

4. Energy savings achieved by the industry sector as at 2010

The industry sector has achieved negative final energy savings of —798.6 ktoe in the period 2004—2010. These negative savings were relatively minor thanks in the main to the changes taking place within the sector itself, changes that are estimated to have generated savings of 1,655.6 ktoe. On the other hand we observe negative savings of —2,454.1 ktoe due to the fact that the decline in the production ratios of various producers had a negative effect on the energy efficiency of certain industrial processes.

Table 18. *Energy savings according to technology and structure indicators in industry sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total Industrial sector**	***LT+LE***	**2.131,1**	**-798,6**
	Technological effect	*LT*	285,2	-2.454,1
	Structural effect	*LE*	1.845,9	1.655,5
Base 2007 [ktoe]	**Total Industrial sector**	***LT+LE***	**136,7**	**-2.865,6**
	Technological effect	*LT*	-1.205,5	-3.987,7
	Structural effect	*LE*	1.342,2	1.122,1

In the case of the industry sector there are no knock-on effects or dangers of double accounting. This is because *PDM1* formulae are aggregative, the total being the sum of the parts.

III. TRANSPORT SECTOR

1. Summary of savings in the transport sector

TRANSPORT SECTOR

In the period studied the transport sector, with 39.3% of the total final energy consumed in 2010, continued as the leading consumer, above industry and other sectors. Energy consumption bears a direct relationship with activity. Periods of major downturns in consumption such as the present give rise to energy savings resulting from the decline in distances and the amount of fuel employed, particularly in the case of freight transport.

Sector consumption

	Final energy 2010 [ktoe]
TOTAL CONSUMPTION TRANSPORT SECTOR	**36,744**
ROAD MODE	29,375
RAILWAY MODE	1,156
MARITIME MODE	1,100
AIR MODE	5,112

Result of the savings achieved

	Final Energy Saving 2010 [ktoe]		Primary Energy Saving 2010 [ktoe]		CO_2 emissions avoided 2010 [$ktCO_2$]	
	Base 2004	Base 2007	Base 2004	Base 2007	Base 2004	Base 2007
TOTAL SAVINGS TRANSPORT SECTOR	**6,451.1**	**4,561.1**	**6,874.1**	**4,909.2**	**21,471.2**	**13,330.1**
ROAD MODE	6,701.4	4,910.4	7,499.0	5,489.7	22,759.6	14,773.0
RAILWAY MODE	-317.4	-206.7	-677.8	-419.2	-1,468.0	-953.9
MARITIME MODE	52.3	-99.9	58.6	-111.9	166.8	-342.1
AIR MODE	-68.0	-48.3	-76.1	-54.1	-228.8	-162.5
INTERMODAL	82.7	5.6	70.4	4.7	241.7	15.6

Conclusions

Savings vary depending on transport mode. Most of the savings obtained in the sector come from road transport (6,701.4 ktoe), particularly of freight, which offset the negative savings in rail and air transport.

Rail transport made negative savings of —317.4 ktoe, with performance varying according to the perimeters defined for passenger and freight transport. Within rail passenger transport there were limited savings from improvements in technical efficiency (24.3 ktoe), though insufficient to offset the negative savings in rail freight due to low load factors and the rise in consumption per tonne-kilometer transported.

Sea transport genererated quite high positive savings (52.3 ktoe) considering its relative size, thanks to an increase in traffic that outpaced the rise in fuel consumption.

Air transport produced negative savings of —68.0 ktoe as a result of a higher ratio of fuel consumed to loads shipped in the period analysed.

In general all modes showed a decline in consumption and traffic totals in the latter years of the period analysed as a result of the economic downturn. This was particularly noticeable in road freight transport, where the strong decline in industrial activity led to a fall in the consumption and load of trucks and light vehicles, while the stock of such vehicles remained constant.

Lastly, the indicators measuring modal shift showed some savings (82.7 ktoe) in both freight and passenger transport. Passenger transport by both rail and road showed growth, whereas freight traffic by rail and sea declined in the period under study, due in the main to the slowdown in economic activity.

With respect to renewal of cars, application of EU rule 443/2009 and vehicle registration tax benefits encouraged buyers to acquire more efficient vehicles, generating an overall energy saving of 425.3 ktoe/year. Additionally, IDAE direct actions in collaboration with the regional administrations, as well as specific plans for the renewal of vehicles, have reported savings of 309.6 ktoe/year. The total savings associated with improving energy efficiency of passenger cars amounted to 734.9 ktoe/year.

Measures – mechanisms Matrix

Measures	Mechanisms	Cooperation agreements between the IDAE and regional administrations	IDAE support programmes to strategic projects	Strategy to promote electric vehicle in Spain 2010-2015	"Prever" plan	Tax discrimination in the vehicle registration tax	Decree Law 443/2009	Initial qualification and continuous training for road transport drivers (RD 1032/2007)	"VIVE" Plan	"2000E" Plan	Total
2010 Base 04 [ktoe]	PMUS y PTT (1)	860.0									860,0
	Fleet management of road transport	1.3									1,3
	Eco-driving for trucks and buses	30						30.6			60,6
	Eco-driving for cars and vans	53.5									53,5
	Renovation of road transport fleets	1.5									1,5
	Replacing car fleets	6,9		2,1	275,3	425,3			10,0	15,4	734,9
	Total	953,2		2,1	275,3	425,3		30,6	10,0	15,4	1.711,8
2010 Base 07 [ktoe]	PMUS y PTT (1)	563.4									563,4
	Fleet management of road transport	1.2									1,2
	Eco-driving for trucks and buses	21.7						30.3			52,0
	Eco-driving for cars and vans	40.9									40,9
	Renovation of road transport fleets	1.0									1,0
	Replacing car fleets	4,9		2,1	-	188,5			10,0	15,4	220,9
	Total	633,1		2,1		188,5		30,3	10,0	15,4	879,4

(1) Urban mobility plansand Plans and Mobility plans for companies and activity centres

ROAD TRANSPORT

The energy savings achieved in road transport (6,701.4 ktoe in 2004—2010) corresponded in the main to freight transport, hit by the decline in activity, and in cars, thanks to the improvements in the fuel efficiency of the stock. Road transport accounted for nearly 80% of all final energy consumed by the transport sector in Spain in 2010.

The following breakdown shows the energy savings obtained in the period 2004—2010 in road transport. To calculate the external perimeter of global savings we used the *P* indicators proposed by the European Commission and bottom-up indicators of our own, whereas to assess the savings resulting from specific measures only bottom-up indicators were used.

Results obtained

		Final Energy saving 2010 [ktoe]	
		Base 2004	Base 2007
A2	Trucks	5,880.4	3,864.8
P8	Cars	116.4	1,005.7
BU_{gf}	Road fleet Management	1.3	1.2
BU_{cec}	Road transport fleet Eco-driving	60.6	52.0
BU_{cet}	Eco-driving cars	*53.5*	40.9
BU_{rf}	Renewal of road transport fleets	1.0	1.0
BU_{rp}	Renewal of cars fleets	734,9	220,8
PB	Buses	32.6	39.9
TOTAL ROAD MODE *		**6,701.4**	**4,910.4**

*Indicators affecting totals are shown in the shaded cells.

Breakdown of savings

Savings with respect to road transport are arranged in three main groups, depending on the type of vehicle the measure is aimed at, i.e., cars, freight vehicles or collective vehicles (buses).

ROAD TRANSPORT: BU_{rp} +BU_{cet}+A2+PB = 6,701.4 mtoe2010(base 2004)

CARS: BU_{rp} +BU_{cet} = 788.4 mtoe2010(base 2004)

- Vehicle replaced (BU_{rp}) 734.9 $mtoe_{2010(base\ 2004)}$
- Efficient driving of private vehicles (BU_{cet}) 53.5 $mtoe_{2010(base\ 2004)}$

FREIGHT VEHICLES: A2 = 5,880.4 $mtoe_{2010(base\ 2004)}$

- Renovation of road transport fleets (BU_{rf}) 1.0 mtoe $_{2010(base\ 2004)}$
- Road transport fleet management (BU_{gf}) 1.3 mtoe $_{2010(base\ 2004)}$
- Efficient driving of industrial vehicles (BU_{cec}) 60.6 mtoe $_{2010(base\ 2004)}$

COLLECTIVE TRANSPORT: PB = 32.6 $mtoe_{2010(base\ 2004)}$

Conclusions

According to top-down and bottom-up indicators global savings of 6,701.4 ktoe were achieved as from 2004, with freight transport generating the greatest savings (5,880.4 ktoe according to indicator A2). The indirect savings resulting from specific measures resulted in savings of 734.9 ktoe from the renewal of cars and of 53.5 ktoe from measures to promote Eco-driving for cars and vans. In the period analysed collective transport generated savings of 32.6 ktoe.

OTHER TRANSPORT MODES

Energy savings in Other transport modes and in modal shift (—250.3 ktoe in 2004—2010) resulted in part from an improvement in the efficiency of sea transport (52.3 ktoe) and the switch of passengers to more efficient modes (82.7 ktoe). Other transport modes accounted for 20% of final transport sector energy consumption in Spain in 2010.

To calculate the external perimeter we used the corrected *M* and *P* indicators proosed by the European Commission, whereas to estimate the savings obtained from modal shift we used *P* indicators (those of share), corrected or not as per the measure adopted.

Results obtained

		Final Energy saving 2010 [ktoe]	
		Base 2004	Base 2007
P10	Passengers	24.3	29.8
P11	Freight	-341.7	-236.5
TOTAL RAILWAY MODE		-317.4	-206.7
M7	Maritime transport	52.3	-99.9
Mav	Air transport	-68.0	-48.3
TOTAL REST OF MODES		-15.6	-148.2
P12	Intermodal passengers	84.7	6.7
P13	Intermodal passengers	-2.0	-1.1
BU_{pm}	Sustainable Urban Mobility Plans (PMUS) and Mobility plans for companies and activity centres (PTT)	860.0	563.4
BU_{cc}	Increased participation for the collective transport by road	44.7	-12.3
BU_{fimer}	Passengers fee	85.4	64.1
BU_{fipas}	Freight fee	-	-
TOTAL INTERMODALITY		82.7	5.6

* Indicators that affect the totals correspond to the shaded cells.

Conclusions

Overall, the savings corresponding to rail, sea and air modes resulted in negative energy savings in the period analysed, due in the main to the poor performance of freight rail transport. Overall rail transport was calculated as the sum of the *P10* and *P11* indicators proposed by the European Commission, giving a result of —317.4 ktoe.

Sea transport showed relatively high positive performance given its size thanks to an increase in traffic greater than that of fuel consumption, returning savings of 52.3 ktoe in 2010 with respect to 2004, calculated according to the *M7* indicator proposed by the European Commission.

Lastly, according to our top-down indicator *Mav,* based on those proposed by the European Commission, there were no savings in air transport in the period under study. The sector generated negative savings due to a relative increase in energy consumption in operations between 2004 and 2010, particularly between 2007 and 2010.

The top-down modal shift indicator *P* showed an improvement in energy efficiency (82.7 ktoe) in both freight and passenger transport. To calculate the savings resulting from direct measures we used corrected modal shift *P* indicators. The measures analysed show reduced savings as a consequence of the fact that collective transport achieved no significant advance in the period. The economic crisis, in raising the level of unemployment, discouraged urban and inter-urban passenger transits across all transport modes.

2. External perimeters

In order to calculate the energy savings in the *Transport* Sector we defined a series of analysis perimeters according to the indicators selected. First the sector was divided into four transport modes: road, rail, sea (coastal and inland waterways) and air. Some transport modes were further subdivided to calculate the savings indices. The road transport subsector was subdivided into cars, freight vehicles (trucks and light vehicles) and collective vehicles (buses). Rail transport was subdivided into passenger and freight traffic.

The breakdown of energy savings in the sector overall is shown in Figure 8, which gives the savings achieved in 2010 in comparison with 2004 by transport mode.

Figure 8. *Breakdown of energy savings in the transport sector in 2010 with respect to 200*

TRANSPORTE TOTAL			$[BU_{rp}+BU_{cet}+A2+PB]+[P10+P11]+[M7]+[Mav]+[P12+P13]$ = **6,451.1 mtoe**$_{2010\ (Base\ 2004)}$
Road transport:			$[BU_{rp}+BU_{cet}]+[A2]+[PB]$ = **6,701.4 mtoe**$_{2010\ (Base\ 2004)}$
Road transport cars			$[BU_{rp}+BU_{cet}]$ = **788.4 mtoe**$_{2010\ (Base\ 2004)}$
Road transport freight vehicles (trucks and light vehicles)			[A2] = **5,880.4 mtoe**$_{2010\ (Base\ 2004)}$
Road transport collective (buses)			[PB] = **32.6 mtoe**$_{2010\ (Base\ 2004)}$
Rail transport:			[P10+P11] = **-317.4 mtoe**$_{2010\ (Base\ 2004)}$
Passengers [P10] = 24.3 mtoe$_{2010\ (base\ 2004)}$	[P12] = 84.7 mtoe 2010(base 2004)	Freight	[P11] = -341.7 mtoe$_{2010\ (base\ 2004)}$
Maritime transport:		[P13] = -2.0 mtoe 2010(base 2004)	[M7] = **52.3 mtoe**$_{2010\ (Base\ 2004)}$
Air transport:			[Mav] = **-68.0 mtoe**$_{2010\ (Base\ 2004)}$

Below we detail the calculation methods used and the key variables with respect to energy savings in the different modes of transport: road, rail, sea and air.

2.1. Road transport

Road transport accounts for nearly 80% of final energy consumption in the national sector in 2010. To give greater depth to our analysis of the savings made with respect to different vehicle types, sizes and operating modes, we made further subdivisions by vehicle type: cars, freight vehicles (trucks and vans) and collective transport (buses).

Method

The detailed breakdown of energy savings achieved in road transport is given in Figure 9, which shows the figures obtained in 2010 in comparison with those of 2004, listed according to activity.

Figure 9. *Breakdown of energy savings in the road mode in 2010 with respect to 2004*

ROAD TRANSPORT: BU_{rp} +BU_{cet}+A2+PB = 6,701.4 mtoe2010(base 2004)

CARS: BU_{rp} +BU_{cet} = 788.4 mtoe2010(base 2004)

- Vehicle replaced (BU_{rp}) 734.9 $mtoe_{2010(base\ 2004)}$
- Efficient driving of private vehicles (BU_{cet}) 53.5 $mtoe_{2010(base\ 2004)}$

FREIGHT VEHICLES: A2 = 5,880.4 $mtoe_{2010(base\ 2004)}$

- Renovation of road transport fleets (BU_{rf}) 1.0 mtoe $_{2010(base\ 2004)}$
- Road transport fleet management (BU_{gf}) 1.3 mtoe $_{2010(base\ 2004)}$
- Efficient driving of industrial vehicles (BU_{cec}) 60.6 mtoe $_{2010(base\ 2004)}$

COLLECTIVE TRANSPORT: PB = 32.6 $mtoe_{2010(base\ 2004)}$

To calculate the energy savings achieved in road transport we used both the top-down indicators proposed by the European Commission and our own top-down and bottom-up indicators. We also used bottom-up indicators to calculate the impact of certain measures and schemes introduced by the administrations.

Cars

Base 2004

The savings corresponding to this category in 2010 with respect to base year 2004 were calculated on the basis of the sum of the bottom-up indicators BU_{rp}.and BU_{cet}.

The BU_{rp} indicator, which we designed, is based on the unit saving obtained from each vehicle replaced, according to the type of vehicle that takes its place:

- End of useful life with replacement
- End of useful life without replacement
- Campaigns to replace vehicles
- Replacement by hybrid vehicle
- Replacement by electric vehicle

$$BU_{rp} = UErp_t^x$$

where:

- $UErp^x_t$ = Unit saving per vehicle depending on the type of replacement

On this basis the savings obtained are calculated according to the following equation:

$$\text{Energy savings } BU_{rp} = \sum_{\text{base year}=t}^{t=i} \left(UE_t^x \cdot O_t^x\right) \cdot D_i$$

where:

- *UE xt* = Unit saving per car depending on the type of replacement
- *Di* = Average distance covered by cars in the year
- *Oxt* = Number of operations per year (replacement plans, number of registrations of hybrid vehicles, etc.)

The indicator BU_{cet}, which we also modelled, is based on the unit saving resulting from the courses in Eco-driving techniques given to drivers and driving instructors by the IDAE. The savings associated with this initiative were calculated by means of a bottom-up indicator measuring the reduction in unit consumption achieved by the courses.

The savings result to be applied to the indicator is as follows:

$$\text{Energy savings } BU_{cet} = \left(UE^{CA} - UE^{CATrained}\right) \cdot Di_{t}^{\text{av.kmCA}} \cdot S_{students}$$

where:

- UE^{CA} = Average unit consumption of cars
- $UE^{CAtrained}$ = Average unit consumption of cars driven by trained drivers
- $Di_t^{av.km.CA}$ = Average distance covered by cars
- $S_{student}$ = Number of student equivalents trained

Base 2007

In order to calculate the savings for those years having 2007 as base, the indicator *P8,* "car energy per passenger-kilometre" (proposed by the European Commission) was used, as it allows us to identify the savings resulting from improved techniques and efficiency in driving cars. The savings are calculated as the difference in the energy consumption ratio of traffic measured in passenger-kilometres.

$$P8 = \left(\frac{E^{\text{CA}}}{T^{\text{CA}}}\right)$$

where:

- E^{CA} = Total consumption by cars
- T^{CA} = Total car traffic

The savings obtained within road transport as a whole, as measured by indicators *P* and *M*, are the result of multiplying the difference between the two indicators for the base year (2007) and the year of calculation (2010) by the activity variable with respect to the indicator.

For example, for indicator *P8* in year 2010 with 2007 as base year savings would be:

$$\text{Energy savings } P8 = \left(\frac{E_{2007}^{\text{CA}}}{T_{2007}^{\text{CA}}} - \frac{E_{2010}^{\text{CA}}}{T_{2010}^{\text{CA}}}\right) \cdot T_{2010}^{\text{CA}}$$

Freight vehicles

The savings corresponding to this segment in year 2010 with 2004 as base year were calculated using top-down indicator *A2*.

For the subdivisions we used the indicator proposed by the European Commission, *A2,* "Energy consumption of trucks and light vehicles per vehicle". This indicator is calculated as the ratio between the total energy consumption of freight transport by road and the total stock of trucks and light vehicles.

$$A2 = \left(\frac{E^{\text{TLV}}}{S^{\text{TLV}}}\right)$$

where:

- E^{TLV} = Consumption of road freight transport
- S^{TLV}= Total stock of trucks and light goods vehicles

The next subdivision is that of top-down indicators measuring the specific steps taken and campaigns conducted with respect to trucks and light goods vehicles in the period under study.

Collective transport

The savings corresponding to the initial division were calculated using the bottom-up indicator *PB*, understood as the minimum indicator proposed by the European Commission, *M5,* "Energy consumption of road vehicles in toe/km per vehicle equivalent", calculated for buses only. This indicator provides a comparison of the total consumption of road transport in collective vehicles with the stock of buses present. The variation in the indicator identifies all the energy savings obtained in the period with respect to collective transport.

$$PB = \left(\frac{E^{Col}}{S^{Bus}} \right)$$

where:

- E^{Col} = Consumption in collective road transport
- S^{Bus} = Total stock of buses

For base year 2004, the sum of the individual savings associated with the indicators BU_{rp}, BU_{cet}, *A2 and PB* gives the overall savings made in road transport in 2010. For base year 2007, the overall savings produced in road transport in 2010 is the sum of the particular savings associated with indicators *P8, A2 and PB,* which show a more consistent performance.

Key variables in road transport

This section covers all variables having a direct effect on calculating the savings obtained in this transport mode.

Table 19. *Evolution of energy comsumption in the Transport Sector in the period 2004-2010*

	2004	2007	2008	2009	2010
Total transport consumption [ktoe]	38,317	40,804	39,313	37,464	36,744

Source: IDAE

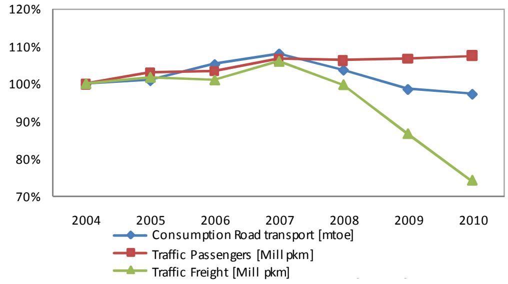
Table 20. *Evolution of generic activity variables in road mode in the period 2004-2010*

	2004	2007	2008	2009	2010
Total road consumption [ktoe]	30,082	32,460	31,158	29,749	29,375
Total consumption of cars [ktoe]	11,775	13,112	12,778	12,336	12,400
Total consumption of trucks and light vehicles [ktoe]	16,789	17,503	16,325	14,944	13,500
Total consumption of buses [ktoe]	963	1,039	997	952	1,028
Total car traffic [Mill pkm]	330,192	343,293	342,611	350,536	350,980
Total bus traffic [Mill pkm]	53,458	59,163	60,864	57,233	59,691
Car fleet circulating [Unit]	14,798,238	16,478,026	16,769,713	16,647,129	16,711,309
Buses [Unit]	39,370	42,192	42,992	43,315	43,383

Source: IDAE

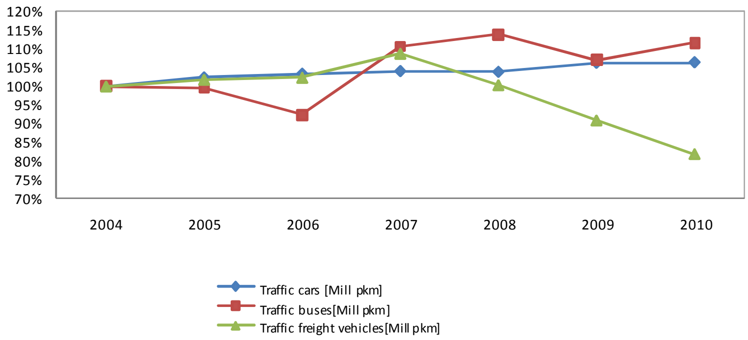
Due to the present state of the economy we have witnessed a downward trend in total consumption in the latter years of the period under study. It is in freight transport where the pronounced decline in industrial activity is having its greatest impact, causing falls in the consumption, while the size of freight vehicle fleets remains static.

Figure 10. *Relative evolution of consumption and traffic in the passenger and freight transport in the period 2004-2010*



The share of collective road transport (buses) versus car traffic in 2010 remains similar to that of 2004, though it varied considerably in the interim.

Figure 11. *Evolution of traffic per type of vehicle in the road mode in the period 2004-2010*



This is due to former users of public road transport, mostly buses, tending to switch to rail for both suburban and inter-urban travel. Also, the rise in unemployment has significantly reduced suburban and inter-urban journeys across all transport modes.

Table 21. *Evolution of average distances per vehicle in the period 2004-2010*

	2004	2007	2008	2009	2010
Average distance of car[km]	13.437	12.824	12.428	12.703	12.665
Average distance of urban cars [km]	9.033	9.039	8.544	8.573	8.540
Average distance of intercity car [km]	4.404	3.784	3.885	4.130	4.125
Average distance of trucks and light vehicles (pond.) [km]	45.195	47.505	45.855	44.399	40.335

Source: IDAE

Total savings obtained in road transport

To calculate the energy savings achieved in the period we applied the indicators BU_{rp}, BU_{cec}, *A2 and PB* to the subsector variables shown in the above table.

Table 22. *Energy saving in the road mode in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total road**	BU_{rp}+ BU_{cet}+A2+PB	**5.368,8**	**6.701,4**
	Renovation of car fleet	BU_{rp}	651,7	734,9
	Cars	*P8*	164,4	116,4
	Trucks	*A2*	4,573.9	5,880.4
	Buses	*PB*	107.1	32.6
	Efficient car driving	BU_{cec}	41.2	60.6
Base 2007 [ktoe]	**Total road**	***P8+A2+PB***	**3,710.9**	**4,910.4**
	Renovation of car fleet	BU_{rp}	138,7	220,9
	Cars	*P8*	1,052.6	1,005.7
	Trucks	*A2*	2,543.9	3,864.8
	Buses	*PB*	114.4	39.9
	Efficient car driving	BU_{cet}	23,5	40,9

According to the sum of bottom-up and top-down indicators in Table 22, the volume of energy savings in road transport in the period 2004—2010 was 6,837.3 ktoe, equivalent to a percentage saving of 23.3% of the final energy associated with this mode of transport. This result is heavily dependent on the A2 indicator, which quantifies the savings associated with freight transport by road, as can be seen in Figure 13.

Figure 12. *Evolution of "P8" indicator in the period 2004 -2010*

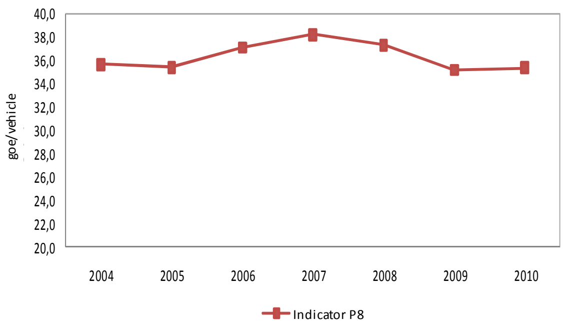
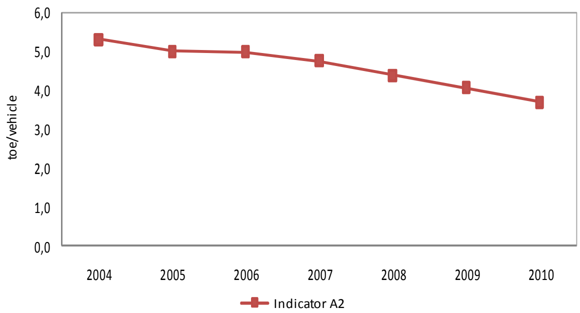


Figure 13. *Evolution of "A2" indicator in the period 2004-2010*



2.2. Rail transport

Rail transport accounted for 3.1% of total national transport energy consumption in 2010. To refine the calculation of specific savings achieved in this transport mode we defined two analysis parameters to cater for the two predominant rail transport loads, passengers and freight.

Method used

The breakdown of energy savings in rail transport is shown in Figure 14, which gives the results for 2010 v. 2004 by activity, passenger or freight.

Figure 14. *Breakdown of energy saving in the railway mode in 2010 with respect to 2004*

RAIL TRANSPORT	P10+P11 = **-317.4 ktep** $_{2010(base\ 2004)}$
PASSENGERS P10 = 24.3 ktep $_{2010(base\ 2004)}$	FREIGHT P11 = -341.7 ktep $_{2010(base\ 2004)}$

To calculate rail transport savings we used the two indicators proposed by the European Commission in its report, "Recommendations on Measurement and Verification Methods": the indicators *P10, "Energy consumption of passenger rail transport per passenger-km"*, and *P11, "Energy consumption of freight rail transport per tonne-km"*.

Both indicators enable measurement of energy savings by means of establishing a ratio between energy consumption and rail traffic, for passengers on the one hand *(P10)* and for freight *(P11)* on the other.

Passengers

Calculating the savings resulting from rail passenger traffic is based on the *P10* indicator proposed by the European Commission, calculated as the ratio between energy consumption and passenger traffic. Changes in the indicator show savings resulting from improvements in energy efficiency and in load factor.

$$P10 = \left(\frac{E^{RF}}{T^{RF}} \right)$$

where:

- E^{RF} = Total rail transport consumption
- T^{RF}= Total rail passenger traffic

Freight

Calculating the savings resulting from rail freight traffic is based on the *P11* indicator proposed by the European Commission. It is calculated as the ratio between energy consumption and freight traffic. Similar to the indicator described above, changes in the indicator show savings resulting from improvements in energy efficiency and in load factor.

$$P11 = \left(\frac{E^{RFm}}{T^{RFm}} \right)$$

where:

- E^{RFm} = Total rail freight consumption
- T^{RFm}= Total rail freight traffic

Key variables in rail transport

Table 23 shows all the variables having a direct bearing on calculating the savings generated in this transport mode.

Table 23. *Evolution of generic activity variables in the railway mode in the period 2004-2010*

	2004	2007	2008	2009	2010
Total consumption of railway transport [ktoe]	1,090	1,193	1,169	1,124	1,156
Consumption of passengers rail transport [ktoe]	224	246	241	232	238
Consumption of freight rail transport [ktoe]	866	948	929	893	918
Total railway passengers traffic [Mill pkm]	20,386	21,857	23,969	23,137	23,824
Total railway freight traffic [Mill tkm]	12,018	11,124	10,287	7,391	8,000

Source: IDAE

Freight rail traffic has declined in the period studied, due in the main to the slowdown in economic activity and the greater flexibility of rival transport modes.

However, passenger rail traffic has performed quite differently, showing significant growth in the period examined. This is due in the main to the opening of new high-speed rail links, especially the link connecting Madrid and Barcelona.

Figure 15. *Relative evolution of passenger and freight traffic in the period 2004 - 2010*

Total savings achieved in rail transport

To calculate the energy savings obtained in the period we used the sector variables to calculate the indicators.

Table 24. *Energy saving in the railway mode in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Rail transport	*P10 + P11*	**-337.1**	**-317.4**
	Passengers rail transport	*P10*	23.3	24.3
	Freight rail transport	*P11*	-360.4	-341.7
Base 2007 [ktoe]	Rail transport	*P10 + P11*	**-234.6**	**-206.7**
	Passengers rail transport	*P10*	28.6	29.8
	Freight rail transport	*P11*	-263.2	-236.5

According to the top-down indicators *P10* and *P11* no savings were achieved in the period due in the main to the poor performance of freight rail transport. In the case of passenger rail transport, limited savings can be obtained by means of technical efficiency. On the other hand, freight rail transport performs negatively in terms of energy savings.

Positive savings were not possible due in the main to the economic downturn which caused a significant fall in traffic volumes, with energy consumption declining only fractionally as a result of smaller average loads.

Figure 16. *Evolution of "P10" indicator related to passenger railway transport in the period 2004-2010*

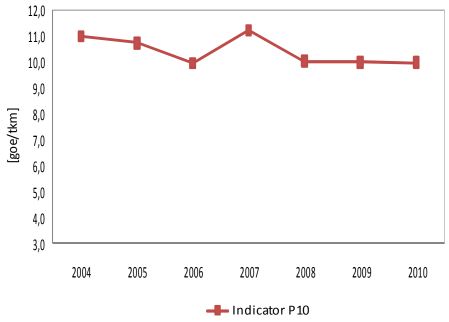
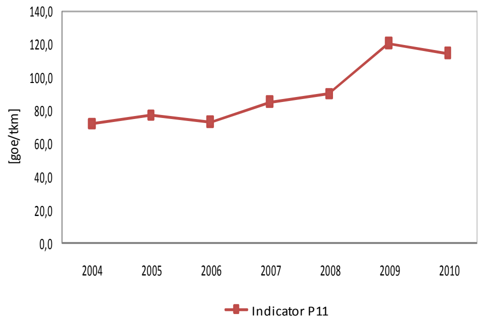


Figure 17. *Evolution of "P11" indicator related to freight railway transport in the period 2004-2010*



2.3. Maritime transport

Maritime transport, understood for present purposes as the sum of coastal and inland waterway transport, accounted for 3.0% of total final energy consumption of the transport sector in Spain in 2010. The scope of this analysis is limited to freight transport, which accounts for 81.9% of the total consumption of this transport mode.

Method used

To calculate the savings obtained in maritime transport the *M7* indicator proposed by the European Commission, understood as the ratio of total consumption to total maritime freight transport, was used. The movement in the indicator reflects the savings resulting from improvements in energy efficiency and load factors.

$$M7 = \left(\frac{E^{W}}{T^{W}} \right)$$

where:

- E^{W} = Maritime freight consumption (coastal and inland waterways)
- T^{W}= Maritime freight transport (coastal and inland waterways)

Key variables in maritime transport

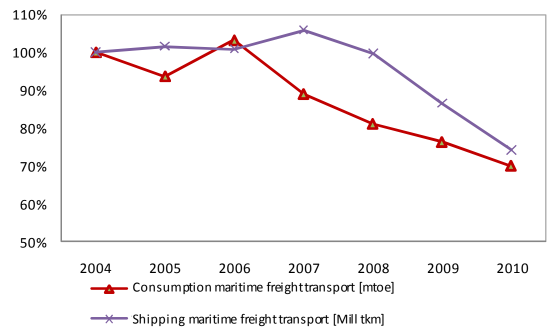
Table 25. *Evolution of maritime transport consumption and traffic in the period 2004-2010*

	2004	2007	2008	2009	2010
Total consumption of freight maritime transport [ktoe]	1,285	1,144	1,042	981	900
Total freight maritime transport traffic [Mill tkm]	43,120	45,675	43,005	37,345	31,973

Source: IDAE

Maritime freight transport was heavily affected by the economic crisis. However, the decline in energy consumption was more pronounced in relative terms than the fall in freight transport between 2004 and 2010, as can be seen in Figure 18.

Figure 18. *Evolution of freight maritime transport consumption and traffic in the period 2004-2010*



Total savings achieved in maritime transport

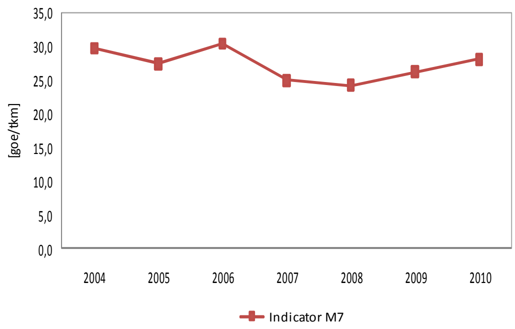
To calculate the energy savings obtained in the period the above indicators were used, calculated according to the sector variables.

Table 26. *Energy saving in the maritime mode in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Maritime transport	*M7*	**131.9**	**52.3**
Base 2007 [ktoe]	Maritime transport	*M7*	**- 45.9**	**- 99.9**

The maritime transport sector shows savings in 2010 in comparison with the situation in 2004 of 52.3 ktoe, representing a percentage saving of 5.5% of final energy associated with maritime freight transport.

Figure 19. *Evolution of "M7" indicator related to the maritime mode in the period 2004-2010*



2.4. Air transport

Air transport accounted for 13.9% of the total energy consumption of the transport sector in Spain in 2010.

Method used

To calculate the savings associated with air transport we used as reference the *M5, M6 and M7* indicators proposed by the European Commission for other modes of transport. This new indicator, called *Mav,* is calculated as the ratio between total energy consumption and total traffic in number of operations conducted per year.

$$Mav = \left(\frac{E^{Air}}{T^{Air}} \right)$$

where:

- E^{Air}= Air transport consumption
- T^{Air}= Total air traffic (in number of operations)

Key variables in air transport

Table 27 shows all the variables having a direct bearing on calculating the savings produced in this transport mode.

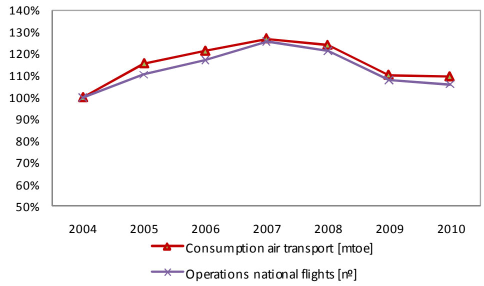
Table 27. *Evolution of consumption and traffic in the air mode in the period 2004-2010*

	2004	2007	2008	2009	2010
Energy consumption of domestic traffic [ktoe]	1,902	2,413	2,357	2,097	2,083
Domestic flights operations [Unit]	820,409	1,030,450	994,158	885,427	869,222

Source: IDAE, INE

As will be seen in Figure 20 air transport has suffered a severe decline in operations as from 2008 (—13%), although the ratio consumption—operation held steady practically throughout the period. This sector will require major efforts to improve consumption by acquiring more efficient aircraft, optimising traffic control and implementing measures to improve the way the aircraft are flown. There is also considerable room for improvement in the efficient use of the land vehicles employed in airport handling.

Figure 20. *Relative evolution of consumption and domestic flights operations in the air mode in the period 2004-2010*



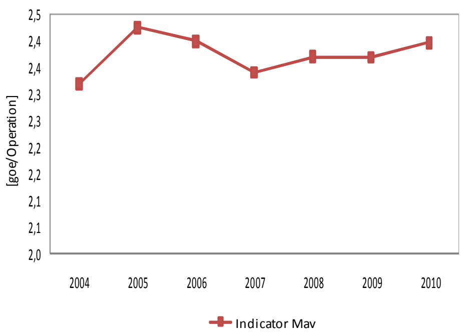
Total savings obtained in the air transport mode

To calculate the energy savings achieved in the period the *Mav* indicator was used, applying the sector variables shown in Table 28.

Table 28. *Energy saving in the air mode in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Air transport mode	*Mav*	- 44.5	- 68.0
Base 2007 [ktoe]	Air transport mode	*Mav*	- 24.4	-48.3

Figure 21. *Evolution of "Mav" indicator related to the air mode in the period 2004-2010*



The decline in operations was most pronounced in the short-range segment. Despite the results obtained in the period, the air transport sector has taken a large number of initiatives designed to reduce its operating costs and their impact on the demand for air transport.

2.5. Modal shift

A large part of the energy efficiency measures introduced by IDAE basically, in collaboration with regional administrations in this period were focused on modal shift, that is to say, on promoting the use of transport modes that use energy more efficiently.

Method used

The savings resulting from a transfer of air passenger and freight traffic to more efficient modes of transport were calculated on the basis of the *P12* indicator, “Share of public transport in land passenger transport”, and the *P13* indicator, “Share of rail and inland waterways freight transport in total freight transport” as defined by the European Commission in its report, ‘*Recommendations on Measurement and Verification Methods*’”.

Passenger transport

With respect to passenger transport the savings were calculated on the basis of the changes in public road transport versus road transport as a whole. To achieve this the change in percentage was multiplied by the difference between the unit energy consumption of public road transport and that of road transport as a whole, adjusted for the road traffic volume registered in 2010.

$$P12=\left(\frac{T^{\mathrm{Pa}}_{Public}}{T^{\mathrm{Pa}}}\right)$$

where:

- T^{Pa} = *Total passenger traffic*
- T_{Public}^{Pa} = *Total passenger traffic in collective transport*

For example, for the *P12* indicator in 2010 versus 2004 were:

$$\text{Energy savings}\ P12=\left(\frac{T^{\mathrm{Pa}}_{Public\ 2010}}{T^{\mathrm{Pa}}_{2010}}-\frac{T^{\mathrm{Pa}}_{Public\ 2004}}{T^{\mathrm{Pa}}_{2004}}\right)\cdot T^{Pa}_{2010}\cdot\left(UE^{CA}_{2010}-UE^{PT}_{2010}\right)$$

where:

- T^{Pa} = Total passenger traffic
- T_{Public}^{Pa} = Total passenger traffic in collective transport
- UE^{CA}= Unit consumption of car
- UE^{PT}= Unit consumption of collective transport vehicle

Freight

The energy savings in freight transport were calculated on the basis of the changes in the shares of rail and sea traffic versus other modes of transport. To obtain this figure the change in share was multiplied by the difference between the unitary consumption of rail and sea transport versus road transport, as adjusted for the traffic volumes recorded in 2010.

$$P13=\left(\frac{T^{\mathrm{Fr}}_{\mathrm{RW}}}{T^{\mathrm{Fr}}}\right)$$

where:

- T^{Fr} = *Total freight transport*
- T_{Rw}^{Fr} = *Total freight transported by rail and sea*

Total savings achieved by modal shift

This section gives the result of total savings obtained by changing to more efficient transport modes, whether for passengers or freight, including the savings resulting from indirect effects on the sector.

The calculate the energy saving obtained in the period we applied the indicators described in the first section, using the sector variables employed for calculating the indicators of modal shift.

Table 29. *Energy saving in the modal shift in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	**Total saving by modal shift**	***P12+P13***	**14.8**	**82.7**
	Passengers	*P12*	33.3	84.7
	Freight	*P13*	-18.5	-2.0
Base 2007 [ktoe]	**Total saving by modal shift**	***P12+P13***	**-54.4**	**5.6**
	Passengers	*P12*	-45.1	6.7
	Freight	*P13*	-9.3	-1.1

According to the 'share' indicators *P12* and *P13* savings of 82.7 ktoe resulted from modal shift with respect to 2004, which accounts for 0.2% of final energy consumption within the *Transport* Sector (Table 29).

Due to the economic downturn in Spain as from 2008, the expected growth in public transport did not materialise, with the result that the predicted savings from modal shift were also absent, given that the corresponding savings indicator depends on total traffic.

Figure 22. *Evolution of "P12" indicator related to the passenger modal shift in the period 2004-2010*

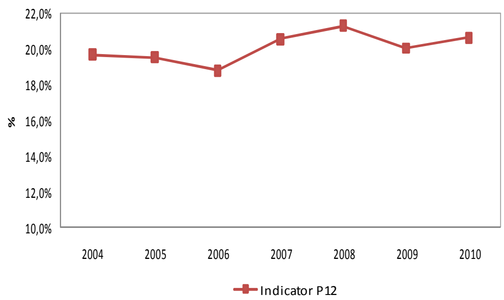
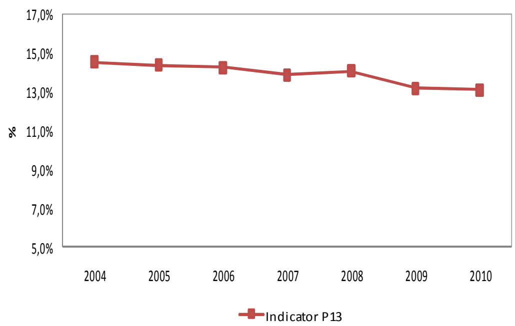


Figure 23. *Evolution of "P13" indicator related to the freight modal shift in the period 2004-2010*



3. Sustainable Urban Mobility Plans (PMUS) and Mobility plans for companies and activity centres

The Sustainable Urban Mobility Plans (PMUS) aim at promoting more sustainable modes of transport (on foot, by bicycle or public transport) that are compatible with economic growth and contribute to the quality of life of urban dwellers. PMUS have been set in train in Spain relatively recently and is framed of a well-defined strategic framework through standards as PEIT (Strategic Infrastructure and Transport 2005-2020) and Action Plans 2005-2007 and 2008-2012.

Method used

To assess the likely effect of this measure we used the information provided by regional administrations on the savings available thanks to public funding of this initiative. Such savings equal the sum of those reported each year between 2004 or 2007 depending on the calculation base used.

$$BU_{pm} = \sum_{t}^{i} Ah_{pmus}$$

where:

- Ah_{pmus} : Annual savings reported by regional administrations viz. PMUS

Key variables

Table 30 gives the variables that have a direct bearing on calculation of the savings to be achieved by this measure.

Table 30. *Evolution of specific variables related to PMUS and PTT in the period 2004-2010*

	2004	2007	2008	2009	2010
Saving per 100 bicycles [toe]	9.32	9.32	9.32	9.32	9.32
Bicycles used [number]	-	5,285	6,883	6,883	6,883
IDAE investment in PMUS [k€]	-	9,602	17,048	11,551	8,962

Source: IDAE

Under the heading “IDAE investment in PMUS” there are various different items. The investment outlay extends to amounts earmarked for “Sustainable Urban Mobility Plans” (PMUS) and also for “Mobility plans for companies and activity centres”, given that the latter, the PTT, are a pre-requisite for successful introduction of PMUS in an urban context.

Of the measures set in train, the following are the most important:

- Integrated studies on sustainable mobility.
- Moves to incentivise the use of bicycles in built-up areas; the design and introduction of standard-size bicycle dispensers for public use (see Table 30).
- Viability and pilot studies on initiatives entailing PMUS and PTT.
- Follow-up studies on the introduction of sustainable urban mobility measures.
- Training courses for mobility wardens.

Direct savings made

In order to calculate the energy saving made by this measure in the applicable time period we used the bottom-up indicator BU_{pm} in conjunction with the sector variables set out in Table 31.

Table 31. *Energy saving in the measures PMUS and PTT in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Sustainable Urban Mobility Plans (PMUS) and Mobility plans for companies and activity centres	BU_{pm}	725.6	860.0
Base 2007 [ktoe]	Sustainable Urban Mobility Plans (PMUS) and Mobility plans for companies and activity centres	BU_{pm}	429.0	563.4

As shown in Table 31, the PMUS and PTT resulted in energy savings of 860.0 ktoe in the period 2004—2010, equivalent to 2.3% of the total final energy consumed by the transport sector in 2010.

4. Increased participation of collective means of road transport (buses)

This measure seeks to foster a greater presence on the roads of collective means of transport, as opposed to cars, with a view to improving both the means of public transport and the quality of the services provided.

Method used

The savings associated with the use of collective or public means of road transport was calculated using the *P12* indicator proposed by the European Commission, adjusted to account for the changes in the presence of such means (buses) as opposed to private means (cars).

$$BU_{cc} = \left(\frac{T^{\text{PaColCarr}}}{T^{\text{Pa}}} \right)$$

where:

- T^{Pa} = Total passenger traffic by road
- $T^{\text{PaColCarr}}$ = Total passenger traffic by collective road transport (buses)

For example, for the indicator BU_{cc} the savings in year 2010 v. base year 2004 would be as follows:

$$\text{Energy savings } P12 = \left(\frac{T_{2010}^{\text{PaColCarr}}}{T_{2010}^{\text{Pa}}} - \frac{T_{2004}^{\text{PaColCarr}}}{T_{2004}^{\text{Pa}}} \right) \cdot T_{2010}^{Pa} \cdot \left(UE_{2010}^{CA} - UE_{2010}^{PT} \right)$$

where:

- T^{Pa} = Total passenger traffic by road
- $T^{\text{PaColCarr}}$ = Total passenger traffic by collective road transport (buses)
- UE^{CA}= Unit consumption of car
- UE^{PT}= Unit consumption of collective road vehicle (bus)

Key variables

Table 32 gives all the variables having a direct bearing on calculating the savings resulting from this measure.

Table 32. *Evolution of specific variables related to collective means in the period 2004-2010*

	2004	2007	2008	2009	2010
Total interurban car traffic [Mill pkm]	330,192	343,293	342,611	350,536	350,980
Total interurban buses traffic [Mill pkm]	53,458	59,163	60,864	57,233	59,691

Source: MINISTERIO DE FOMENTO, IDAE

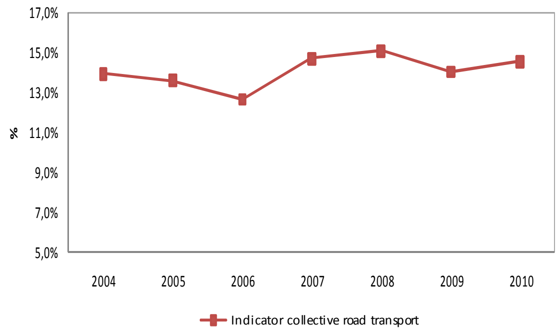
Direct savings made

To calculate the energy savings made by this measure the indicator *BUcc* was applied, using the sector variables shown in Table 33.

Table 33. *Energy saving in the measure "Higger collective mode participation by road transport" in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Greater participation of collective means of road transport	BU_{cc}	7.7	44.7
Base 2007 [ktoe]	Greater participation of collective means of road transport	BU_{cc}	-50.3	-12.3

Figure 24. *Evolution of indicator "collective mode road transport" in the period 2004-2010*



According to Table 35, the measure "Greater participation of collective means of road transport, i.e. buses" achieved savings of 44.7 ktoe in the period 2004—2010, equivalent to 0.1% of total final energy consumption in the *Transport* Sector in 2010.

Due to the economic crisis affecting Spain since 2008, the expected growth in the relative share of collective means of road transport was lower than expected, a circumstance that led to the savings expected from this modal shift being negative, given that the savings indicator applicable in this case depends on total traffic.

5. Greater share of rail in inter-urban transport

The attempt to achieve a greater share for rail in inter-urban transport, in terms of both passengers and freight, has become a priority target of the Spanish administrations.

A greater share of rail in freight transport makes it easier for Spain to meet European emissions targets. However, such growth should not be contemplated as an isolated improvement but rather as the lynch-pin of a broader logistic operation combining all modes of transport in the best way possible. The administrations has made a major effort to ensure that by 2020 rail plays a key role in the transport sector.

Method used

To calculate savings we used the bottom-up indicators *P12* and *P13* proposed by the European Commission, corrected to account for the differences between urban and inter-urban transport.

As far as passenger rail transport is concerned, we calculated the changes in share of inter-urban passenger rail transport with respect to other transport modes, apportioning to the different shares the difference in the per unit consumption of rail compared with that of its competitor modes (road and air) and adjusting for the traffic volumes of 2010.

$$BU_{fipas} = \left(\frac{T^{RPa}}{T^{Pa}} \right)$$

where:

- T^{Pa} = Total inter-urban rail passenger traffic
- T^{RPa} = Total inter-urban passenger traffic

Similarly, for freight transport we calculated the savings on the basis of the differences in share of rail freight transport in comparison with alternative modes. This difference was then multiplied by the difference between the unit consumption of rail and the weighted average tonne kilometre of competitor transport modes (i.e. road, and coastal and inland waterways), adjusted for the actual tonne kilometres recorded in 2010.

$$BU_{fimer} = \left(\frac{T^{RFr}_{2004}}{T^{Fr}_{2004}} \right)$$

where:

- T^{Fr} = Total inter-urban rail freight traffic
- T^{RFr} = Total inter-urban freight traffi

The total saving to be made by this measure is obtained by adding together the savings obtained by the indicators BU_{fipas} and BU_{fimer}.

Key variables

Table 34. *Evolution of specific variables related to "Greater share of rail in inter-urban transport" in the period 2004-2010*

	2004	2007	2008	2009	2010
Unitary consumption of car [goe/pkm]	35.7	35.4	37.1	38.2	37.3
Unitary consumption of bus [goe/pkm]	60.6	60.3	60.0	59.8	59.5
Unitary consumption of airplane [goe/pkm]	18.0	18.2	20.4	17.6	16.4
Unitary consumption of railway [goe/pkm]	11.01	11.24	10.05	10.01	9.99
Interurban-bus passengers traffic [Mill pkm]	47,286	52,953	54,795	51,343	53,555
Interurban -car passengers traffic [Mill pkm]	330,192	343,293	342,611	350,536	350,980
Interurban -railway passengers traffic [Mill pkm]	10,767	11,698	13,917	13,659	14,561
Airplane passengers traffic [Mill pkm]	20,641	25,933	22,237	20,343	20,206
Total IDAE investment [€]	-	48,424	-	38,400	-

Source: MINISTERIO DE FOMENTO, INE, IDAE

Passenger traffic on inter-city bus services reached its maximum in 2008, after which these services suffered a sharp decline, particularly in 2009 when they registered volumes below those of 2007, experiencing a minor recovery in 2010.

In the case of inter-city rail passenger transport, a quantitative leap occurred when the new high-speed rail connections, particularly that between Madrid and Barcelona, came into operation. On the other hand, normal speed rail passenger traffic, both regional and long-distance, showed limited or negative growth.

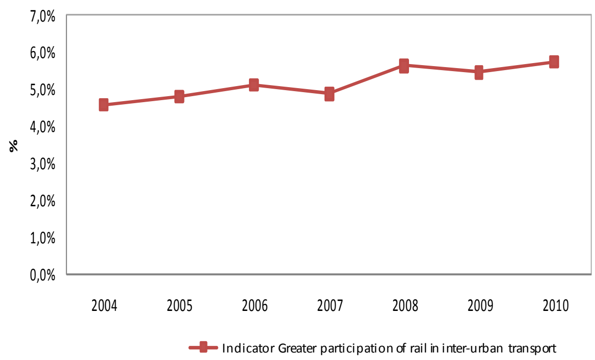
Direct savings made

To calculate the energy savings made by this measure in the period we applied the indicators stated BU_{fipas} and BU_{fimer} (Table 35) to the sector variables.

Table 35. *Energy saving in the measure "Greater share of rail in interurban transport" in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Railway transport	$BU_{fipas}+BU_{fimer}$	63.2	85.4
	Freight	BU_{fimer}	-	-
	Passengers	BU_{fipas}	63.2	85.4
Base 2007 [ktoe]	Railway transport	$BU_{fipas}+BU_{fimer}$	42.3	64.1
	Freight	BU_{fimer}	-	-
	Passengers	BU_{fipas}	42.3	64.1

Figure 25. *Evolution of indicator "Greater share of rail in inter-urban transport" in period 2004-2010*



As seen in Table 35 overall the measure "Greater participation of rail in inter-urban transport" produced positive savings in 2010 both with respect to 2004 and 2007. Passenger transport in 2010 v. 2004 achieved savings of 85.4 ktoe, which accounts for 6.9% of energy consumption in rail transport. In comparison with 2007 the values achieved were 64.1 ktoe and 5.3%.

As far as rail freight transport is concerned, no savings were made, as the significant decline in rail freight as a result of the prevailing economic conditions meant that energy consumption in this subsector was higher than weighted average unit consumption of competing transport modes (road and river/coastal).

6. Greater share for maritime transport in freight movements

The condition for achieving this objective requires ports to become preferred intermodal nodes acting as key components in the gradual roll-out of a truly intermodal freight network. To this end the port authorities must act as key agents in developing intermodal logistic installations not only within the perimeters of the ports themselves but much further inland, taking an active role in consolidating the rail-sea linkage of a truly intermodal operating system.

To calculate the savings made we used the bottom-up indicator P13 proposed by the European Commission, given the necessary cooperation between the rail and maritime networks to achieve genuine penetration. The P13 indicator is described in the section devoted to modal shift.

7. Road transport fleet management

The purpose of this measure was to reinforce general use of new telematic and other road fleet management tools in the two subsectors, freight and passengers.

The measure covered promotion and training subsidies, together with additional support for companies operating fleet management techniques on criteria of energy efficiency.

Method used

Although the measure was aimed at both road freight and road passenger transport, for purposes of simplification and given the data available, we refer here only to fleet management systems (FMS) introduced by road freight hauliers as part of the "IDAE—Regional Administrations Cooperation Programme". In terms of quantifying the results of this initiative, we leave aside measures unrelated to quantifiable direct savings, such as subsidies for audits or training related to fleet management issues.

The savings made from the introduction of fleet management systems (FMS hereafter) were quantified in the following way:

$$\text{Energy savings}\, BU_{gf} = F_{av} \cdot UE^{TLV} \cdot S_{ims} \cdot S_{TLVe}$$

where:

- UE^{TLV}= Unit consumption of trucks and light goods vehicles.
- F_{av} = Percentage savings on unit consumption by means of FMS
- S_{ims}= Number of companies with implementation of FMS
- S_{TLVe}= Average stock of trucks and light goods vehicles per company setting up an FMS

Once the figure of annual energy savings achieved by introducing an FMS (in toe/km) is obtained, it is multiplied by the average distance covered per vehicle (trucks and light goods vehicles) per year. Thus, the savings obtained in a given period correspond to the accumulated savings in toe/km achieved by installing and operating a recognised FMS, multiplied by the distance covered per year at the end of the measurement period.

Key variables

Table 36 shows all the variables directly relating to calculation of the savings generated by this measure.

Table 36. *Evolution of specific variables related to "Road transport fleet management" in the period 2004-2010*

	2004	2007	2008	2009	2010
FMS implanted [Nº]	-	32	22	97	127
Total IDAE investment in the measure [k€]	-	597	1,580	1,847	2,355

Source: IDAE

Direct savings achieved

In order to calculate the energy savings obtained by this method within the period we applied to the BU_{gf} indicator the sector variables shown in Table 36.

Table 37. *Energy saving in the measure "Road transport fleet management" in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Road transport fleet management	BU_{gf}	0,8	1,3
Base 2007 [ktoe]	Road transport fleet management	BU_{gf}	0,6	1,2

The savings achieved by means of the measure "Road Freight Fleet Management", as shown in Table 37, are in absolute terms 1.3 ktoe in 2010 v. 2004, equivalent to a percentage saving of 0.01% in terms of the final energy consumption of road freight haulage.

8. Eco-driving for cars and vans

In recent times vehicle technology has progressed significantly. However, the way vehicles are driven remains largely unchanged. This measure seeks to correct the problem, introducing a new way of driving to take advantage of technological improvements.

Eco-driving help to reduce fuel consumption and exhaust contamination, while increasing safety. The measure aims at teaching Eco-driving techniques to both new and experienced car drivers.

Method used

The savings resulting from this measure were linked to the direct savings obtained by both drivers and instructors as a result of the IDAE Eco-driving training courses. Calculating the savings resulting from this measure was done by means of a bottom-up indicator based on the reduction in unit consumption.

In order to calculate this indicator a series of considerations or hypotheses were taken into account:

- The number of learners and instructors participating as at 1 January of the first year of the training courses is noted.
- Learners and instructors comprise the total number of drivers that improve their driving performance as a result of the courses.
- An improvement factor in unit consumption over the average consumption of the vehicles driven of 15% is assumed.
- A ratio of 5 to 1 is assumed as adequate to reflect the usual savings of a trained instructor in comparison with those of a normal driver.

The savings resulting from this initiative were quantified as follows:

$$\text{Energy savings } BU_{cet} = \left(UE^{CA} - UE^{CAFormado}\right) \cdot Di_t^{av.kmCA} \cdot S_{alumnos}$$

where:

- UE^{CA}= Average unit consumption of cars
- $UE^{CAtrained}$= Average unit consumptionof cars driven by trained drivers
- $S_{student}$= Number of student equivalents trained
- $Di_t^{av.km.CA}$= Average distance covered per car

Key variables

Table 38 gives all the variables having a direct bearing on calculating the savings resulting from this measure.

Table 38. *Evolution of specific variables related to "Eco-driving for cars and vans" in the period 2004-2010*

	2004	2005	2006	2007	2008	2009	2010
Equivalent students trained [number]	-	7,500	13,274	34,735	31,458	73,878	79,515
Total IDAE investment in the action [k€]	-	600	1,025	2,172	3,368	4,117	3,324

Source: IDAE

Direct savings achieved

In order to calculate the energy savings obtained by this measure in the period 2004—2010, we applied the indicator BU_{cet} to the above variables.

Table 39. *Energy saving in the measure "Eco-driving for cars and vans" in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Eco-driving for cars and vans	BU_{cet}	36.1	53.5
Base 2007 [ktoe]	Eco-driving for cars and vans	BU_{cet}	23.5	40.9

As can be seen in Table 39 with respect to the situation in 2004 the savings achieved are 53.5 ktoe, representing a percentage saving of 0.43% in final energy consumption in cars.

9. Eco-driving for trucks and buses

The energy consumption of commercial road haulage (passengers and freight) has a major impact on the total national energy consumption. It is therefore a priority to increase the energy efficiency of this sector and reduce its energy requirements in order to improve its competitiveness and sustainability. An Eco-driving technique is a low-cost high-efficiency means whereby transport companies can reduce their fuel consumption and associated costs.

The importance of Eco-driving convinced the European Commission in its Directive 2003/59/EC of 15 July 2003 to include, among others, optimisation of fuel consumption as part of the training programmes at the initial and refresher levels of professional drivers. In addition, the measure encompassed a system of quality certification for passenger and freight transport by road on the basis of the aforesaid training of drivers.

Method used

The savings resulting from this measure are estimated on the basis of the lessons in Eco-driving imparted by the IDAE to pupils and instructors. The savings calculation was made using a bottom-up indicator based on the per unit consumption achieved as a result of the driving courses.

To calculate the aforesaid indicator the following considerations and assumptions were made:

- Note was taken of the number of pupils and instructors in training as at 1 January of the year in which the training courses began.
- Pupils and instructors comprise the total number of drivers who improve their driving performance as a result of the courses.
- An improvement factor of 15% is assumed in per unit consumption in comparison with the standard consumption of road vehicles.
- The ratio of 5:1 is used to estimate the savings achieved by an instructor with respect to those achieved by a normal driver.

The savings resulting from this scheme were calculated as follows:

$$\text{Energy savings } BU_{cec} = \left(UE^{TLV} - UE^{TLVFormado}\right) \cdot Di_{t}^{\text{av.kmTLV}} \cdot S_{alumnosTLV}$$

where:

- UE^{TLV}= Average unit consumption of trucks and light goods vehicles
- $UE^{TLVtrained}$= Average unit consumption of trucks and light goods vehicles driven by trained drivers
- $S_{studentTLV}$= Number of student equivalents trained
- $Di_t^{av.kmTLV}$ = Average distance covered by truck and light goods vehicle

Key variables

Table 40 gives all the variables having a direct bearing on calculating the savings achieved by this measure.

Table 40. *Evolution of specific variables related to "Eco-driving for trucks and buses" in period 2004-2010*

	2004	2005	2006	2007	2008	2009	2010
Equivalent students trained [number]	-	-	4,785	13,253	15,748	45,146	49,795
Total IDAE investment in the action [k€]	-	-	1,206	2,215	2,594	3,465	2,919

Source: IDAE

Direct savings obtained

To calculate the energy savings achieved by this measure in the period we applied the indicator BU_{cec} to the sector variables shown in Table 41.

Table 41. *Energy saving in the measure "Eco-driving for trucks and buses" in 2009 and 2010 with base 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Eco-driving for trucks and buses	BU_{cec}	41.2	60.6
Base 2007 [ktoe]	Eco-driving for trucks and buses	BU_{cec}	31.6	52.0

As we can see from Table 41, with respect to base year 2004 the savings represent 60.6 ktoe, equivalent to a percentage saving of 0.4% with respect to the final energy consumption of trucks and light goods vehicles. With respect to base 2007, the savings amounted to 52.0 ktoe and 0.4%.

10. Replacing car fleets

Renovating the stock of cars permits greater energy efficiency. When it comes to understanding the potential energy savings to be obtained from renovated car stocks we find that there are two measures or actions available: that of promoting technology improvements to reduce consumption and emissions; and that of subsidising the purchase of more efficient vehicles. Of the major initiatives aimed at fostering the renovation of car stocks, we highlight the following:

- The number of European Directives and Regulations having this intention: for example, Regulation (EC) 443/2009 of the European Parliament and of the Council, of 23 April 2009, "setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles".
- National supportive mechanisms, such as the tax benefits available when registering a new car according to its CO2 emissions.
- Plans to promote the purchase of new vehicles.
    - "Plan Prever" (1997-2007). The so-called "Foresee Plan" was introduced in 1997 with the aim of accelerating renewal of Spain's stock of cars, one of the oldest in Europe, with 35% of cars being more than ten years old. It is estimated that subsidies were granted to more than 3.3 million car owners to buy a new vehicle, a measure that generated significant savings in CO2 emissions (Decree Law 13/2006 of 29 December).

- *Plan VIVE* (*Vehículo Innovador, Vehículo Ecológico* — "Innovative Vehicle, Ecological Vehicle" (2008—2010)), a two-year scheme of subsidies to acquire a new vehicle. This plan aimed at replacing vehicles older than 15 years by new vehicles having CO2 emission levels of less than 120 grammes per kilometre. (Official State Gazette A-2008-10970)
- *Plan 2000E* (2010): vehicle purchase subsidies provided by Spain's central administrations, regional administrations and car manufacturers. The subsidies are worth 2,000 euros provided the car conforms to the requirements of the scheme (Decree Law 898/2009, of 22 May).
- *Proyecto Piloto demostrativo del vehículo eléctrico MOVELE*. "Pilot Project to Demonstrate the *MOVELE* electric car", managed and coordinated by the IDAE, the project consists of introducing within a term of two years (2009 and 2010), in urban areas, 1,100 electric vehicles of various categories across a broad range of companies, institutions and private individuals, together with installing 149 charging points for these cars, plus 409 charging points out of this Project.
- An IDAE—regional-administrations cooperation agreement and IDAE grants for strategic projects with incentives to purchase hybrid electric vehicles

Grants for the purchase of new cars are orchestrated by means of cooperation agreements between the IDAE and the regional administrations, with other administrations bodies such as the ICO (State-owned and managed bank), the Ministry of the Economy, etc., also involved. Under the scheme, any institution, body or individual, public or private, is in principle eligible for a grant.

Method used

To calculate the energy savings effect of this measure we used bottom-up indicators.

Key variables

The first indicator, BU_{pr1}, measures the energy savings resulting from adding a car (unsubsidised) to the existing stock, either to replace an existing car (which is deregistered) or to increase the stock.

The first positive component is the energy saving made by acquiring a car to replace an existing one. The second is the saving obtained from a new vehicle that increases the stock.

$$\text{Energy savings } BU_{pr1} = N_{sus} \cdot UE_{sus} + N_{in} \cdot UE_{in}$$

where:

- N_{sus}= Number of new registrations replacing a deregistration. New registrations relating to car replacement schemes are not included.
- UE_{sus} = Unit consumption of new car replacing an old car
- N_{in}= Number of new registrations adding to the total stock (difference between registrations and deregistrations, if present). New registrations relating to vehicle replacement schemes are not included
- UE_{in} = Unit saving of new car constituting an addition to the stock (difference between registrations and deregistrations, if present)

Schemes to renovate car stocks

The results obtained from these indicators (BU_{pr2}, BU_{pr3} and BU_{pr4}) measure the energy savings achieved by replacing cars using some form of stimulus for owners to exchange their existing car for a new one.

$$\text{Energy savings Plan x} = N_x \cdot UE_x$$

where:

- N_x= Number of operations conducted under the car renewal scheme “x”
- UE_x = Unit saving per new car pursuant to a car replacement scheme

The vehicle replacement schemes considered here coincide at some point in time with the period 2004—2010:

Plan	Indicator	Year beginning	Year ends
Plan PREVER[9]	*BUpr2*	1997	2007
Plan VIVE	*BUpr3*	2008	2010
Plan 2000E	*BUpr4*	2010	2010

Electrification of the stock of cars

This indicator BU_{pr5} measures the energy savings obtained by introducing in the existing stock of cars either hybrid or entirely electric vehicles, regardless of whether they replace existing vehicles. As with the bottom-up indicator BU_{pr1} already described, this indicator employs two addends: the first impinges on the savings perimeter resulting from hybrid vehicles; the second on the savings obtained from electric vehicles.

$$\text{Energy savings } BU_{pr5} = N_h \cdot UE_h + N_e \cdot UE_e$$

where:

- N_h= Number of new hybrid vehicles
- UE_h = Unit saving per new hybrid vehicle added to the stock
- N_e= Number of new electric vehicles
- UE_e = Unit saving per new electric vehicle added to the stock

To calculate these indicators we took into account several factors as follows. For new vehicles replacing existing ones the saving corresponds to the difference in the unit consumption of the new vehicle and the average unit consumption of newly registered vehicles in the minimum number of years required to deregister a vehicle under the scheme. In the case of cars not replacing an existing vehicle, the unit saving is calculated as the difference between the consumption of the new vehicle and the average unit consumption of the stock in the year concerned. For these purposes we assumed an average stock rotation period per vehicle of ten years.

IDAE—regional administrations cooperation programme and IDAE programme of grants for Strategic Projects

In order to assess in energy accounting terms the effects of the IDAE — regional administrations cooperation programme and the IDAE programme of subsidies for Strategic Projects within the “Renovation of the national car stock” scheme, we used the reports issued by the regional administrations on the energy savings achieved by public funds employed for this purpose together with the reports of the IDAE itself. The savings obtained in 2010 result from adding the savings reported in each year from 2004 or 2007 depending on the base year chosen.

[9] The time frame considered for this plan is the period between 2004 and 2007

$BUpr6 = \sum_t^i Ah_{rencar}$

where:

- Ah_{rencar}: Annual savings reported by the regional administrations with respect to the measure "Renewal of the stock of cars"

To obtain the total saving in a given year we accumulated the savings obtained in the period elapsing from the base year and multiplied them by the kilometres travelled in the measurement year, as shown in the following formula:

$$\text{Energy savings } BU_{rp} = \sum_{\text{base year} = t}^{t=i} \left(UE_t^x \cdot O_t^x\right) \cdot D_i$$

where:

- UE^x_t = Unit savings per car depending on the type of replacement
- D_i = Average distance covered by cars in a year
- O^x_t = Number of operations per year (replacements, number of registrations of hybrid vehicles, etc.)

Key variables

The following tables give the variables having a direct bearing on calculating the savings resulting from this scheme.

Table 42. *Evolution of specific variables related to "Replacing car fleet" in period 2004-2010 – Natural renovation of fleet*

	2004	2007	2008	2009	2010
New registrated cars [number]	1,653,798	1,633,774	1,185,407	971,094	990,000
Deregistered cars [number]	800,000	887,395	734,638	937,297	750,000
Replacement operations [number]	455,623	329,687	720	100,940	200,000
Electric and hybrid vehicles sales [number]	600	2,000	2,000	5,848	8,272
Saving per vehicle replaced base 2004/2007 [goe/km]	7,44	5,21	4,86	5,48	6,06
Saving per vehicle increased base 2004 [goe/km]	3,57	4,28	4,37	6,51	8,03
Saving per vehicle increased base 2007 [goe/km]	-	3,41	3,50	5,64	7,15

Source: DGT, IDAE

Table 43. *Evolution of specific variables related to "Replacing car fleet" in period 2004-2010 - Private vehicles replacement plans*

	2004	2007	2008	2009	2010
Operations Plan Vive [number]	-	-	360	50,470	-
Operations Plan Prever [number]	455,623	329,687	-	-	-
Operations Plan 2000E [number]	-	-	-	-	200,000

Source: MINISTERIO DE INDUSTRÍA, TURISMO Y COMERCIO

Table 44. *Evolution of specific variables related to "Replacing car fleet" in period 2004—2010- Car fleet electrification*

	2004	2007	2008	2009	2010
Electric vehicles sales [number]	-	-	-	448	1,082
Hybrid sales [number]	600	2,000	2,000	5,400	7,190

Source: IDAE

Direct savings achieved

Calculation of the energy savings obtained in the period under study from "Renovating the car stock" was carried out using the positive indicators listed in the foregoing sections.

Table 45. *Energy saving in the measure "Replacing car fleet" in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Replacing car fleet	ΣBU_{rpi}	651.7	734.9
	Natural renovation	BU_{rp1}	360.4	425.3
	Plan PREVER	BU_{rp2}	276.1	275.3
	Plan VIVE	BU_{rp3}	10.0	10.0
	Plan 2000E	BU_{rp4}	-	15.4
	Strategy to Promote Electric Vehicle in Spain 2010-2015	BU_{rp5}	0.6	2.1
	IDAE — Regional administrations cooperation programme + IDAE strategic projects	BU_{rp6}	4.5	6.9
Base 2007 [ktoe]	Replacing car fleet	ΣBU_{rpi}	138.7	220.9
	Natural replacing car fleet	BU_{rp1}	125.6	188.5
	Plan PREVER	BU_{rp2}	-	-
	Plan VIVE	BU_{rp3}	10.0	10.0
	Plan 2000E	BU_{rp4}	-	15.4
	Strategy to Promote Electric Vehicle in Spain 2010-2015	BU_{rp5}	0.6	2.1
	IDAE — Regional administrations cooperation programme + IDAE strategic projects	BU_{rp6}	2.5	4.9

In absolute terms the energy savings obtained in 2010 with respect to 2004 were 734.9 ktoe as can be seen in Table 45, representing a percentage saving of 7% of the final energy consumption of the current stock of cars.

11. Renovation of road transport fleets

This measurement is to determine the energy savings achieved by introducing more efficient vehicles in the fleets used to convey passengers and freight by road.

Method used

To calculate the effect produced by this measure we used the annual reports issued by the regional administrations on the savings obtained by devoting public funds to this purpose.

The savings obtained in 2010 result from adding the savings reported in each year from 2004 or 2007 depending on the base year used, as adjusted for the average distance covered by trucks and light goods vehicles.

$$BUrf = \sum_{t}^{i} Ah_{renfleet}$$

where:

- $Ah_{renfleet}$: Annual savings reported by regional administrations with respect to the measure "Renewal of road transport fleets"

Key variables

Table 46 gives all the variables having a direct bearing on calculating the energy savings obtained by this scheme.

Table 46. *Evolution of specific variables related to "Replacing transport fleet by road" in period 2004—2010*

	2004	2007	2008	2009	2010
IDAE actions [number]	-	154	97	241	203
Total IDAE investment in the action [k€]	-	2,215	2,594	3,465	2,919

Source: IDAE

Direct savings obtained

Table 47. *Energy saving in the measure "Replacing transport fleet by road" in 2009 and 2010 with base 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Renovation of road transport fleets	BU_{rf}	1.1	1.5
Base 2007 [ktoe]	Renovation of road transport fleets	BU_{rf}	0.6	1.0

Finally, according to the results stated in Table 47, the energy savings obtained from the scheme "Renovation of road transport fleets" in 2010 with respect to 2004 were 1.0 ktoe in absolute terms.

12. Savings obtained in the transport sector as at 2010

The transport sector achieved energy savings of 6,451.1 ktoe in the period 2004—2010. These savings were achieved in the main in road transport (6,701.4 ktoe), especially in road freight transport, which compensated the negative savings in rail and air transport. Maritime transport contributed positive energy savings of 52.3 ktoe, while the energy savings resulting from modal shift were 82.7 ktoe.

Table 48. *Energy saving in the transport sector in 2009 and 2010 with base 2004 y 2007*

		Indicator associated	2009	2010
Base 04 [ktoe]	Transport sector	*∑Ah. per mode*	5,133.9	6,451.1
	Road mode	$BU_{rp}+BU_{cet}+A2+PB$	5,368.8	6,701.4
	Railway mode	*P10 + P11*	-337.1	-317.4
	Maritime mode	*M7*	131.9	52.3
	Air mode	*Mav*	-44.5	-68.0
	Modal shift	*P12 + P13*	14.8	82.7
Base 07 [ktoe]	Transport sector	*∑Ah. Per mode*	3,351.5	4,561.1
	Road mode	*P8 + A2 + PB*	3,710.9	4,910.4
	Railway mode	*P10 + P11*	-234.6	-206.7
	Maritime mode	*M7*	-45.9	-99.9
	Air mode	*Mav*	-24.4	-48.3
	Modal shift	*P12 + P13*	-54.4	5.6

Below we give the possible indirect and unquantifiable savings occurring in the transport sector and the risks of double accounting in these figures.

12.1. Indirect effects

With respect to the possible indirect effects that may have been observed, it is worth noting the following observations, with respect to each of the transport modes observed:

Road transport

With respect to the measure “Road Freight Fleet Management”, the difficulty of obtaining full information on the savings resulting from the internal decisions of privately owned companies meant that the relative savings achieved by this measure are limited to the scheme “IDAE—Regional Administrations Cooperation Programme”. As a result it was not possible to ascertain how many Fleet Management Systems (FMS) were installed in Spain between 2004 and 2010.

With respect to the measure “Eco-driving for cars and vans”, the complexity of measuring the savings resulting from drivers’ individual performance was such that only the direct savings resulting from the courses in Eco-driving sponsored by the IDAE were included. Consequently, there are a series of indirect effects associated with this measure that remain un-quantified, such as:

- The driving efficiency improvements resulting from media advertising campaigns and news stories.
- The knock-on effects resulting from the economic crisis such as the rise in the price of oil or the loss of purchasing power.
- The improvement in driving efficiency resulting from the increasing use of on-board computers, GPS systems and other driving aids that help drivers

measure fuel consumption in real time and select which driving method to employ in different road conditions.
- The improvement in driving resulting from the tightening of speed limits and closer policing of compliance.

In the same way, with respect to the measure “Eco-driving for trucks and buses”, only the courses held by the IDAE - directly or in collaboration with the regional administrations- for pupils and instructors could be included. Consequently, there remains a series of indirect unquantifiable effects:

- More Eco-driving as a consequence of the introduction by transport companies of computerised Fleet Management Systems, although its effect is partially accounted for under the measure “Road transport fleet management”.
- The use of variable driver payment rates depending on recorded energy consumption.

The energy savings achieved by measures directed at renovating car fleets depend, at bottom, on the number of new cars and their unitary consumption. As a result, certain indirect effects have been observed as a consequence of the present economic recession. One such effect is the decline in the rate of registration of new more efficient vehicles as from 2008. On the other hand, the economic situation and the rise in the price of fuel, such as increasing sales of smaller lighter vehicles.

Rail transport

In rail transport, the direct energy savings resulting from schemes such as the “Strategic Infrastructure and Transport Plan 2005—2020” (PEIT in Spanish) and the “Spanish Sustainable Mobility Strategy” could not be quantified.

Maritime transport

It has not proved possible to put a figure on the energy savings obtained as a consequence of the maritime freight transport: “Maritime Fleet Renewal”. The immediate aim of this initiative was to upgrade the Spanish merchant fleet by installing improved propellers, mechanisms to monitor fuel consumption and hybrid diesel/natural gas engines.

Also, the concrete energy savings resulting from the “IDAE Communication and Awareness Programmes”, the “Energy Savings and Efficiency Activation Plan” (31 specific measures) and the maritime transport component of the “Spanish Sustainable Mobility Strategy” could not be tabulated statistically.

Air transport

The savings obtained as a consequence of the following air-transport measures, schemes and circumstances could not be quantified:

- The improvement of aircraft fleet management. In the last few years airlines have tried to cut back the number of flights in order to maintain reasonable load factors. The frequency of flights on certain routes has also been revised.

- Efficient piloting. Within the sphere of air transport various initiatives have been taken to achieve energy savings by means of training and promoting piloting courses and signing agreements with companies to introduce efficiency protocols in their procedures.
- The autonomous technological progress of aircraft design and operating standards and its impact on normal fleet renewal.

Other IDAE initiatives, the results of which could not be quantified precisely, were the “IDAE — Regional Administrations Cooperation Programme”, the “Communication and Awareness Programmes” and the “2008—2011 Energy Savings and Efficiency Activation Plan”.

Modal shift

There are a number of indirect effects having an impact on collective transport (bus, underground and rail) and resulting from current economic circumstances, such as fluctuations in the price of fuel and in the level of employment. Another ‘incidental’ effect is when people who habitually walk or cycle to their daily destinations start to use public transport when this becomes available to them, thereby contributing to cost-bearing energy consumption.

Within the sphere of long-distance passenger transport the increasing share of high-speed rail may have the knock-on effect of boosting long-distance passenger road transport. The introduction of high-speed rail links tends to cannibalise the existing slow-speed services, leaving long-distance bus services to become the favoured means of transport of lower-income groups.

Due to their multimodal scope and content, a certain degree of overlap can be seen between the “Strategic Infrastructure and Transport Plan 2005—2020 (PEIT in Spanish) and the measure known as “Transport Infrastructure Management”. The PEIT seeks to boost public transport by building the share of rail transport for passengers and freight, increasing the use of coastal maritime transport and achieving a greater degree of coordinated intermodal transport across all networks. The “Transport Infrastructure Management” initiative, on the other hand, has not been quantified due to its scope and relative intangibility, which would inevitably lead to a certain amount of double accounting with many of the measures contained in the PEIT, especially those aimed at achieving changes in transport mode.

12.2. Double accounting

In all our calculations of the savings associated with different measures and schemes every effort has been made to avoid double accounting. In quantifying the savings resulting from the so-called modal-change initiatives, a risk of double accounting undoubtedly exists:

- The campaign “Greater Participation of Rail in Inter-urban Transport” sets out to foster passenger (collective) rail transport, a goal that is also mentioned in the initiative known as “Sustainable Urban Mobility Plans” (PMUS in Spanish). However, the latter plans are circumscribed to contiguous urban metropolitan areas, thereby excluding suburban trains and hence the risk of double accounting.

- Drawing up the details of the so-called “Transport Plans for Companies and Activity Centres”, carried out by the companies of a given municipality, is an intrinsic part of establishing a valid PMUS.
- There is a risk of double accounting where the savings achieved by PMUS initiatives are added to those resulting from the scheme “Greater Participation of Urban Collective Transport (buses) in Road Transport”, given that they are common to both measures.

The possibility of double accounting “Road Transport Fleet Management” initiatives and measures designed to encourage Eco-driving (“Eco-driving for cars and vans, and for Industrial Vehicles”) is a real one given that in many cases improvements in driving techniques go hand in hand with the use of more sophisticated driving aids. That said, quantification of these savings was limited to the “IDAE—Regional Administrations Cooperation Programme”, for which a bottom-up indicator was used, thus avoiding double accounting.

There is a small risk of double accounting with respect to the measure “Renewal of Spain’s stock of cars”, given that within the average per-unit consumption of newly registered cars is included the consumption of hybrid and electric vehicles. However, the effect of this is negligible given the very low level of sales of this vehicle type in comparison with conventional combustion-engine cars.

The risk of double accounting was further reduced by adding the savings of indicator *P12* to those resulting from the part of the measure “Greater Share for Rail in Inter-Urban Transport” associated with rail passenger transport, given that this item is common to the indicators that measure both.

IV.BUILDINGS SEGMENT

1. Summary of savings in the buildings segment

BUILDINGS SEGMENT

The energy savings achieved in the period 2004—2010 in the buildings segment were due in the main to improvements made to the thermal envelope of buildings, lighting and appliances. The final energy consumption on this segment in 2010 was 24,391 ktoe, 26.1% of the national total

Segment consumption

	Final Energy 2010 [ktoe]
TOTAL CONSUMPTION BUILDING SECTOR	24,391.7
THERMAL ENVELOPE AND INSTALLATIONS	17,333.6
LIGHTING USE	2,333.7
EQUIPMENT USE	4,724.5

Result of the savings obtained

	Final energy saving 2010 [ktoe]		Primary energy saving 2010 [ktoe]		CO_2 emissions avoided2010 [$ktCO_2$]	
	Base 2004	Base 2007	Base 2004	Base 2007	Base 2007	Base 2007
TOTAL SAVINGS MEASURES	**2,232.5**	**2,529.1**	**3,165.0**	**4,189.1**	**6,982.8**	**9,269.0**
Rehabilitation and improvement in thermal envelope and installations	1,637.7	2,020.6	1,887.3	3,081.4	4,348.8	6,882.0
Improving interior lighting installations	793.9	301.2	1,987.0	709.8	4,017.1	1,519.8
Renewal of appliances	-199.1	207.3	-709.2	397.8	-1,383.0	867.1

Conclusions

In the buildings segment savings of 2,232.5 ktoe were achieved in the period 2004—2010. 67% of these savings (1,637.7 ktoe) resulted from improvements to the thermal envelope of buildings and their thermal installations and 33% (793.9 ktoe) to the installation of more efficient interior lighting, whereas in the equipment segment no savings were achieved.

These results were achieved by the measures proposed in the Energy Savings and Efficiency Action Plan 2005-2007 and 2008-2012, backed by regulatory measures designed to foster energy efficiency in the building industry.

The four measures of the Action Plan, articulated by means of a cooperation agreement between the IDAE and the regional administrations, encouraged rehabilitation of building envelope, improvements to the thermal and lighting installations and the renewal of household appliances.

These measures were further strengthened by the work done at the legislative level, in particular by the introduction of the Technical Building Code (Decree Law 314/2006), which encouraged greater efficiency in thermal envelope and systems, the new Rules on Thermal Installations in Buildings (Decree Law 1027/2007), which makes the periodic inspection of such installations an obligation, and the rule (Decree Law 47/2007) making it an obligation for all buildings to have an Energy Certificate. The Energy Savings and Efficiency Action Plans (2 for 1 Programme and the Programme for the free distribution of high-efficiency light-bulbs) together with the IDAE aid programmes for Strategic Projects, together with the various communication and information campaigns all contributed to fostering energy efficiency in the buildings sector.

The savings attributable directly to these plans and regulations are estimated at 585.0 ktoe. The Technical Building Code is the regulation to which most of the savings can be attributed (231.7 ktoe), 40% of total savings. The mechanisms relating to the use of interior lighting — the IDAE—regional administrations cooperation programme, the programmes of free distribution of light-bulbs and the 2x1 programme — achieved savings of 127.6 ktoe. Lastly, the household appliance renovation plans saved 81.4 ktoe.

As well as the savings attributable directly to these mechanisms there were other unquantifiable effects observable as the difference between the mechanisms themselves and the savings calculated by top-down indicators. These effects may have been negative, such as the renewal of household appliances, which in some cases led to a greater penetration of certain appliances in the services sector.

Measures-mechanisms Matrix

<table>
<tr><th colspan="2">Mechanisms
Measures</th><th>IDAE- Regional Administrations Programme</th><th>IDAE support programmes to strategic projects</th><th>Programme “2 for1”</th><th>Free distribution programme</th><th>New RITE (RD 1027/2007)</th><th>CTE (RD 314/2006)</th><th>Decree Law 47/2007</th><th>Communication and awareness campaigns</th><th>Unquantified effects</th><th>TOTAL</th></tr>
<tr><td rowspan="5">Base 2004 [ktoe]</td><td>Rehabilitation thermal envelope</td><td>22.3</td><td rowspan="2">60.9</td><td></td><td></td><td colspan="3" rowspan="2">231.7</td><td colspan="2" rowspan="2">1.261.7</td><td rowspan="2">1,637.7</td></tr>
<tr><td>Improvements thermal installations</td><td>61.1</td><td></td><td></td></tr>
<tr><td>Improvements interior lighting</td><td>29.7</td><td></td><td>13.0</td><td>84.9</td><td colspan="5">666.3</td><td>7981.9</td></tr>
<tr><td>Renewal of households appliances</td><td>81.4</td><td></td><td></td><td></td><td colspan="3"></td><td colspan="2">-280.5</td><td>-199.1</td></tr>
<tr><td>TOTAL</td><td>194.5</td><td>60.9</td><td>13.0</td><td>84.9</td><td colspan="5">1,880.2</td><td>2,235.5</td></tr>
<tr><td rowspan="5">Base 2007 [ktoe]</td><td>Rehabilitation thermal envelope</td><td>17.6</td><td rowspan="2">60.9</td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3" rowspan="2">167.0</td><td colspan="2" rowspan="2">1,725.1</td><td rowspan="2">2,020.6</td></tr>
<tr><td>Improvements thermal installationjs</td><td>50.0</td></tr>
<tr><td>Improvements interior lighting</td><td>24.9</td><td></td><td>13.0</td><td>83.7</td><td colspan="5">179.6</td><td>301.2</td></tr>
<tr><td>Renewal of households appliances</td><td>56.5</td><td></td><td></td><td></td><td colspan="3"></td><td colspan="2">150.8</td><td>207,3</td></tr>
<tr><td>TOTAL</td><td>149.0</td><td>60.9</td><td>13.0</td><td>83.7</td><td colspan="5">2,222.5</td><td>2,529.1</td></tr>
</table>

* Direct savings achieved due to mechanisms

** Indirect savings achieved due to mechanisms

USE OF THERMAL ENVELOPE AND INSTALLATIONS

The savings made in the use of thermal envelope and installations were determined by improvements in the systems of space heating, cooling and the provision of sanitary hot water in the residential and services sectors. The final energy consumption devoted to these uses in 2010 was 17,333.6 ktoe, 71% of energy consumption in buildings.

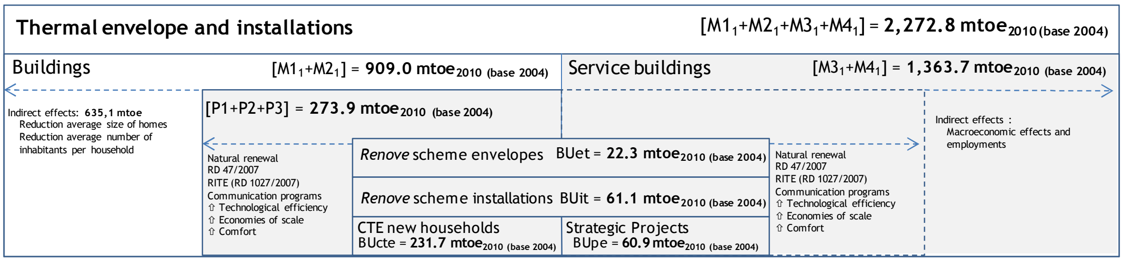
In order to calculate the external perimeter of global savings we used the *M* indicators proposed by the European Commission, while to evaluate the savings obtained from rehabilitation of thermal envelope and installations we used P indicators. We were only able to estimate savings in the residential segment given that in the services segment there was insufficient statistical information available for the use of corresponding P indicators. Finally, the effects of renewal programmes encouraged by the authorities by means of the "Renove" Plans and implementation of the Building Code were measured by bottom-up indicators.

Results obtained

		Final energy saving 2010 [ktoe]	
		Base 2004	Base 2007
$M1_{11}$	Savings thermal consumption on space heating per home	290.7	316.0
$M1_{12}$	Savings thermal consumption on water heating per home	356.5	338.5
$M2_{11}$	Savings electric power consumption on space heating per home	182.0	105.4
$M2_{12}$	Savings electric power consumption on cooling per home	-72.5	19.5
$M2_{13}$	Savings electric power consumption on water heating per home	152.4	132.3
$M3_{11}$	Savings thermal consumption on space heating per employee	1,278.0	736.0
$M3_{12}$	Savings thermal consumption on water heating per employee	151.1	94.7
$M4_{11}$	Savings electric power consumption on space heating per employee	-306.9	-59.4
$M4_{12}$	Savings electric power consumption on cooling per employee	251.7	544.9
$M4_{13}$	Savings electric power consumption on water heating per employee	-10.1	5.9
P1	Savings electric and thermal consumption on space heating per m^2	153.7	316.3
P2	Savings electric power consumption on cooling per m^2	-76.6	16.9
P3	Savings electric power and heat consumption on water heating per inhabitant	196.9	365.4
BU_{et}	Renove scheme of thermal envelope of buildings	22.3	17.6
BU_{it}	Renove scheme of thermal installation	61.1	50.0
BU_{cte}	Thecnical Code for Building (CTE)	231.7	167.0
BU_{pe}	IDAE support programmes to strategic projects	60.9	60.9
TOTAL SUBSECTOR thermal envelope and installations *($M3_{11}$+$M3_{12}$+$M4_{11}$+$M4_{12}$+$M4_{13}$+P1+P2+P3)*		**1,637.7**	**2,020.6**

Breakdown of savings

The savings achieved with respect to thermal envelope and installations in buildings are divided into two parts, depending on the sector targeted, residential or services.



Conclusions

The top-down indicators *M* confirm global savings of 2,272.8 ktoe, the use of space heating being the segment in which most savings were obtained (64% of the total) given that the penetration of cooling systems — and its associated consumption — increased in homes. The top-down *P* indicators show savings in the residential segment of 273.9 ktoe. In the services sector, no equivalent indicators being available, the results obtained from *M* indicators (1,363.7 ktoe) are adhered to.

The initiatives known as the "Renove" plans achieved savings of 22.3 ktoe in the renewal of building envelope (walls, roofs and windows) and of 61.1 ktoe in the renewal of thermal installations (space heating, cooling and the provision of sanitary hot water). In addition, using bottom-up indicators it was possible to calculate the savings resulting from introduction of the Technical Building Code (231.7 ktoe), as well as those achieved by means of the IDAE aid programmes for strategic projects (60.9 ktoe).

Finally, from the differences in the perimeters of external and internal savings it was possible to distinguish certain indirect effects, particularly in households, of 635.1 ktoe, resulting from the reduction in the average size of homes and the average number of residents living there.

Furthermore, there are a number of unquantifiable effects associated with these measures that, while not being the result of direct action, are related to it:

- Greater demand for more efficient air conditioning and thermal envelope has prompted greater economies of scale by producers, bringing end prices down.
- Changing consumer habits in two directions: greater comfort may provoke a less stringent use of air conditioning; while the acquisition of energy intensive equipment may encourage a greater awareness of the need to save.

USE OF INTERIOR LIGHTING

The energy savings achieved in the use of interior lighting in the home and services environments are determined in the main by the spread of low-consumption light bulbs. The energy consumption attributable to this use in 2010 was 2,333.7 ktoe, 10% of the energy consumption of buildings.

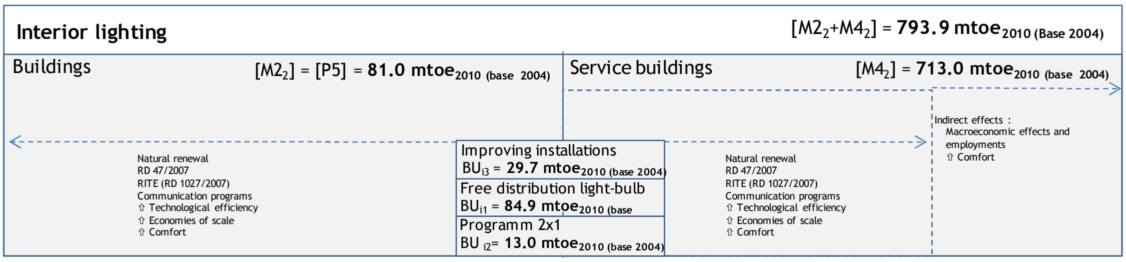
In order to calculate the external perimeter of the global savings obtained we used the *M* indicators proposed by the European Commission. In the residential sector the P indicator proposed is equivalent to these. Using bottom-up indicators we calculated the renewal effect promoted by the central administrations by means of agreements made with regional administrations and the special programmes to promote the use of efficient light bulbs.

Results obtained

		Final energy saving 2010 [ktoe]	
		Base 2004	Base 2007
$M2_2$	Saving electric power consumption on lighting per home	81.0	53.3
$M4_2$	Saving electric power consumption on lighting per employee	713.0	247.9
P5	Saving electric power consumption on lighting per home	81.0	53.3
BU_{i1}	Programme of distribution low-consumption light bulbs	84.9	83.7
BU_{i2}	Programme of low-consumption light bulbs “2 for 1”	13.0	13.0
BU_{i3}	Improved interior lighting installations of existing buildings	29.7	24.9
TOTAL SUBSECTOR INTERIOR LIGHTING [ktoe] *($M4_2$+P5)*		**793,9**	**301.2**

Breakdown of savings

The savings obtained on interior lighting were divided into two main areas, depending on the sector the measures were aimed at, households or services.



Conclusions

The global savings in the sub-segment of internal lighting were calculated using the *M* and *P* indicators proposed by the European Commission at 793.9 ktoe, mainly in services (90% of the total).

The *bottom-up* savings were obtained from the annual information of the regional administrations on the energy improvements obtained as a result of the agreements with the IDAE. At the same time, the two initiatives begun under the “Energy Savings and Efficiency Action Plan” (84.9 ktoe), the “2 for 1 programme for distributing efficient light-bulbs” (84.9 ktoe) were also quantified.

-

USE OF HOUSEHOLD AND OFFICE EQUIPMENT

The energy savings obtained by the use of household and office equipment are determined in the main by the energy-efficient use of household appliances, kitchen equipment and office systems both in households and services buildings. The final energy consumption devoted to this use in 2010 was 4,724.5 ktoe, 19% of the energy consumption of buildings.

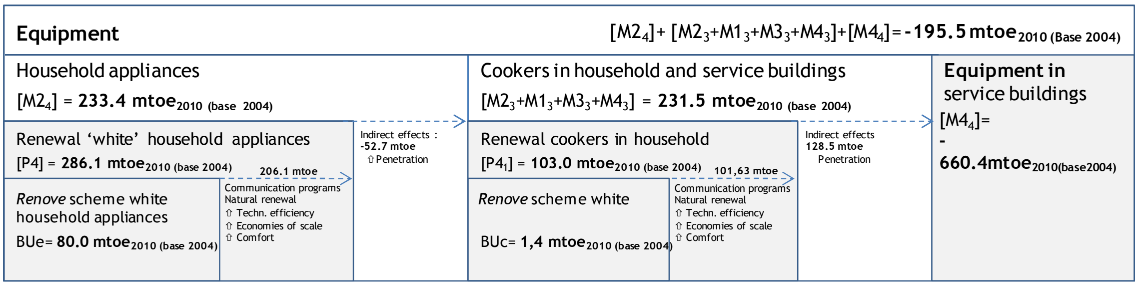
To calculate the external perimeter we used the indicators proposed by the European Commission, whereas to estimate the savings obtained as a result of the measures promoting renewal of household appliances and cookers we used corrected *P* indicators. Finally, bottom-up indicators were used to estimate the effect of the renewal of these items promoted by the administrations by means of the so-called "Renove" plans.

Results obtained

		Final energy saving 2010 [ktoe]	
		Base 2004	Base 2007
$M1_3$	Saving thermal consumption of cookers per home	183.0	132.9
$M2_4$	Saving electric consumption of appliances per home	277.6	156.5
$M2_3$	Saving electric consumption of cookers per home	-23.7	-0.4
$M3_3$	Saving thermal consumption of cookers per employee	83.0	27.8
$M4_3$	Saving electric consumption of cookers per employee	-10.7	-7.9
$M4_4$	Saving electric consumption of office automation per employee	-660.4	-54.8
$P4$	Saving electric unitary consumption of appliances per appliance	286.1	164.6
$P4_1$	Saving electric and thermal unitary consumption per cooker[10]	103.0	77.8
BU_e	Renove scheme for white range appliance	80.0	55.1
BU_c	Renove scheme for appliance cookers	1.4	1.4
TOTAL SUBSECTOR EQUIPMENT [ktoe] *($M3_3$+$M4_3$+$M4_4$+P4+$P4_1$)*		**-199.1**	**207.3**

Breakdown of savings

The savings on equipment were divided into three main areas taking into account the type of equipment and the sector — household or services — it is used in.



Conclusions

The top-down indicators *M* suggest that no savings were obtained in the period under study (—195.5 ktoe) due in the main to an increased use or spread of equipment both in households and, especially, in services buildings. In particular it should be taken into account that the variable by which consumption in the services sector is measured, the number of full-time employees, is one that is particularly sensitive to present economic circumstances.

That said, the top-down *P* indicators, calculated for households, show savings (389.1 ktoe) in the renovation of equipment given that these are calculated on the basis of household appliances and cookers, unitary variables that are directly related with energy consumption.

In order to calculate the savings made as the result of direct intervention, bottom-up indicators were employed. By means of the per unit saving obtained with each renovation, given the number of replacements reported under the so-called "Renove" plans, total energy savings were 81.4 ktoe.

Lastly, as a result of differences between the internal and external perimeters it was possible to assess at —199.1 ktoe certain unquantifiable indirect effects resulting from the measures. Basically an increase in the energy consumption of households, due in the main to increased possession and use of appliances and equipment.

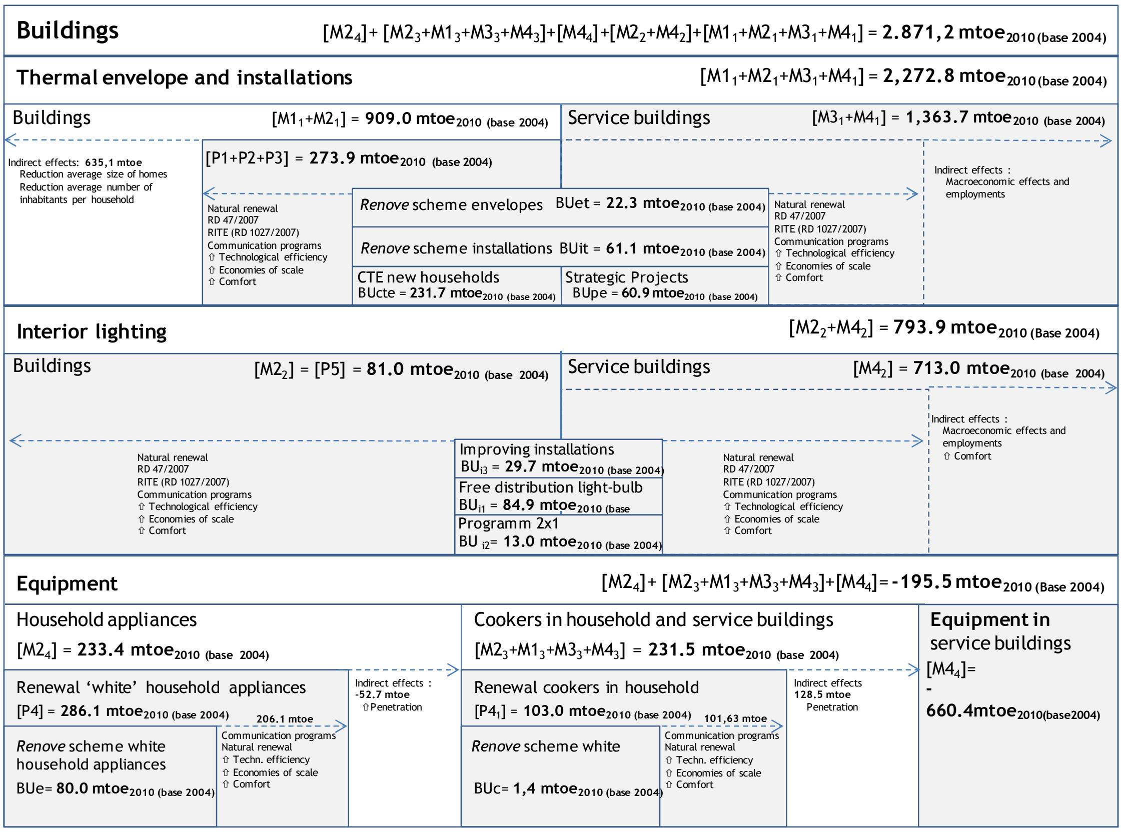
[10] The *P4 indicator calculates the unit savings of electric, gas and mixed cookers, as well as savings in the use of independent ovens.*

2. External perimeters

The buildings segment has achieved substantial energy savings thanks to the improvement — in both the residential and services sectors — in thermal protection and installations, and in lighting and equipment.

The breakdown of energy savings in buildings is given in Figure 26, which shows the results obtained in 2010 v. 2004, with savings differentiated by use and subsector.

Figure 26. *Breakdown of energy saving in the building sector in 2010 with respect to 2004*



Below we describe the methodologies used to calculate savings according to the energy usage of buildings categorised as: thermal envelope and installations, interior lighting and household appliances.

2.1. Thermal envelope and installations

Measures associated with the thermal envelope of buildings are designed to improve the roofs, frontages and windows of both residential and service buildings. As for thermal installations, measures are related to boilers, air-conditioning equipment and the supply of hot sanitary water.

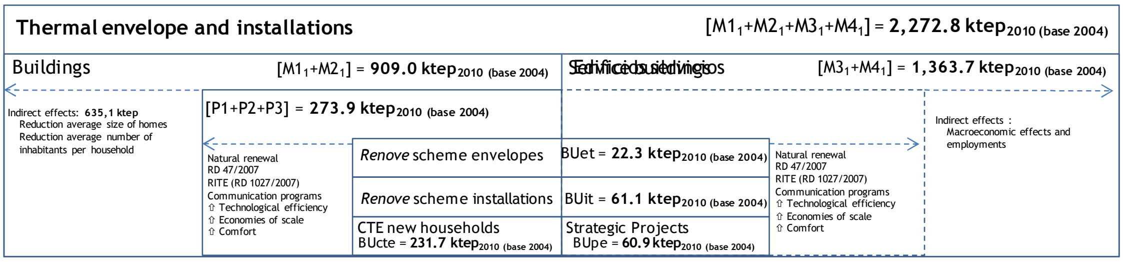
Method used

In the first place, differentiation was made between houses (single-family houses and housing blocks) and service-sector buildings (Figure 27). As there are no specific indicators proposed by the European Commission to calculate the savings in these subsectors, a number of top-down *M* indicators were adapted to cater for them.

We then calculated the savings resulting from the measure, “Energy rehabilitation of thermal envelope and improvements to the thermal installations of existing buildings”. For this purpose the European Commission proposes for the housing sector three top-down *P* indicators.

Lastly, using the bottom-up indicators BU_{et} y BU_{it} we calculated the savings obtained from the various measures promoted by the authorities by means of cooperation agreements between the IDAE and regional administrations, notably the “Thermal Envelope and Installation Renovation Plans” and the “Strategic Projects”. In the same way we calculated the energy savings resulting from implementation in 2006 of the “Technical Building Code” using the bottom-up indicator BU_{cte}.

Figure 27. *Breakdown of energy saving in thermal envelope and installations in 2010 with respect to 2004*



In order to estimate the savings resulting from the use of thermal envelope and installations it is necessary to establish the electric and thermal energy devoted to these two ends.

In addition it is necessary to find an appropriate variable with which to adjust these consumptions in order to gauge the energy improvement resulting from the difference in per unit consumption. In the housing sub-segment consumption is intimately related to the number of households, with the result that it was considered appropriate to analyse per unit consumption on the basis of this variable. In the sub-segment of service buildings, energy consumption can be associated with the number of full-time employees.

Consequently, in order to calculate the overall savings within the buildings segment we opted to use the *M* indicators proposed by the European Commission, which relate the thermal or electric consumption with the aforesaid activity variables pertaining to the domestic or service sub-segments, multiplied by the percentage consumption, electrical or thermal as applicable, of space heating, cooling and hot sanitary water. Thus, the indicators used are:

- In the domestic subsector, the indicator *M1* “thermal consumption per household” adjusted to distinguish consumption devoted to space heating from that producing hot sanitary water. The *M2* indicator, “Per household electricity consumption” was adjusted to differentiate the consumptions devoted to space heating, cooling and hot sanitary water.

$$M1_1 = \left(\frac{E^{\text{Hnon-el}}}{D} \right) \cdot FC$$

where:
- $E^{\text{Hnon-el}}$: Thermal consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic thermal consumption devoted to space heating and hot sanitary water

$$M2_1 = \left(\frac{E^{\text{Hel}}}{D}\right) \cdot FC$$

where:
- *E^{Hel} :* Electricity consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic electricity consumption devoted to cooling, space heating and hot sanitary water

- In the services sector the *M3* indicator, “Thermal consumption per full-time employee” was adjusted to distinguish consumption devoted to space heating from that of hot sanitary water. The *M4* indicator, “Electricity consumption per full-time employee”, was adjusted to measure consumption for space heating, cooling and hot sanitary water.

$$M3_1 = \left(\frac{E^{\text{Snon-el}}}{em}\right) \cdot FC$$

where:
- *$E^{Snon\text{-}el}$:* Thermal consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of thermal consumption in the services sector devoted to heading and hot sanitary water

$$M4_1 = \left(\frac{E^{\text{Sel}}}{em}\right) \cdot FC$$

where:
- *E^{Sel} :* Energy consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of electricity consumption in the services sector devoted to cooling, space heating and hot sanitary water

In the case of the indicators relating to space heating and cooling, a secondary correction was made to account for climate, by means of the quotient of the average degree-days of heating in the last 25 years and the degree-days of heating in the year of calculation of the savings.

The savings relating to the external perimeter within the sub-segment of thermal envelope result from multiplying the difference in the values of these indicators for the base year (2004 or 2007) in the year of calculation (2010) by the value of the activity variable with respect to the indicator. By way of example, for the indicator $M1_1$ the result would be:

$$\text{Energy savings } M1_1 = \left[\left(\frac{E_{2004}^{\text{Hnon-el}}}{D_{2004}}\right) \cdot FC_{2004} - \left(\frac{E_{2010}^{\text{Hnon-el}}}{D_{2010}}\right) \cdot FC_{2010}\right] \cdot D_{2010}$$

where:
- *$E^{Hnon\text{-}el}$* : Thermal consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic thermal consumption devoted to heading and hot sanitary water

By adding together the specific savings associated with each of these four adjusted indicators *(M1+M2+M3+M4)* we obtain the global savings resulting from the improvement in thermal envelope and installations of the buildings.

Key variables

This section gives all the variables having a direct bearing on calculating the savings produced in this subsector.

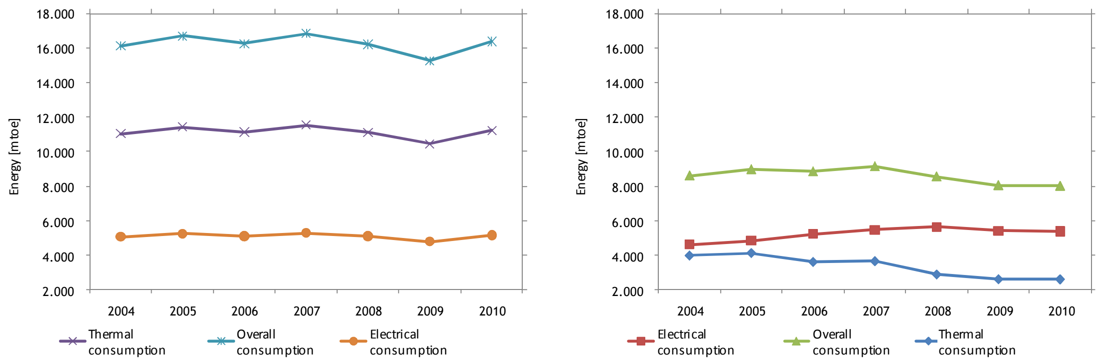
Table 49. ***Evolution of specific variables related to thermal envelope and installations in the period 2004-2010***

	2004	2007	2008	2009	2010
Thermal consumption in homes [ktoe]	11,045	11,534	11,103	10,448	11,223
Electric power consumption in homes [ktoe]	5,072	5,296	5,098	4,798	5,154
Thermal consumption in services [ktoe]	3,982	3,658	2,903	2,635	2,627
Electric power consumption in services [ktoe]	4,619	5,476	5,646	5,414	5,388
Occupied dwellings [thousands]	14,904	16,280	16,741	17,068	17,304
Full time employees [thousands]	11,518	13,471	13,786	13,439	13,408
Degrees-Days heating	2546	2378	2431	2242	2305
GD heating reference (25 years)	2126	2136	2144	2151	2139
Degrees-Days cooling	568	426	568	563	564
GD cooling reference (25 years)	560	560	560	560	560

Source: IDAE

Electricity consumption in both homes and service buildings underwent a notable increase between 2004 and 2010 (2% and 16% respectively) due in the main to the rise in appliances and equipment in homes and service companies. On the other hand, thermal consumption fell in the period, particularly in the services sector (−34%).

Figure 28. *Evolution of thermal, electric and total consumption in the domestic and services sector in the period 2004-2010*



In addition, the increase in the number of occupied homes declined, and there was a fall in the number of full-time service employees as from 2008, presumably as a result of the present economic climate.

Figure 29. *Evolution of occupied dwellings and full time employees in the period 2004-2010*

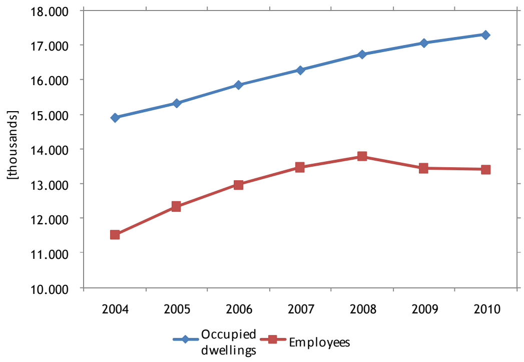
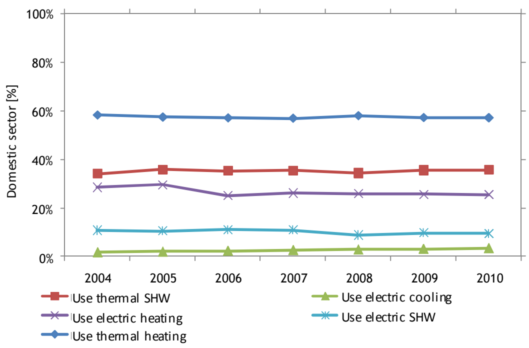


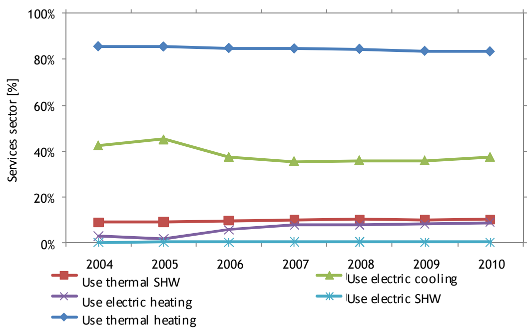
Table 50. *Distribution per thermal and electric uses of thermal envelope and installations in the period 2004-2010*

	2004	2007	2008	2009	2010
Domestic thermal use on space heating [%]	58,2	56,8	57,9	57,1	57,0
Domestic thermal use on water heating [%]	34,0	35,4	34,3	35,5	35,7
Domestic electric use on cooling [%]	1,7	2,6	2,8	3,1	3,3
Domestic electric use on space heating [%]	28,4	26,1	25,9	25,6	25,4
Domestic electric use on water heating [%]	10,8	11,0	8,8	9,8	9,4
Thermal use in services sector on space heating [%]	85,5	84,6	84,4	83,6	83,4
Thermal use in services sector on water heating [%]	9,1	10,0	10,3	10,1	10,3
Electric use in services sector on cooling [%]	42,5	35,5	35,9	35,9	37,4
Electric use in services sector on space heating [%]	3,0	7,8	7,8	8,3	8,8
Electric use in services sector on water heating [%]	0,2	0,5	0,5	0,4	0,4

Source: IDAE

Figure 30. *Evolution of percentage of thermal and electric consumption on space heating, water heating and cooling in the domestic and services sector in the period 2004-2010*





In terms of space heating, the housing sector has reduced its percentage use of both electric and thermal energy in recent years. However, in the case of the services sector this decline in usage only affected thermal energy, the percentage usage of electricity having risen by nearly 6%.

In the period studied the cooling of homes almost doubled in terms of use, thanks to increased market penetration. However, in the services sector, the percentage consumption of such systems fell by 5%, which could be a consequence of improved technology, the need to cut costs or the energy efficiency measures introduced.

Lastly, the percentage use of sanitary hot water generated thermally in homes rose (1.7%). Electrically generated domestic hot water increased by 1.4%. In the services sector electrically generated sanitary hot water also rose by 1.4%, while thermal hot water production increased by 1.2%.

Total energy savings made

The total energy savings obtained from the use of thermal envelope and installations cover direct and indirect savings.

To calculate the energy savings obtained in the period the indicators described above, applying the appropriate sector and economic variables, were used. The results are given in Table 51 and the indicator performance in Table 52 and Figure 31.

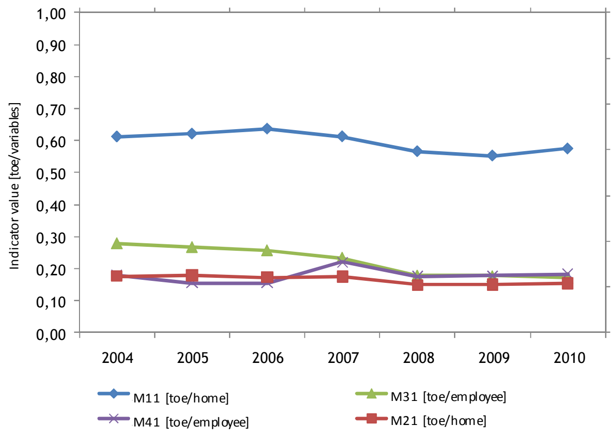
Table 51. *Energy savings in the thermal envelope and installations use in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Envelope and thermal installations	$M1_1+M2_1+M3_1+M4_1$	**2,699.2**	**2,272.8**
	Domestic sector	$M1_1+M2_1$	1,321.7	909.0
	Services sector	$M3_1+M4_1$	1,377.5	1,363.7
Base 2007 [ktoe]	Envelope and thermal installations	$M1_1+M2_1+M3_1+M4_1$	**2,660.1**	**2,233.7**
	Domestic sector	$M1_1+M2_1$	1,324.3	911.7
	Services sector	$M3_1+M4_1$	1,335.7	1,322.0

Table 52. *Evolution of "M" indicators related to envelope and thermal installations use in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
$M1_1$	Unitary thermal consumption indicator in the envelope and thermal installations per home [toe/home]	0.612	0.612	0.566	0.552	0.574
$M2_1$	Unitary electric consumption indicator in the envelope and thermal installations per home [toe/home]	0.123	0.123	0.105	0.105	0.108
$M3_1$	Unitary thermal consumption indicator in the envelope and thermal installations per employee [toe/employee]	0.278	0.234	0.179	0.177	0.172
$M4_1$	Unitary electric consumption indicator in the envelope and thermal installations per employee [toe/employee]	0.179	0.220	0.175	0.177	0.184

Figure 31. *Evolution of "M" indicators related to envelope and thermal installations use in the period 2004-2010*



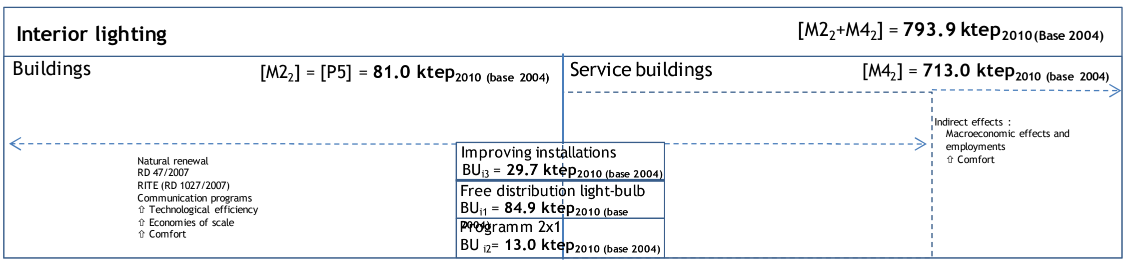
The savings in the period under study 2004—2010 were 2,272.8 ktoe, of which 40% were obtained in homes and 60% in the services sector. Improvements in heating systems are responsible for most of the savings obtained in this period, with a total of 1,443.8 ktoe in 2010 in comparison with 2004.

2.2. Interior lighting

The use of interior lighting in buildings can be divided into two segments: domestic interior lighting and interior lighting in the services sector.

Of the various indicators of the catalogue proposed by the European Commission to calculate energy savings, none makes express mention of lighting, other than indicator *P5,* used to calculate interior perimeters. Consequently, we were obliged to adapt some of the top-down *M* indicators to cater for this subsector. We adapted the *M2* indicator "household electricity consumption" and the *M4* indicator "electricity consumption per full-time employee" to obtain the percentage consumption of electric power on interior lighting in homes and in service sector buildings.

Figure 32. *Breakdown of energy saving in the interior lighting in 2010 with respect to 2004*



With respect to homes we used the *P5* indicator proposed by the European Commission. For services sector buildings, however, it was not possible to calculate the associated savings.

The savings result obtained by the *P5* indicator shows the general renovation that has occurred in homes, whether driven by the normal course of events or by specific measures promoted by the IDAE.

In the latter case we quantified the savings associated with the bottom-up indicators BU_{i1}, BU_{i2} and BU_{i3} taken from the annual reports drawn up by regional administrations and from other similar projects.

Method used

In order to obtain the savings achieved in these sub-segments it is necessary to establish the change in electricity consumption on interior lighting both in homes and in the services sector. As with thermal use, in order to adjust the savings we have assumed that households (in the case of domestic usage) and employees (in the case of service buildings) are the key variables, being the factors most closely related to consumption.

On this basis in order to calculate the overall savings within the interior lighting sub-segment, the indicators *M2* "Electricity consumption by household" and *M4* "Electricity consumption by full-time employee" were adjusted for the electricity consumption of interior lighting in households and in buildings housing service companies.

$$M2_2 = \left(\frac{E^{\text{Hel}}}{D}\right) \cdot FC$$

where:
- E^{Hel} : Electricity consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic electicity consumption devoted to interior lighting

$$M4_2 = \left(\frac{E^{\text{Sel}}}{em}\right) \cdot FC$$

where:
- E^{Sel} : Electricity consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of electricity consumption in the services sector devoted to interior lighting

The savings relating to the external perimeter are the result of multiplying the difference between the values of these indicators for the base years (2004 or 2007) and the calculation year (2010) by the activity value given by the indicator.

Thus, the result for indicator $M2_2$ would be:

$$\text{Energy savings } M2_2 = \left[\left(\frac{E^{\text{Hel}}_{2004}}{D_{2004}}\right) \cdot FC_{2004} - \left(\frac{E^{\text{Hel}}_{2010}}{D_{2010}}\right) \cdot FC_{2010}\right] \cdot D_{2010}$$

where:
- E^{Hel} : Electricity consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic electricity consumption devoted to interior lighting

Key variables

In this section we give all the variables having a direct bearing on calculating the savings made in interior lighting.

Table 53. *Evolution of specific variables related to interior lighting use in the period 2004-2010*

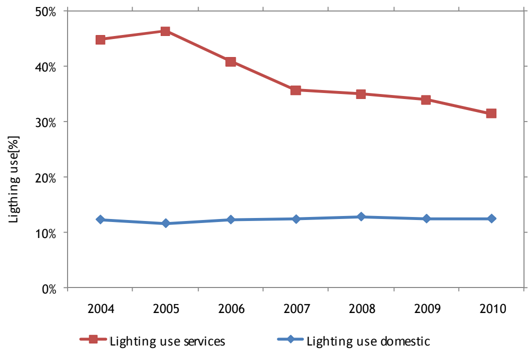
	2004	2007	2008	2009	2010
Electric power consumption in homes[ktoe]	5,072	5,296	5,098	4,798	5,154
Electric power consumption in services [ktoe]	4,619	5,476	5,646	5,414	5,388

	2004	2007	2008	2009	2010
Occupied dwellings [thousands]	14,904	16,280	16,741	17,068	17,304
Full time employees [thousands]	11,518	13,471	13,786	13,439	13,408
Domestic electric use on lighting [%]	12.3%	12.3%	12.8%	12.4%	12.4%
Electric power use in services on lighting [%]	44.7%	35.6%	34.9%	33.9%	31.4%

Source: INE, IDAE

In Table 53 and Figure 33 it will be noted how the percentage usage of interior lighting in homes remains flat, whereas that of the services sector falls markedly (—13,3%), contributing indirectly but significantly to the energy savings achieved in interior lighting.

Figure 33. *Evolution of percentage of interior lighting use in domestic and services sector in the period 2004-2010*



Total savings made

To calculate the energy savings achieved in the period we applied the indicators stated above together with the variables of the sector and the requisite economic variables to calculate the indicators. The results are shown in Table 54, with the results of the indicators in Table 55.

Table 54. *Energy saving in the interior lighting use in 2009 and 2010 with respect to 2004 and 2007*

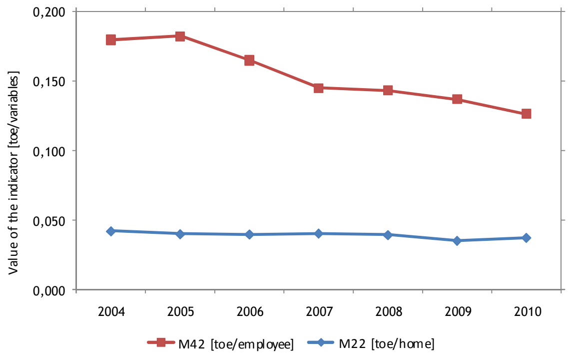
		Indicator associated	2009	2010
Base 2004 [ktoe]	Interior lighting Subsector	$M2_2 + M4_2$	**691.8**	**793.9**
	Domestic sector	$M2_2$	116.4	81.0
	Services sector	$M4_2$	575.4	713.0
Base 2007 [ktoe]	Interior lighting Subsector	$M2_2 + M4_2$	**198.4**	**301.2**
	Domestic sector	$M2_2$	89.1	53.3
	Services sector	$M4_2$	109.2	247.9

If we bear in mind the downward adjusted *M* indicators proposed by the European Commission, in the period analysed energy savings of 793.9 ktoe were achieved in interior lighting (28% of total savings in the buildings segment). The majority of these savings (90%) were obtained in the services sector.

Table 55. *Evolution of "M" indicators related to interior lighting use in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
$M2_2$	Unitary electric power consumption on lighting per home [toe/home]	0.0417	0.0401	0.0390	0.0349	0.0370
$M4_2$	Unitary electric power consumption on lighting per employee [toe/employee]	0.1794	0.1447	0.1430	0.1366	0.1263

Figure 34. *Evolution of "M" indicators related to interior lighting use in the period 2004-2010*

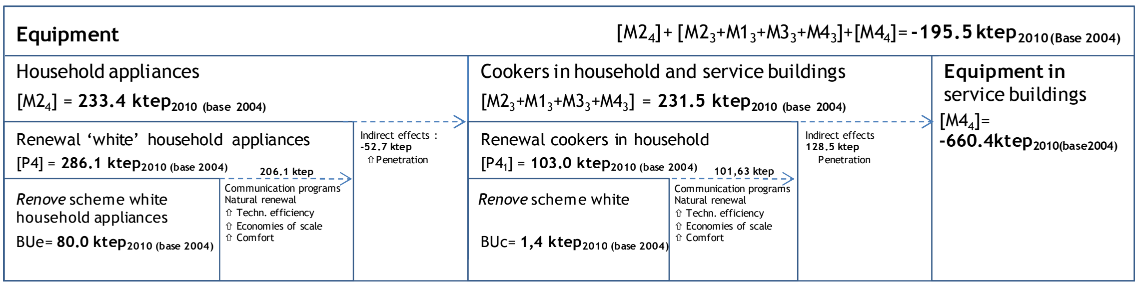


2.3. Electrical equipment and appliances

The equipment subsector was structured in three main divisions bearing in mind the type of electrical appliance studied and the domestic or services environment to which it pertains: household appliances in households, cookers in households and on premises used to house service activities, and equipment and appliances in services buildings. (Figure 35).

The perimeters related to the aforesaid environments were established by means of the *M* indicators proposed by the European Commission. Below we analyse the special factors applying to each indicator with respect to the calculation variables employed.

Figure 35. *Breakdown of energy saving in the equipment use in 2010 with respect to 2004*



This analysis enabled us to quantify the measures having a bearing on the renovation of so-called 'white' household appliances and cookers. For the former we used the *P4* indicator proposed by the European Commission, whereas for cookers we were obliged to establish a new indicator, $P4_1$, as shown in Figure 35.

The savings result given by both indicators reveals both the conventional turnover of household appliances plus ovens and cookers and the additional rate of renewal fostered by the incentives promoted by the IDAE. In the latter case, we were able to quantify them by means of the bottom-up indicators (BUe and BUc) from information available in the statistics for the so-called “Renove” schemes.

Method used

Household appliances

The variation in the consumption of household appliances and other items of equipment per occupied household in Spain between the base years (2004 and 2007) and the calculation year (2010) tells us what the per unit improvement in energy consumption per household amounted to. Thus, in order to calculate the total savings achieved in this subsector we used the indicator proposed by the Commission, *M2*, “Electricity consumption per household”, adjusted for the percentage of domestic consumption of electricity by both household appliances and other items of equipment.

$$M2_4 = \left(\frac{E^{\text{Hel}}}{D} \right) \cdot FC$$

where:
- E^{Hel}: Electricity consumption in households
- *D* : Number of houses occupied
- *FC* : % of domestic electricity consumption devoted to appliances and other equipment

Cookers in households and in service buildings

The change in the electricity consumption of cookers with regard to the number of households or the number of full-time service-sector employees allows us to estimate the improvement in unitary terms of the intensity of energy usage both per household and per full-time service employee.

It should be pointed out that whereas the variable “occupied family dwellings” shows a relatively stable performance over time that of full-time service employees can oscillate significantly in periods of economic recession, with the result that such variables should be examined first when assessing results in the services sector.

In order to calculate total energy savings in cookers we used a more complex combination of *M* indicators than was the case in household appliances, given that cookers may use either electricity or thermal energy, whether in homes or in service buildings.

The selected indicators were adjusted according to the percentage of electricity and thermal consumption for cookers and ovens:

- In the domestic setting the *M1* indicator “thermal consumption per home” and the *M2* indicator “electricity consumption per home” adjusted for cooker usage.

$$M1_3 = \left(\frac{E^{\text{Hnon-el}}}{D} \right) \cdot FC$$

where:
- $E^{\text{Hnon-el}}$: Thermal consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic thermal consumption devoted to cookers and ovens

$$M2_3 = \left(\frac{E^{\text{Hel}}}{D} \right) \cdot FC$$

where:
- E^{Hel} *:* Electricity consumption in households
- *D :* Number of houses occupied
- *FC :* % of domestic electricity consumption devoted to cookers and ovens

- In the services setting: the *M3* indicator, “Thermal consumption per full-time employee” and the *M4* indicator “Electrical consumption per full-time employee”, adjusted for cooker usage.

$$M3_3 = \left(\frac{E^{\text{Snon-el}}}{em} \right) \cdot FC$$

where:
- *E* $^{\text{Snon-el}}$ *:* Thermal consumption of the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of the thermal consumption of the services sector devoted to cookers and ovens

$$M4_3 = \left(\frac{E^{\text{Sel}}}{em} \right) \cdot FC$$

where:
- *E* $^{\text{Sel}}$ *:* Electricity consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of the electricity consumption of the services sector devoted to cookers and ovens.

Equipment in the services sector

Lastly, the variation in energy consumption dedicated to office machinery and other equipment employed by full-time service-sector employees allows us to calculate the per unit savings in energy intensity per service-sector employee. Notice again how the number of full-time employees is affected by periods of economic recession.

With respect to calculating the energy savings, we used the *M4* indicator proposed by the Commission, *“Electricity consumption per full-time employee”,* adjusted for the percentage consumption of such equipment in the services sector.

$$M4_4 = \left(\frac{E^{\text{Sel}}}{em} \right) \cdot FC$$

where:
- *E* $^{\text{Sel}}$ *:* Electricity consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC :* % of electricity consumption in the services sector devoted to appliances and office equipment

The savings with respect to the external perimeter are arrived at by multiplying the difference in the values of these indicators between the base year (2004 or 2007) and the year of calculation (2010) and the value of the activity variable with respect to the indicator.

By way of example, for the $M4_4$ indicator:

$$\text{Energy savings } M4_4 = \left[\left(\frac{E_{2004}^{\text{Sel}}}{em_{2004}} \right) \cdot FC_{2004} - \left(\frac{E_{2010}^{\text{Sel}}}{em_{2010}} \right) \cdot FC_{2010} \right] \cdot em_{2010}$$

where:
- *E* $^{\text{Sel}}$ *:* Electricity consumption in the services sector
- *em :* Number of full-time employees in the services sector
- *FC* : % electricity consumption in the services sector devoted to appliances and office equipment

Key variables

In this section we give all the variables having a direct bearing on calculating the savings generated in this subsector.

Table 56. *Evolution of specific variables related to "M" indicator in the equipment use in the period 2004-2010*

	2004	2007	2008	2009	2010
Thermal consumption in homes [ktoe]	11,045	11,534	11,103	10,448	11,223
Electric power consumption in homes [ktoe]	5,072	5,296	5,098	4,798	5,154
Thermal consumption in services [ktoe]	3,982	3,658	2,903	2,635	2,627
Electric power consumption in services [ktoe]	4,619	5,476	5,646	5,414	5,388
Occupied dwellings [thousands]	14,904	16,280	16,741	17,068	17,304
Full time employees [thousands]	11,518	13,471	13,786	13,439	13,408

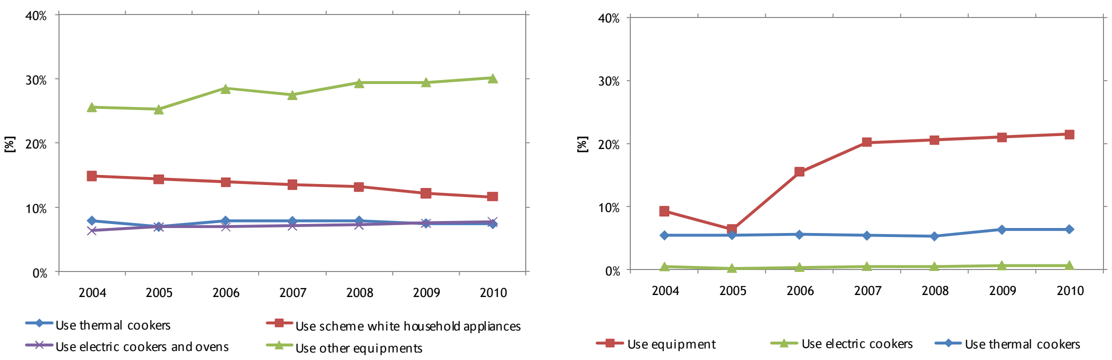
Source: IDAE

Table 57. *Distribution per uses in equipment use in the period 2004-2010*

	2004	2007	2008	2009	2010
Domestic electric power use of appliances and others [%]	40.5%	41.0%	42.6%	41.7%	41.8%
Domestic thermal use of cookers and ovens [%]	7.8%	7.8%	7.8%	7.4%	7.3%
Domestic electric power use of cookers and ovens [%]	6.3%	7.0%	7.2%	7.5%	7.7%
Thermal use of cookers and ovens in services sector [%]	5.4%	5.3%	5.2%	6.3%	6.4%
Electric power use of cookers and ovens in services sector [%]	0.4%	0.5%	0.5%	0.6%	0.6%
Electric power use of equipment in services sector [%]	9.2%	20.2%	20.5%	21.0%	21.4%

Source: IDAE

Figure 36. *Evolution of consumption of cookers, equipment and appliances in domestic and services sector in the period 2004-2010*



In Figure 36 we see how the services sector has made a notable increase in its equipment in the period studied, moving from 9.2% of consumption in 2004 to 21.4% of consumption in 2010.

This phenomenon can also be observed in the household setting, where there has been an increase in non-kitchen electrical equipment (televisions, DVDs players, tape decks, computers, etc.).

At the same time kitchen equipment (refrigerators, washing machines, dishwashers, driers, etc. has seen a fall in percentage use, while the level of market penetration has only risen in certain areas, thus resulting in energy savings.

Total savings made

In order to calculate the energy saving achieved in the period we applied the above indicators using the key variables of the sector and the economic data required by the indicators.

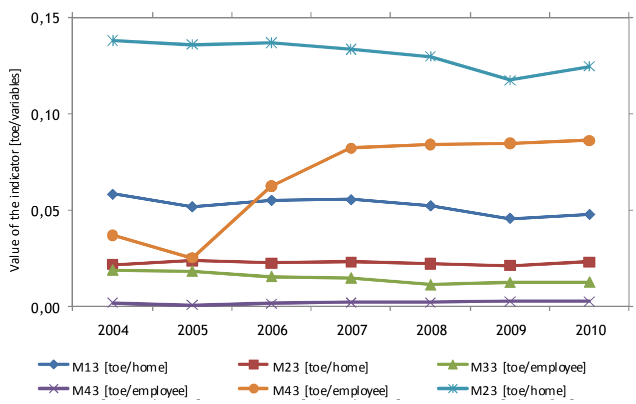
Table 58. *Energy saving in the equipment use in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Equipment Subsector	$M2_4+M2_3+M1_3+M3_3+M4_3+M4_4$	**11.4**	**-195.5**
	Appliances in homes	$M2_4$	353.4	233.4
	Cookers in homes and services sector	$M2_3+M1_3+M3_3+M4_3$	298.1	231.5
	Equipment in services sector	$M4_4$	-640.1	-660.4
Base 2007 [ktoe]	Equipment Subsector	$M2_4+M2_3+M1_3+M3_3+M4_3+M4_4$	**463.5**	**254.0**
	Appliances in homes	$M2_4$	277.5	156.5
	Cookers in homes and services sector	$M2_3+M1_3+M3_3+M4_3$	219.2	152.3
	Equipment in services sector	$M4_4$	-33.1	-54.8

Table 59. *Evolution of "M" indicator related to equipment use in the period 2004-2010*

	Descripción	2004	2007	2008	2009	2010
$M1_3$	Unitary thermal consumption indicator of cookers and ovens per home [toe/home]	0.0581	0.0552	0.0520	0.0455	0.0475
$M2_3$	Unitary electric power consumption indicator of cookers and ovens per home [toe/house]	0.0215	0.0229	0.0219	0.0210	0.0229
$M3_3$	Unitary thermal consumption indicator of cookers and ovens per employee [toe/employee]	0.0186	0.0145	0.0110	0.0123	0.0125
$M4_3$	Unitary electric power consumption indicator of cookers and ovens per employee [toe/employee]	0.0017	0.0019	0.0019	0.0025	0.0025
$M2_4$	Unitary electric power consumption indicator of appliances per home [toe/home]	0.1379	0.1334	0.1296	0.1172	0.1244
$M4_4$	Unitary electric power consumption indicator of equipment and office automation per employee [toe/employee]	0.0368	0.0820	0.0839	0.0844	0.0860

Figure 37. *Evolution of "M" indicator related to equipment use in the period 2004-2010*



In the period examined there were no savings achieved in the use of equipment, due in the main to the extended use of equipment in both households and the services sector in recent years. Although both the authorities and private enterprise have succeeded in improving the efficiency of these items of equipment, their efforts have been outweighed by the increase in absolute value, when measured by top-down indicators of the *M* type.

With respect to households, although moderate savings have been achieved in the case of kitchen equipment, they were greatly outweighed by the much wider degree of usage of non-kitchen equipment items.

As far as purchasing trends of end users of electrical equipment are concerned, it was found that buyers of kitchen appliances pay attention to energy efficiency mainly as a consequence of administrations moves to foster energy consumption labelling.

3. Energy rehabilitation of thermal envelope and energy efficiency improvements in thermal installations of residential buildings

This is the aim of rehabilitating the thermal envelope of buildings and reducing the energy consumed in space heating and cooling in existing buildings by means of rehabilitating totally or partially the building's thermal envelope.

The new Rules on Thermal Envelope of Buildings (RITE in Spanish) introduce the obligation to conduct periodic inspections of the energy efficiency of these installations, making a reduction in the consumption of final energy the priority purpose of improvements in the space heating and cooling of existing buildings and in their capacity to produce hot sanitary water.

Method used

The three uses affected by these two measures are space heating, cooling and hot sanitary water production. In order to calculate the savings made, it is necessary to look at the way per unit consumption has changed in the period under study.

For the purpose of regulating this per unit consumption, it is necessary to have an activity variable capable of acting as a key monitor of forward progress. For space heating and cooling, it is understood that consumption is intimately related to the surface area of houses, whereas in the case of hot sanitary water, the key factor is the number of persons living there.

According to the variables required for calculating savings, for this measure it was decided to use the three top-down *P* indicators proposed by the European Commission for the housing segment: the *P1* "Domestic energy consumption per m^2"; the *P2* "Domestic energy consumption on cooling per m^2"; and the *P3* "Domestic energy consumption per inmate on the production of hot sanitary water."

By adding the results of these three indicators (*P1*, *P2* and *P3*) we obtain the savings generated by existing households with respect to the energy rehabilitation of their thermal envelope and the energy efficiency improvements to their thermal installations.

Heating

The *P1* indicator proposed refers to the per unit energy consumption per m^2 on space heating. The expression that allows us to calculate this indicator is:

$$P1 = \left(\frac{E^{\mathrm{Hel}} \cdot FC_1 + E^{\mathrm{Hnon-el}} \cdot FC_2}{F} \right) \cdot \left(\frac{MDD_{25}^{\mathrm{Heating}}}{ADD^{\mathrm{Heating}}} \right)$$

where:

- E^{Hel} : Electricity consumption in households
- FC_1 : % of E^{Hel} devoted to space heating
- $E^{\mathrm{Hnon\text{-}el}}$: Thermal consumption in households
- FC_2 : % del $E^{\mathrm{Hnon\text{-}el}}$ devoted to space heating
- F : m^2 of surface area in occupied dwellings
- ADD^{Heating} : Degree-days of heating
- $MDD_{25}^{\mathrm{Heating}}$: Average of ADD^{Heating} in the last 25 years

The energy consumption for space heating purposes in households is obtained by multiplying total consumption by the percentage consumption devoted to space heating, whether electrical or thermal.

This indicator is then corrected by the climatic factor, by multiplying it by the quotient between the average degree-days of heating in the last 25 years and the degree-days of heating in the year for which the savings are calculated.

Cooling

Indicator *P2* refers to per unit domestic energy consumption by m^2 on cooling.

$$P2 = \left(\frac{E^{\mathrm{Hel}} \cdot FC}{F} \right) \cdot \left(\frac{MDD_{25}^{\mathrm{Cooling}}}{ADD^{\mathrm{Cooling}}} \right)$$

where:

- E^{Hel} : Electricity consumption in households
- FC : % del E^{Hel} devoted to cooling
- F : m^2 of surface area in occupied dwellings
- ADD^{Cooling} : Degree-days of cooling
- $MDD_{25}^{\mathrm{Cooling}}$: Average of ADD^{Cooling} in the last 25 years

The expression used to calculate this indicator is very similar to that used in the case of the previous *P1* indicator. This difference lies in that cooling systems in houses rely entirely on electrical energy with the result that domestic electricity consumption is adjusted solely for the percentage of consumption devoted to cooling.

With respect to the indicator adjustment for climate factor, this is done using cooling degree-days as opposed to heating degree-days.

Sanitary hot water

Indicator *P3* relates to the per unit domestic energy consumption per inhabitant on sanitary hot water, according to the expression:

$$P3 = \left(\frac{E^{\mathrm{Hel}} \cdot FC_1 + E^{\mathrm{Hnon-el}} \cdot FC_2}{P} \right)$$

where:

- E^{Hel} : Electricity consumption in households
- FC_1 : % of the E^{Hel} devoted to sanitary hot water
- $E^{\mathrm{Hnon\text{-}el}}$: Thermal consumption in households
- FC_2 : % of the $E^{\mathrm{Hnon\text{-}el}}$ devoted to sanitary hot water
- P : Population

In this case energy consumption is adjusted by the percentage consumption of sanitary hot water, the variable being the number of inhabitants.

Key variables

This section gives all the variables having a direct bearing on calculating the savings generated by this measure.

Table 60. *Evolution of specific variables related to measure rehabilitation of thermal envelope and energy efficiency improvements in thermal installations in the period 2004-2010*

	2004	2007	2008	2009	2010
Thermal consumption in homes [ktoe]	11,045	11,534	11,103	10,448	11,223
Electric power consumption in homes [ktoe]	5,072	5,296	5,098	4,798	5,154
Homes surface [km^2]	1,350,669.9	1,433,563.1	1,459,322.7	1,477,011.8	1,502,495.9
Population [thousands people]	43,197.7	45,200.7	46,157.8	46,745.8	47,021.0
Degrees-Days heating	2,546	2,378	2,431	2,242	2,305
GD heating reference (25 years)	2,126	2,136	2,144	2,151	2,139
Degrees-Days cooling	568	426	568	563	564
GD cooling reference (25 years)	560	560	560	560	560

Source: OCC, IDAE

Figure 38. *Evolution of average homes surface and population (left) and space heating and cooling degrees-days (right) in the period 2004-2010*

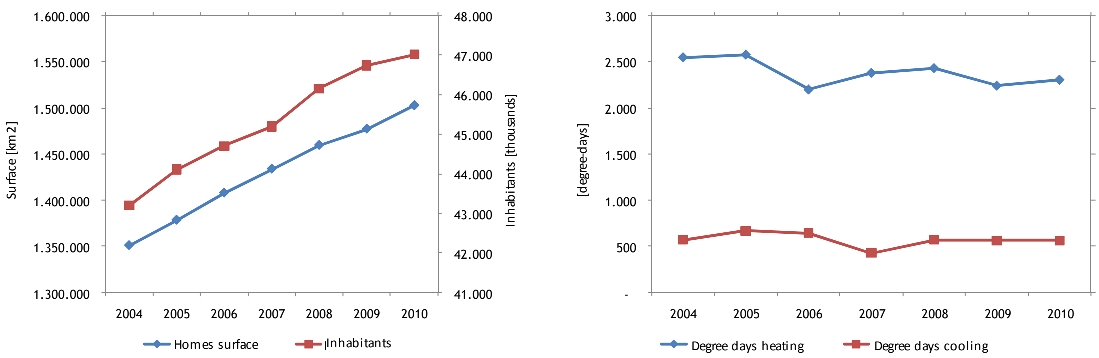


Table 61. *Distribution per domestic uses related to measure rehabilitation of thermal envelope and energy efficiency improvements in thermal installations in the period 2004-2010*

	2004	2007	2008	2009	2010
Domestic thermal use on space heating [%]	58.2	56.8	57.9	57.1	57.0
Domestic thermal use on water heating [%]	34.0	35.4	34.3	35.5	35.7
Domestic electric power use on cooling [%]	1.7	2.6	2.8	3.1	3.3
Domestic electric power use on space heating [%]	28.4	26.1	25.9	25.6	25.4
Domestic electric power use on water heating [%]	10.8	11.0	8.8	9.8	9.4

Source: IDAE

3.1. Public support programmes for the thermal envelope rehabilitation

Public support programs for the thermal envelope rehabilitation was developed as part of the agreements signed by the IDAE and regional administrations.

Method used

To calculate the effect of these programmes we used the annual information drawn up by the regional administrations on the savings achieved from public subsidies to renew facades, roofs and windows.

It was assumed, as proposed by the European Commission, that the useful life of this kind of measures is 30 years for walls and windows and 25 years for floors and roofs. This exceeds the period of analysis with the result that the savings obtained in 2010 are taken from the result of the sum of savings reported each year from 2004 or 2007 depending on the base year of calculation chosen.

Thus, the energy saving measurement is provided by the following bottom-up indicator:

$$BU_{et} = \sum_{t=2004-2007}^{2010} Ah_{et}$$

where:

- Ah_{et} : Annual savings reported by regional administrations with respect to the public support programmes for the thermal envelope rehabilitation

3.2. Public support programmes for the thermal installations rehabilitation

Public support programs for the thermal installations rehabilitation is a mechanism that forms part of the broader scheme, "Improvements in the energy efficiency of thermal installations of existing buildings", and is being articulated through the cooperation agreements reached between the IDAE and the regional administrations.

Method used

To calculate the effect produced by these programmes we used the information issued by the regional administrations on the savings achieved through public subsidies for renovating space heating, cooling and sanitary hot water systems.

The useful life of this kind of measures — 15 years for cooling and 30 years for space heating — exceeds the analysis period, with the result that the savings achieved in 2010 will be the sum of the savings reported from 2004 or 2007 depending on the base year of calculation chosen. The indicator is calculated using the following expression:

$$BU_{it} = \sum_{t=2004-2007}^{2010} Ah_{it}$$

where:

- Ah_{it} : Annual savings reported by regional administrations with respect to the public support programmes for the thermal installations rehabilitation

3.3. Technical Building Code

The rules comprising the "Technical Building Code" (Decree Law 314/2006), hereinafter the TBC, relate exclusively to buildings begun after the code came into force. For this reason it is only applicable to buildings begun in 2007 or later, classifying them from the letter "A" for the most efficient and the letter "E" for those that barely meet regulatory requirements.

Method used

The savings resulting in the period are calculated by multiplying for each energy-saving rating (A, B, C and D) the square metres of newly built homes by the difference between their consumption (on space heating and cooling) and the consumption expected of an E-rated home. Thus the savings can be calculated using the following indicator:

$$BU_{CTE} = \sum_{X=A}^{D} F_{t}^{Newlys} \cdot \left(C^{E} - C^{X}\right)_{t}$$

where:

- F^{Newly} : surface square metres of newly built homes having space heating or cooling systems
- C^{E} : Heating or cooling consumption of a Class E home per plant surface unit
- C^{X} : Heating or cooling consumption of homes of classes A, B, C or D per plant surface unit

Key variables

In this section we give all the variables having a direct bearing on calculating the savings produced by this mechanism.

Table 62. *Evolution of specific variables related to "Technical Building Code" in the period 2004-2010*

	2006	2007	2008	2009	2010
New occupied dwelling [thousands]	N/A	424,844	460,941	326,817	235,392
Average houses in block of flats [m^2]	N/A	98.3	96.8	95.6	94.3
Average single family houses surface [m^2]	N/A	167.6	172.7	175.6	179.1
New houses in block of flats [%]	N/A	0.84	0.80	0.77	0.75
New single family houses [%]	N/A	0.16	0.20	0.23	0.25
Ratio occupied dwelling / houses [%]	N/A	0.61	0.68	0.76	N/A
Houses with space heating equipment [%]	N/A	0.70	0.70	0.70	0.70
Houses with cooling equipment [%]	N/A	0.36	0.36	0.36	0.36

Source: INE, IDAE

Figure 39. *Distribution per energetic rating of new dwellings in 2010*

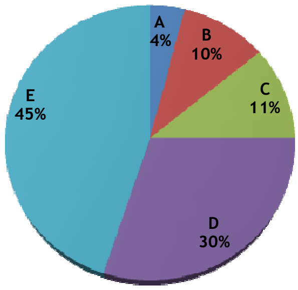


Table 63. *Single family houses built per rating*

	2007	2008	2009	2010
Single family houses rating A [unit]	2,639	3,693	2,968	2,314
Single family houses rating B [unit]	6,599	9,232	7,419	5,784
Single family houses rating C [unit]	7,259	10,155	8,161	6,362
Single family houses rating D [unit]	19,796	27,695	22,257	17,351
Single family houses rating E [unit]	29,694	41,542	33,386	26,027

Source: IDAE

Table 64. *Houses in block of flats built per rating*

	2007	2008	2009	2010
Houses in block of flats rating A [unit]	14,354	14,745	10,105	7,102
Houses in block of flats rating B [unit]	35,886	36,863	25,263	17,755
Houses in block of flats rating C [unit]	39,474	40,549	27,789	19,531
Houses in block of flats rating D [unit]	107,657	110,588	75,788	53,266
Houses in block of flats rating E [unit]	161,486	165,881	113,682	79,899

Source: IDAE

Table 65. *Energy saving on space heating in new single family houses per rating*

	2007	2008	2009	2010
Saving in Single family houses rating A [kWh]	21,592,355	31,221,851	26,209,552	20,842,178
Saving in Single family houses rating B [kWh]	48,474,676	70,095,729	58,838,597	46,789,220
Saving in Single family houses rating C [kWh]	43,914,847	63,508,026	53,302,664	42,386,974
Saving in Single family houses rating D [kWh]	78,061,748	112,928,401	94,737,846	75,336,772
Saving in Single family houses rating E [kWh]	0	0	0	0

Source: IDAE

Table 66. *Energy saving on space heating in new houses in block of flats per rating*

	2007	2008	2009	2010
Saving in Houses in block of flats rating A [kWh]	57,342,175	58,213,158	40,594,981	28,158,251
Saving in Houses in block of flats rating B [kWh]	130,099,372	132,054,821	92,042,261	63,844,077
Saving in Houses in block of flats rating C [kWh]	120,444,218	122,226,311	85,127,972	59,048,058
Saving in Houses in block of flats rating D [kWh]	226,959,607	230,167,429	159,966,901	110,959,237
Saving in Houses in block of flats rating E [kWh]	0	0	0	0

Source: IDAE

Table 67. *Energy saving on cooling in new single family houses per rating*

	2007	2008	2009	2010
Saving in Single family houses rating A [kWh]	1,019,242	1,449,103	1,159,893	922,362
Saving in Single family houses rating B [kWh]	2,189,835	3,113,523	2,491,966	1,981,644
Saving in Single family houses rating C [kWh]	1,889,637	2,686,518	2,150,493	1,710,100
Saving in Single family houses rating D [kWh]	2,452,796	3,486,400	2,792,260	2,220,442
Saving in Single family houses rating E [kWh]	0	0	0	0

Source: IDAE

Table 68. *Energy saving on cooling in new houses in block of flats per rating*

	2007	2008	2009	2010
Saving in Houses in block of flats rating A [kWh]	2,426,864	2,419,131	1,604,806	1,113,155
Saving in Houses in block of flats rating B [kWh]	5,242,410	5,225,762	3,466,596	2,404,565
Saving in Houses in block of flats rating C [kWh]	4,481,259	4,466,575	2,963,463	2,055,573
Saving in Houses in block of flats rating D [kWh]	5,610,087	5,589,811	3,710,679	2,573,870
Saving in Houses in block of flats rating E [kWh]	0	0	0	0

Source: IDAE

Table 69. *Efficiency according to energy rating*

	Rating E	Rating D	Rating C	Rating B	Rating A
Traditional boiler seasonal efficiency	0.70	0.70	0.70	0.70	0.70
Efficient boiler seasonal efficiency	0.70	0.75	0.80	0.85	0.90
Traditional AACC seasonal efficiency	1.80	1.80	1.80	1.80	1.80
Efficient AACC seasonal efficiency	1.80	2.00	2.30	2.50	3.00

Source: IDAE

3.4. IDAE support program for Strategic Projects

IDAE support for "Strategic Projects" is an initiative of the IDAE comprising improvement schemes covering all the energy uses of buildings, usually aimed at the thermal envelope where energy savings are centred on this use.

A basic requirement of this type of initiative is to present the IDAE with a full report explaining the activities undertaken and the savings achieved, thereby permitting an assessment of the savings.

Method used

To calculate the energy savings achieved through the mechanism of IDAE support for "Strategic Projects", we used the annual reports drawn up by the companies benefiting from these grants on the savings achieved, estimated according to the formula:

$$BU_{et} = \sum_{t=2004-2007}^{2010} Ah_{pe}$$

where:

- Ah_{pe}: Annual savings from IDAE support program for "Strategic Project"

3.5. Summary of direct savings obtained from thermal envelope and installations

Direct savings are those resulting from implementation of specific measures by the building industry, together with the measures introduced by the administrations to improve the efficiency of thermal envelope and installations.

On the basis of available information it was only possible to calculate the savings achieved as a result of this measure in the domestic sphere.

Table 70. *Energy saving in the measure "Energy rehabilitation of thermal envelope and energy efficiency improvements in thermal installations" in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Thermal envelope rehabilitation and EE	*P1+P2+P3*	**706.7**	**273.9**
	Domestic consumption on space heating	*P1*	275.1	153.7
	Domestic consumption on cooling	*P2*	-53.8	-76.6
	Domestic consumption on water heating	*P3*	485.5	196.9
Base 2007 [ktoe]	Thermal envelope rehabilitation and EE	*P1+P2+P3*	**1,126.0**	**698.6**
	Domestic consumption on space heating	*P1*	434.9	316.3
	Domestic consumption on cooling	*P2*	38.1	16.9
	Domestic consumption on water heating	*P3*	653.1	365.4

The top-down *P* indicators of Table 70 show savings in the domestic sphere in the period 2004—2010 of 273.9 ktoe in the period 2004—2010 (which accounted for 11% of the total savings in the domestic sphere) and 698.6 ktoe in the period 2007—2010 relating to energy recovery through the upgrading of existing homes.

Table 71. *Evolution of "P" indicators related to "Energy rehabilitation of thermal envelope and energy efficiency improvements in thermal installations" in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
P1	Unitary domestic consumption on space heating per m^2 [toe/m^2]	0.00486	0.00497	0.00468	0.00467	0.00476
P2	Unitary domestic consumption on cooling per m^2 [toe/m^2]	0.00006	0.00012	0.00010	0.00010	0.00011
P3	Unitary domestic consumption on water heating per inhabitant [toe/inhabitant]	0.09965	0.10324	0.09211	0.08927	0.09547

Figure 40. *Evolution of "P" indicators related to "Energy rehabilitation of thermal envelope and energy efficiency improvements in thermal installations" in the period 2004-2010*

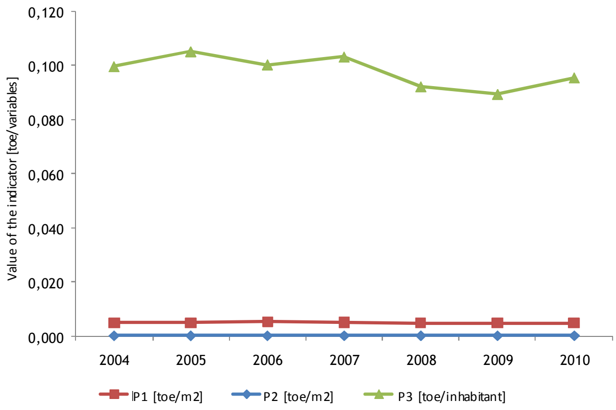


Table 72 shows the savings achieved by each of the thermal envelope and installations efficiency measures introduced in the subsector in the period examined.

Table 72. *Energy saving achieved by mechanisms in the thermal envelope and installations use in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	IDAE support programmes for thermal envelope rehabilitation	BU_{et}	15.0	22.3
	IDAE support programmes for thermal installation rehabilitation	BU_{it}	44.8	61.1
	Technical Building Code	BU_{cte}	191.97	**231.73**
	IDAE support programmes for strategic projects	BU_{pe}	53.2	63.5
Base 2007 [ktoe]	IDAE support programmes for thermal envelope rehabilitation	BU_{et}	10.3	17.6
	IDAE support programmes for thermal installation rehabilitation	BU_{it}	33.7	50.0
	Technical Building Code	BU_{cte}	127.28	**167.04**
	IDAE support programmes for strategic projects	BU_{pe}	53.2	63.5

Table 73. *Subvention to the mechanisms related to envelope and thermal installations use in the period 2006-2010*

	2006	2007	2008	2009	2010
IDAE support programmes for thermal envelope rehabilitation [k€]	15,329.9	8,244.9	23,967.8	27,380.6	36,576.7
IDAE support programmes for thermal installation rehabilitation [k€]	13,522.9	12,868.8	41,511.9	38,820.0	38,802.8
IDAE support programmes for strategic projects [k€]	N/A	N/A	25,158.3	32,552.7	38,834.5

Source: IDAE

As seen in Table 72, the most important savings arose from schemes centred on the Technical Building Code, 61% of the total savings obtained across all schemes, as they affected all housing built from 2007 onwards.

Improved energy efficiency in the interior lighting installations of existing buildings
The purpose of this measure is to reduce the energy consumption of interior lighting installations of buildings, both homes and service-sector buildings, thereby improving energy efficiency.

To this end the scheme is directed at existing interior lighting installations that meet, as a minimum, the specifications of the Technical Building Code, permitting their renovation to reduce energy consumption.

Method used

As well as the other measures aimed at measuring the savings obtained in interior lighting in the residential sector, the first requirement is to ascertain the per unit energy consumption with respect to a suitable activity variable, in this case the increase in the number of homes.

Thus, in order to calculate the savings, *P5* indicator proposed by the European Commission was used. This indicator relates the power consumption of interior lighting to the number of occupied homes.

$$P5 = \left(\frac{E^{\mathrm{Hel}}}{D}\right) \cdot FC$$

where:
- E^{Hel} : Electricity consumption in houses
- *D :* Number of houses occupied
- *FC :* % of domestic electricity consumption on interior lighting

To make the calculation, domestic power consumption was adjusted by percentage consumption in owned and rented homes of interior lighting. This result was divided by the number of permanently occupied dwellings (the homes) to obtain the per unit consumption of domestic lighting.

$$\text{Energy savings } P5 = \left[\left(\frac{E^{\mathrm{Hel}}_{2004}}{D_{2004}}\right) \cdot FC_{2004} - \left(\frac{E^{\mathrm{Hel}}_{2010}}{D_{2010}}\right) \cdot FC_{2010}\right] \cdot D_{2010}$$

where:
- E^{Hel} : Electricity consumption in houses
- *D :* Number of houses occupied
- *FC :* % of domestic electricity consumption on interior lighting

Key variables

The following table gives all the variables having a direct bearing on calculating the savings resulting from this measure.

Table 74. *Evolution of specific variables related to the mechanism "Improved energy efficiency in the interior lighting installations of existing buildings" in the period 2004-2010*

	2004	2007	2008	2009	2010
Electric power consumption in homes [ktoe]	5,072	5,296	5,098	4,798	5,154
Occupied dwellings [thousands]	14,904	16,280	16,741	17,068	17,304
Domestic electric power use on lighting [%]	12.3	12.3	12.8	12.4	12.4

Source: IDAE

3.6. Distribution of low-consumption light bulbs

As part of the Activation Plan Savings and Energy Efficiency (Agreement of the Council of Ministers of August 1, 2008), the "Distribution of Low-Consumption Light Bulbs" initiative, aimed at house owners and tenants, was set in train. This initiative took the form of enclosing vouchers for low-consumption light bulbs in the bi-monthly electricity bill.

Method used

To determine the savings obtained by this initiative, the difference in lighting power of the incandescent bulb replaced and the efficient replacement bulb was calculated. This unitary improvement was then multiplied by the average number of hours of operation per annum and by the number of efficient light bulbs distributed under the programme, according to the formula:

$$BU_{il} = \sum_{t=2004-2007}^{2010} \left(P^{I} - P^{E}\right)_t \cdot H \cdot L(\text{Rep})_t$$

where:

- P^{I} : Rating of an incandescent light bulb
- P^{E} : Rating of an efficient light bulb
- H : Average number of hours in operation
- $L(\text{Rep})$: Number of light bulbs distributed each year under the programme

The average life of low-consumption light bulbs is 15 years, which exceeds the present analysis period, so the savings achieved in 2010 are the result of the savings reported as from 2004 or 2007 depending on the calculation basis chosen.

Key variables

This section gives all the variables having a direct bearing on calculating the savings resulting from this initiative.

Table 75. *Evolution of specific variables related to the mechanism "Low consumption light bulbs distribution" in the period 2004-2010*

	2004	2005	2006	2007	2008	2009	2010
Number of light bulbs (tickets gift) [unit]	-	200,592	-	-	-	7,254,250	6,576,625
Average number of working hours [h]	-	1,050	-	-	-	1,050	1,050
Incandescent light bulbs power [W]	-	100	-	-	-	100	100
Efficient light bulbs power [W]	-	18	-	-	-	18	18

Source: IDAE

3.7. '2 for 1' distribution of low-consumption light bulbs

The '2 for 1' low-consumption light-bulb distribution scheme is aimed at the residential sector and forms part of the Activation Plan Savings and Energy Efficiency (Agreement of the Council of Ministers of August 1, 2008),.

Method used

To calculate the energy savings resulting from this scheme a bottom-up indicator similar to that used in the preceding scheme was employed.

$$BU_{i2} = \sum_{t=2004-2007}^{2010} \left(P^{I} - P^{E}\right)_{t} \cdot H \cdot L(2x1)_{t}$$

where:

- P^{I} : Rating of an incandescent light bulb
- P^{E} : Rating of an efficient light bulb
- H : Average number of annual hours in operation
- $L(2x1)$: Number of light bulbs distributed under the programme

The useful life of low-consumption light bulbs is approximately 15 years, a period that extends beyond the period of analysis, with the result that the savings achieved in 2010 are given as the sum of the savings reported to date as from 2004 or 2007, depending on the base year chosen.

Key variables

This section gives all the variables having a direct bearing on calculating the savings directly attributable to this scheme.

Table 76. *Evolution of specific variables related to the mechanism "Programme '2 for 1' distribution of low-consumption light bulbs" in the period 2004-2010*

	2005	2007	2008	2009	2010
Number of light bulbs '2 for 1' [unit]	-	-	2,400,000	-	-
Average of number of working hours [h]	-	-	1,050	-	-
Incandescent light bulbs power [W]	-	-	100	-	-
Efficient light bulbs power [W]	-	-	15	-	-

Source: IDAE

3.8. Public support for improvement in the energy efficiency of interior lighting installations

Public support for improvement in the energy efficiency of interior lighting installations" is a measure undertaken as part of the cooperation agreements signed by the IDAE and the regional administrations.

Method used

To calculate the effects of these programmes we used the reports provided by the regional administrations on the savings resulting from the grants provided to renovate lighting systems.

$$BU_{it} = \sum_{t=2004-2007}^{2010} Ah_{ii}$$

where:

- Ah_{ii} : Annual savings reported by the regional administrations with respect to the public support for improvement in the energy efficiency of interior lighting installations in existing buildings

The useful life of this kind of improvement (15 years) extends beyond the period of analysis, with the result that the savings achieved in 2010 are given as the sum of the savings reported to date as from 2004 or 2007, depending on the base year chosen.

3.9. Summary of the direct savings achieved in interior lighting

Direct savings were taken as being those resulting directly from the introduction of specific measures to reduce the energy consumption of interior lighting, plus the savings obtained from the schemes set in train by the authorities.

The availability of information restricts estimates of the savings achieved by this measure to the housing sector.

Table 77. *Energy saving achieved by mechanism improved EE in the interior lighting installations of existing buildings in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Improved EE in the interior lighting	*P5*	116.4	81.0
Base 2007 [ktoe]	Improved EE in the interior lighting	*P5*	89.1	53.3

As Table 77 shows, the energy savings achieved decline sharply between 2009 and 2010 (—30%) given that in Spain at that time there was a notable surge in both household electricity consumption and in the number of households.

Table 78. *Evolution of "P" indicator related to interior lighting use in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
P5	Unitary electric power consumption on lighting per home [toe/house]	0.0417	0.0401	0.0390	0.0349	0.0370

Figure 41. *Evolution of "P" indicators related to interior lighting use in the period 2004-2010*

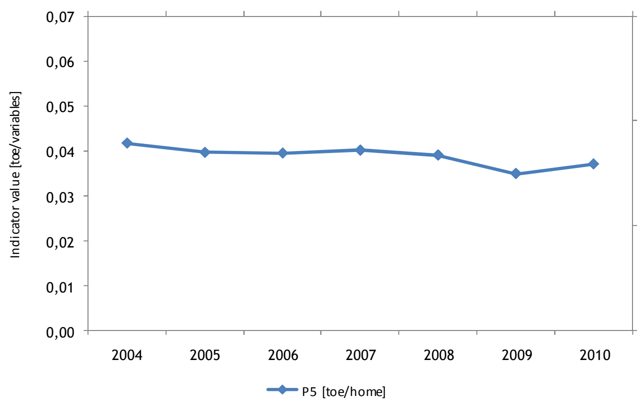


Table 79 gives the savings achieved by each of the schemes introduced relating to interior lighting.

Table 79. *Energy saving achieved by improvement in the interior lighting use in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Distribution of low consumption bulbs	BU_{i1}	45.1	84.9
	'2 for 1' of low consumption bulbs	BU_{i2}	13.0	13.0
	Support for interior lighting installations	BU_{i3}	20.0	29.7
Base 2007 [ktoe]	Distribution of low consumption bulbs	BU_{i1}	43.9	83.7
	'2 for 1' of low consumption bulbs	BU_{i2}	13.0	13.0
	Support for interior lighting installations	BU_{i3}	15.2	24.9

Table 80. *Subvention to the mechanisms related to improvement interior lighting use in the period 2006-2010*

	2006	2007	2008	2009	2010
Distribution of low consumption bulbs [k€]	-	-	-	27,848.34	13,693.43
'2 for 1' of low consumption bulbs [k€]	-	-	3,130.38	-	-
Support for interior lighting installations [k€]	1,781.89	1,859.89	4,058.23	7,420.91	7,400.26

Source: IDAE

As a result of the introduction of the public support programmes for improvement interior lighting installations in existing buildings", further to the cooperation agreements between the IDAE and the regional administrations, in 2010 energy savings of nearly 30 ktoe were obtained with respect to 2004.

At the same time it was also possible to quantify by means of bottom-up indicators two special programmes included in the "Savings in Energy Efficiency Activation Plan": the "'2 for 1' low-consumption light-bulb distribution scheme" (13 ktoe) and the "Free distribution of low-consumption light-bulb programme" (85 ktoe).

4. Renewal of household appliances

This measure was introduced to foster the replacement of existing household appliances, with relatively high energy consumption rates, by others of Class A or above, according to the energy consumption labelling system used.

The end purpose of the measure is to reduce the consumption of electric energy in households by replacing the following household appliances — refrigerators, deep freezes, washing machines, dishwashers and ovens — with new appliances of class A or above.

Method used

Renewal of kitchen household appliances

The indicator *P4* is defined by the European Commission as the consumption of an item of equipment according to its type or stock.

$$P4 = UEC^{X}$$

where:

- *UEC^{X} : Unit annual consumption of electricity per type of appliance*

To calculate the consumption of electricity by type of appliance we employed the usage pattern detailing the amount of use corresponding to each item of equipment as a percentage of the total electricity consumption of all household appliances.

In parallel to this, we calculated the annual turnover (rate of renewal) of each appliance in the analysis year. Multiplying this value by the number of households in Spain we obtained the annual volume of appliance renewals per household, household being understood as a permanently occupied home, i.e., excluding vacant or second homes.

The preferred indicator *P4* is for refrigerators, freezers, dishwashers and washing machines, the range of appliances known in the trade in Spain as "white-line" appliances. In view of this we took the step of creating a new preferred indicator for calculating the savings produced by renovating cookers and ovens, the $P4_1$.

Renewing cookers and ovens

In a manner similar to that of the *P4* indicator recommended by the European Commission, we calculated the savings corresponding to the indicator $P4_1$. This indicator would be defined as the per unit consumption of each type of household appliance multiplied by the stock of cookers and ovens in each year.

$$P4_1 = UECc^{X}$$

where:

- *$UECc^{X}$: Unit annual consumption of electricity of cookers and ovens*

The final result would be the sum of the difference in per unit consumption (i.e. the consumption per item of equipment within the stock) between the base year and the calculation year multiplied by the stock of appliances in the year for which the saving is calculated.

By way of example, for the *P4* indicator:

$$\text{Energy savings } P4 = \sum_{X=equipment} \left(UEC_{2004}^{X} - UEC_{2010}^{X} \right) \cdot Stock_{2010}^{X}$$

where:

- *UEC^{X} : Unit annual consumption of electricity per type of equipment*
- *$Stock^{X}$:* Number of items of equipment

The total savings obtained by the measure "Renovating household appliances, cookers and ovens" could thus be calculated as the sum of the savings achieved by the two indicators *P4* and $P4_1$.

Key variables

In this section we give all the variables having a direct bearing on calculating the savings generated by this measure.

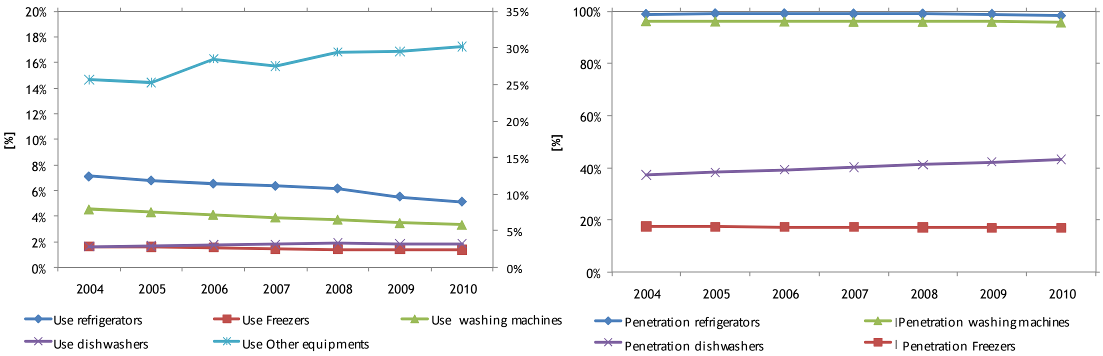
Since 2004, Spain has witnessed a significant increase in the volume of household appliances at Spanish homes, a circumstance that has led to higher energy consumption per household.

Table 81. *Evolution of specific variables related to the measure "Renewal of household appliances" in the period 2004-2010*

	2004	2007	2008	2009	2010
Thermal consumption in homes [ktoe]	11,045	11,534	11,103	10,448	11,223
Electric power consumption in homes [ktoe]	5,072	5,296	5,098	4,798	5,154
Thermal consumption in services sector [ktoe]	3,982	3,658	2,903	2,635	2,627
Electric consumption in services sector [ktoe]	4,619	5,476	5,646	5,414	5,388
Occupied dwellings [thousands]	14,904	16,280	16,741	17,068	17,304
Full time employee [thousands]	11,518	13,471	13,786	13,439	13,408
Domestic electric power use of appliances and others [%]	40.5	41.0	42.6	41.7	41.8
Domestic thermal use of cookers and ovens [%]	6.3	7.0	7.2	7.5	7.7
Domestic electric use of cookers and ovens [%]	7.8	7.8	7.8	7.4	7.3
Thermal use in services of cookers and ovens [%]	5.4	5.3	5.2	6.3	6.4
Electric use in services of cookers and ovens [%]	0.4	0.5	0.5	0.6	0.6
Electric use in services of office automation and equipment [%]	9.2	20.2	20.5	21.0	21.4
Refrigerator use [%]	7.1	6.4	6.2	5.5	5.1
Freezer use [%]	1.6	1.4	1.4	1.4	1.4
Washing machine use [%]	4.5	3.9	3.7	3.5	3.3
Dishwasher use [%]	1.6%	1.8%	1.9%	1.8%	1.8%
Ovens use [%]	3.2%	3.3%	3.5%	3.6%	3.8%
Mixed cooker use [%]	0.6%	0.6%	0.5%	0.4%	0.3%
Electric cooker use [%]	2.5%	3.0%	3.0%	3.1%	3.1%
Non electric cooker[%]	7.8%	6.9%	7.8%	7.8%	7.8%
Other equipment use [%]	25.6%	27.5%	29.4%	29.5%	30.2%
Refrigerator penetration [%]	99.0%	99.1%	99.1%	99.0%	98.4%
Freezers penetration [%]	17.4%	17.1%	17.1%	17.0%	16.9%
Washing machines penetration [%]	96.4%	96.1%	96.1%	96.1%	95.8%
Dishwashers penetration [%]	37.3%	40.2%	41.2%	42.2%	43.2%
Ovens penetration [%]	52.2%	54.3%	56.3%	58.4%	60.5%
Mixed cooker penetration [%]	10.6%	8.9%	7.5%	6.1%	5.0%
Electric cooker penetration [%]	44.4%	46.3%	48.2%	50.1%	51.9%
Non electric cooker penetration [%]	44.0%	43.8%	43.3%	42.8%	42.1%

Source: IDAE

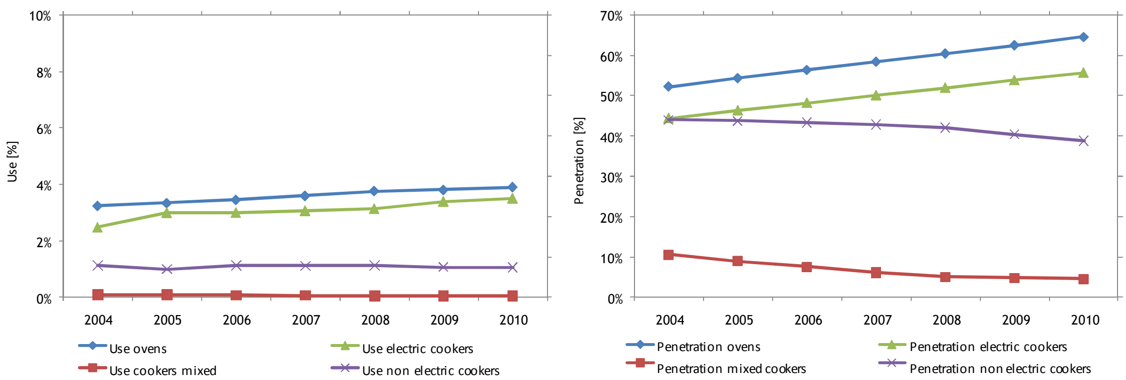
Figure 42. *Evolution of appliances uses and penetrations in the period 2004-2010*



There is a group of household appliances (freezers, dishwashers and ovens) the percentage use of which has remained flat throughout the period under study. Despite the increasingly widespread use of these appliances, the amount of energy they consume in total has held steady as a result of improvements in energy efficiency.

On the other hand, the percentage use of refrigerators (-2.0%) and washing machines (—1.2%) has fallen with respect to the total energy consumed in households. This range of household appliances is rapidly reaching saturation point in the market, meaning that the decline in percentage usage is the result of their greater energy efficiency. Sales of these items are limited very closely to the increase in the number of households, as opposed to the growth in audiovisual and electronic equipment, which has climbed much more steeply.

Figure 43. *Evolution of cookers and ovens penetration in domestic sector in the period 2004-2010*



The use of hybrid cookers (gas and electricity) in households has declined considerably in the period under analysis (—6.1%), leading to reduced consumption. However, the opposite is true of all-electric cookers, the increasing popularity of which has increased energy consumption.

Table 82. *Evolution of specific variables related to the measure "Renewal of household appliances" in the period 2004-2010*

	2004	2007	2008	2009	2010
Refrigerators consumption [ktoe]	360.1	336.7	313.9	263.9	262.8

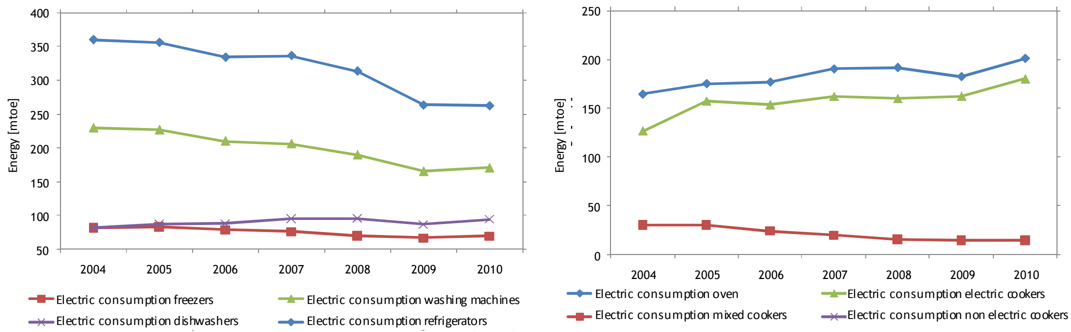
	2004	2007	2008	2009	2010
Freezers consumption [ktoe]	82.2	76.2	70.2	66.8	69.7
Washing machines consumption [ktoe]	229.5	206.4	190.2	165.8	170.7
Dishwashers consumption [ktoe]	82.2	95.1	95.9	86.9	94.4
Ovens consumption [ktoe]	164.4	175.1	176.7	190.3	191.8
Mixed cookers consumption [ktoe]	30.0	30.3	23.9	19.7	15.4
Electric cooker consumption [ktoe]	126.2	157.2	153.3	162.1	159.9
Non electric cooker consumption [ktoe]	866.1	789.5	872.2	898.9	870.9
Refrigerators Stock [thousands of units]	14,752	16,135	16,584	16,899	17,027
Freezers Stock [thousands of units]	2,593	2,792	2,857	2,899	2,924
Washing machines Stock [thousands of units]	14,362	15,651	16,091	16,402	16,577
Dishwashers Stock [thousands of units]	5,554	6,550	6,901	7,205	7,475
Ovens Stock [thousands of units]	7,781	8,318	8,933	9,508	10,123
Mixed cooker Stock [thousands of units]	1,574	1,368	1,190	991	837
Electric cooker Stock [thousands of units]	6,624	7,100	7,642	8,152	8,697
Non electric cooker Stock [thousands of units]	6,557	6,706	6,865	6,974	7,040

Source: IDAE

In order to estimate the individual power usage of each type of household appliance we used the total power consumption with respect to electric household appliances at Spanish homes, multiplying it by the percentage usage of each appliance category. The stock of appliances was obtained from the number of occupied homes and the sales figures of each of the appliances.

As shown in Table 82, in general the per unit energy consumption of household appliances in Spain over recent years has leaned towards greater efficiency, with an increasingly smaller amount of energy needed to perform the same service. However, the volume of appliances has risen due to stronger overall sales and the increase in the number of households.

Figure 44. *Evolution of energy consumption of appliances, cookers and ovens in the period 2004-2010*



4.1. “Renove” scheme for renewing household appliances

The “Renove” scheme for renewing household appliances is part of the broader scheme for replacing household appliances that forms part of the cooperation agreements reached by the IDAE and the regional administrations.

Method used

To calculate the savings obtained by the “Renove” scheme, one bottom-up indicator was established for the so-called “white-line” appliances and another for cookers and ovens.

These indicators measure the unit saving achieved by replacing an item of equipment or, what amounts to the same thing, the difference between the less efficient replaced item and the more efficient replacement item.

$$BU = UFES^{X}$$

where:
- *$UFES^{X}$: Unit electricity saving obtained from the replacement, by equipment type*

The final result of the “Renove” household appliance scheme is obtained by multiplying the number of replacements reported by regional administrations per year of the scheme by the energy saving resulting from replacing an inefficient appliance with an efficient one.

$$\text{Energy savings } BU = \sum_{X=\text{equipment}} \left(UFES^{X} \cdot Replacements \right)$$

where:
- *$UFES^{X}$: Unit electricity savings obtained from the replacement by type of equipment*
- *Replacements* : Number of appliances replaced

Key variables

In this section we give all the variables having a direct bearing on calculating the savings generated by this measure.

Table 83. *Number of units replaced related to mechanism “Renove scheme for renewing appliances” in the period 2007-2010*

	2004	2007	2008	2009	2010
Refrigerators [units]	-	211,322	246,619	238,994	222,651
Freezers [units]	-	20,138	35,298	34,206	31,867
Washing machines [units]	-	285,018	439,765	426,168	397,025
Dishwashers [units]	-	86,862	118,649	114,980	107,118
Ovens [units]	-	-	56,775	55,020	51,257
Cooking top [units]	-	-	26,846	26,016	24,236

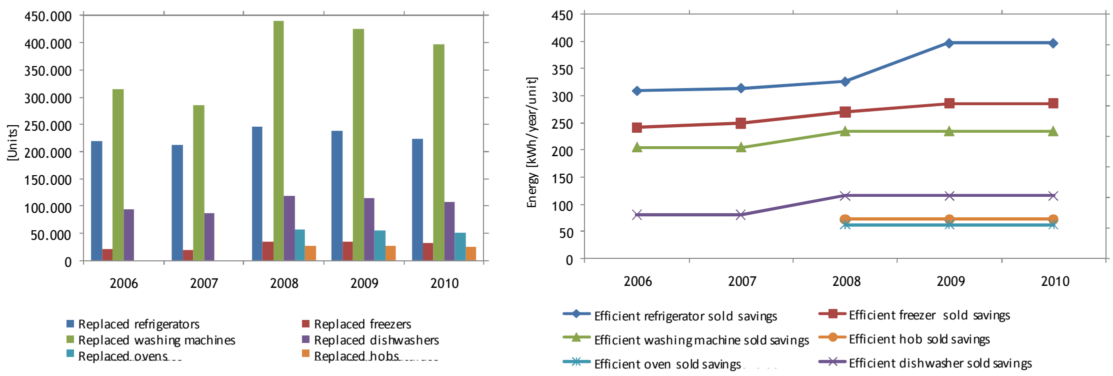
Source: IDAE

Table 84. *Energy saving per efficient unit sold (UFES) in the period 2007-2010*

	2004	2007	2008	2009	2010
Refrigerators [kWh/year/unit]	-	313.9	325.8	397.0	397.0
Freezers [kWh/year/unit]	-	249.7	270.5	285.9	285.9
Washing machines [kWh/year/unit]	-	205.2	234.9	234.9	234.9
Dishwashers [kWh/year/unit]	-	121.9	153.1	153.1	153.1
Ovens [kWh/year/unit]	-	-	62.4	62.4	62.4
Cooking top [kWh/year/unit]	-	-	72.6	72.6	72.6

Source: IDAE

Figure 45. *Units replaced of appliances and energy savings result in the framework of "Renove scheme for renewing appliances", in the period 2006-2010*



4.2. Summary of direct savings in household appliances

As in previous subsectors direct savings are those resulting from the implementation of specific measures relating to household appliances and achieved by initiatives undertaken intentionally by or on behalf of the administrations.

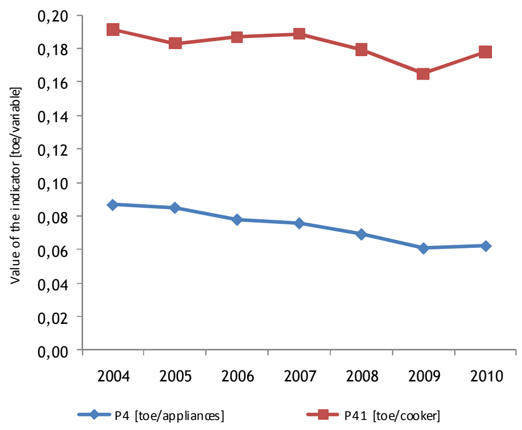
Table 85. *Savings results from measure "Renewal of household appliances" in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Renewal of household appliances	*P4+ $P4_1$*	**481.3**	**389.1**
	White-line appliances	*P4*	289.7	286.1
	Cooker and ovens	*$P4_1$*	191.56	102.98
Base 2007 [ktoe]	Renewal of household appliances	*P4+ $P4_1$*	**335.3**	**242.4**
	White-line appliances	*P4*	169.3	164.6
	Cooker and ovens	*$P4_1$*	165.98	77.79

Table 86. *Evolution of "P" indicators related to equipment use in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
P4	Unitary consumption indicator per appliance [toe/appliance]	0.0869	0.0759	0.0692	0.0608	0.0622
$P4_1$	Unitary consumption indicator per cookers and ovens per home[toe/cooker]	0.1913	0.1830	0.1870	0.1887	0.1794

Figure 46. *Evolution of "P" indicators related to equipment use in the period 2004-2010*



As Table 85 shows, savings of 389.1 ktoe have been achieved as at 2010 with respect to 2004, a saving of 17% with respect to the entire buildings segment (10% base 2007). 74% of these savings derive from the replacement of white-line household appliances; the remaining 26% by replacing cookers and ovens.

Table 87 shows the savings obtained by the "Renove" scheme aimed at the household appliance subsector.

Table 87. *Energy saving achieved by mechanisms in the equipment use in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Renove scheme household appliance	*BU_e+BU_c*	**63,1**	**81,4**
	White-line appliances	*BU_e*	62,2	80,0
	Cooker and ovens	*BU_c*	0,9	1,4
Base 2007 [ktoe]	Renove scheme household appliance	*BU_e+BU_c*	**38,2**	**56,5**
	White-line appliances	*BU_e*	37,3	55,1
	Cooker and ovens	*BU_c*	0,9	1,4

Table 88. *Subvention to the mechanisms related to equipment use in the period 2004-2010*

	2006	2007	2008	2009	2010
"Renove" scheme for renewing appliances [k€]	55,231.26	51,279.81	61,100.15	59,394.49	55,332.88

Source: IDAE

As shown in Table 87, in absolute terms the energy savings obtained in 2010 with respect to 2004 due to measures to renew household appliances amounted to 81.4 ktoe, equivalent to a percentage saving of 4% with respect to the total savings obtained in the buildings segment. Replacing cookers achieved much more modest savings than those obtained from replacing "white-line" appliances, due in the main to:

- Grants to replace cookers and ovens were introduced in 2008, i.e. initially grants were only allowed for replacing "white-line" household appliances.
- As from 2008 the grants and quotas assigned to replacing cookers and ovens were much smaller than those earmarked for "white-line" household appliances, with the result that by the end of the scheme a far smaller number of units had been replaced.

5. Savings obtained in the buildings and household appliance segments as at 2010

The buildings segment has achieved savings of 2,232.49 ktoe in the period 2004—2010. 73% of these savings were obtained in the sub-segment of thermal envelope and installations. The household appliance sub-segment, influenced by the increase in the level of usage in both households and companies, obtained negative savings of —199.1 ktoe.

Table 89. *Energy saving in buildings sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Buildings and equipment sector		**2,692.1**	**2,232.5**
	Thermal envelope and installations	$P1+P2+P3+M3_{11}+M3_{12}+M4_{11}+M4_{12}+M4_{13}$	2,084.2	1,637.7
	Interior lighting	$P5+M4_2$	691.8	793.9
	Equipment	$P4+P4_1+M_{33}+M_{43}+M_{44}$	-83.9	-199.1
Base 2007 [ktoe]	Buildings and equipment sector		**2,984.7**	**2,529.1**
	Thermal envelope and installations	$P1+P2+P3+M3_{11}+M3_{12}+M4_{11}+M4_{12}+M4_{13}$	2,461.8	2,020.6
	Interior lighting	$P5+M4_2$	198.4	301.2
	Equipment	$P4+P4_1+M_{33}+M_{43}+M_{44}$	324.6	207.3

5.1. Indirect and unquantifiable effects

By means of the differences in the scope of savings obtained from the different indicators employed it is possible to detect certain indirect effects resulting from the measures but impossible to quantify. With respect to these effects, observable in the differences between the different analysis perimeters, we notice the following in each of the sub-segments examined:

Thermal envelope and installations

In the sub-segment of thermal envelope and installations, we detected a number of indirect effects, mainly affecting households. Thus, between the perimeters for buildings and the measures adopted by households we estimate savings of 635.1 ktoe, while in the case of the services sector this could rise to 627 ktoe.

The difference between the external perimeter as measured by means of *M* indicators and that calculated for housing, using *P* indicators, is related to the activity variables taken into consideration, causing a reduction in the average size of homes in the period analysed, together with a fall in the average number of household members.

As unquantifiable effects associated with the measures, we note the following:

- In the first place, the subsidies available for purchasing acclimatisation equipment (air conditioning systems, boilers, etc.) carrying the maximum subsidy premium, lead to a concentration of demand for the most efficient machines, thereby favouring economies of scale by manufacturers that lead, in turn, to lower production costs and that may result in such machines monopolising the market. This induces an additional efficiency in the sector.
- Secondly, as an indirect effect, the increase in the energy consumption efficiency of space heating and cooling systems may lead to their incorrect use. Thus, the consumer who knows that his or her acclimatisation systems are more efficient and, therefore, consume less energy, may begin to ignore the energy consumption factor and use them more or less continuously as a means of increasing the degree of comfort of the home. The efficiency effect induced in consumption would thus be countered by additional usage.
- Also, the savings resulting from indirect effects that cannot be quantified, such as the communication and awareness programmes of the IDAE, Decree Law 47/2007 on the energy certification of buildings or the new Regulations on Thermal Installations in Buildings (RITE in Spanish), can also be regarded as indirect effects.

Interior lighting

Despite not being able to quantify numerically certain indirect effects, it is possible to associate them with various predictable results.

- Encouraging the use of more efficient light bulbs stimulates a demand for Class A bulbs, favouring economies of scale by the manufacturers and, hence, cheaper production costs. The net result could be the exclusive presence in the marketplace of efficient light bulbs.
- However, this improvement in the efficiency of the light bulbs used by households may induce people to misuse them as a means of raising their comfort level. Aware that the new bulbs consume less energy, users could employ them for longer periods or use a greater quantity of them to enjoy an uneconomical amount of light.

  In such cases, the efficiency achieved in light bulbs through technological advances could be countered by an increase in the number of hours they are used, possibly reaching the extreme of consuming more energy than had previously been the case with conventional light bulbs.

Household appliances and equipment

In the sub-segment of electrical appliances used inside buildings and the appliances affected by administrations intervention, indirect effects have been detected having contradictory results. Whereas in the so-called "white-line" household appliances indirect negative savings of −52.7 ktoe were detected in 2010, in the case of cookers and ovens used in households and the services sector, the savings are positive, 101.6 ktoe.

- Increasing purchases of certain items of equipment in the period analysed resulted in rising energy consumption per occupied home and thus negative savings. Such is the case with household equipment of the so-called "brown line", i.e. televisions, music systems, DVD players, etc. On the other hand, if such sales were to fall, as is the case for example with hybrid gas and electric cookers, the relative density of such items per household would diminish, resulting in positive savings. In a parallel context, we can see that the significant increase in the use of electronic devices (computers) in the services sector with respect to the number of full-time employees in recent years has reduced the level of energy savings in that sector.

The unquantifiable effects of measures to renew appliances and equipment have a direct impact on per unit consumptions and may be summarised as follows.

- Boosting the purchase of more efficient household appliances focuses demand on class A appliances, thereby encouraging economies of scale among producers and, thus, reducing their relative costs. The outcome is a greater presence of efficient household appliances in the marketplace.
- Lastly, between 2004 and 2010 changes in consumer behaviour occurred given that:
    - A fall in the energy consumption, and thus the running cost, of appliances and equipment may lead to a decline in optimisation of their use due, for example, to a generalised swing towards increasing the level of domestic comfort. This may lead to the circumstance that the savings obtainable from an energy efficient appliance are lost as its usage increases.
    - Acquisition of an electrical appliance that consumes a lot of electricity may impress upon the user the need to use it sparingly.

5.2. Double accounting

The possibility of having accounted for the savings resulting from measures adopted in the sub-segments of household appliances and interior lighting twice were not encountered.

However, with regard to the scheme involving the use of the Technical Building Code to define compliance with energy consumption standards in the case of thermal building envelope and installations, only the savings resulting from houses built after 2007, the date at which the new ruling came into force, were included. Theoretically, this runs counter to certain clauses of the measure, which oblige owners to upgrade buildings to conform to a series of administrative norms with regard to surface area and energy consumption.

In this assessment such upgraded buildings were not included in the calculations as the upgrading process alters some of the principles inherent in the original thermal envelope and installation measures.

V. PUBLIC SERVICES SECTOR

1. Summary of the energy savings achieved in the public services sector

PUBLIC SERVICES SECTOR

The energy savings achieved in the period 2004—2010 in the public services sector structured by use, street lighting and the water supply, were 31.8 ktoe. The energy consumption of this sector accounted for 1% of national final energy consumption in 2010.

Sector consumption

	Final energy 2010 [ktoe]
TOTAL CONSUMPTION PUBLIC SERVICES SECTOR	764.4
STREET LIGHTING USE	325.7
WATER SUPPLY USE	438.7

Savings results obtained

	Final energy saving 2010 [ktoe]		Primary energy saving 2010 [ktoe]		CO_2 emissions avoided 2010 [$ktCO_2$]	
	Base 2004	Base 2007	Base 2004	Base 2004	Base 2007	Base 2004
SAVINGS PUBLIC SERVICES SECTOR	**31,8**	**28,6**	**79,6**	**67,4**	**161,0**	**144,3**
STREET LIGHTING USE	4,6	11,3	11,5	26,5	23,2	56,8
WATER SUPPLY USE	27,2	17,3	68,2	40,9	137,8	87,5

Conclusions

The public services sector achieved energy savings of 31.8 ktoe in the period 2004—2010. Of these, 86% relate to the water supply, specifically to the use of desalination. However, the savings obtained between 2007 and 2010 in street lighting rose proportionally higher (from 14% to 39%)

This result was achieved in part thanks to the measures proposed in the Energy Savings and Efficiency Plan, supported by a series of legislative initiatives (Decree Law 1890/2008) to stimulate energy efficiency in public services.

The initiatives undertaken were articulated by means of a cooperation agreement between the IDAE and the regional administrations to improve the energy efficiency of street lighting and purifying, storing tap water and for de-sludging and desalinating waste water. These activities achieved total savings of 121.0 ktoe. 64% of the savings resulted from the “Renewal of street lighting installations”, 36% from the “Replacement of traffic-light programme”, and the remaining 0.1% from the “Strategic Projects” begun in 2010.

Within the public services sector street lighting is particular affected by the state of the economy, given that the building of new houses has a direct impact on the roll-out and renewal of street lighting in towns and cities. However, implementation of the Rules on street lighting energy efficiency (Decree Law 1890/2008) boosted efficiency in this sector.

In addition there are to unquantifiable effects that may be negative. When renewing street lighting, despite the energy savings obtained directly, overall savings take into account the increase in the consumption of electricity per household resulting from the new districts and the addition of new lighting units.

Combination of measures and mechanisms

Measures \ Mechanisms		IDAE- Regional Administrations Programme	IDAE support programmes to strategic projects	Programme to replace existing traffic light with LED traffic light	Natural renewal	Communication and awareness campaigns	Decree Law 1890/2008	Energy efficiency action plans 2008-2011	Un-quantified effects	**TOTAL**
2010 Base 04 [ktep]	Improvements street lighting	77.7		8.7		-116.4				**-30.0**
	Improvements wáter supply	7.0	0.2		20.0					**27,2**
	TOTAL	**84.7**	**0.2**	**8.7**	**-96.4**					**-12.8**
2010 Base 07 [ktep]	Improvements street lighting	55.0		43.3		-87.0				**11,3**
	Improvements wáter supply	3.8	0.2		13.3					**17,3**
	TOTAL	**58.8**	**0.2**	**43.3**	**-73.7**					**28.6**

* Direct savings achieved due to mechanisms

** Indirect savings achieved due to mechanisms

STREET LIGHTING

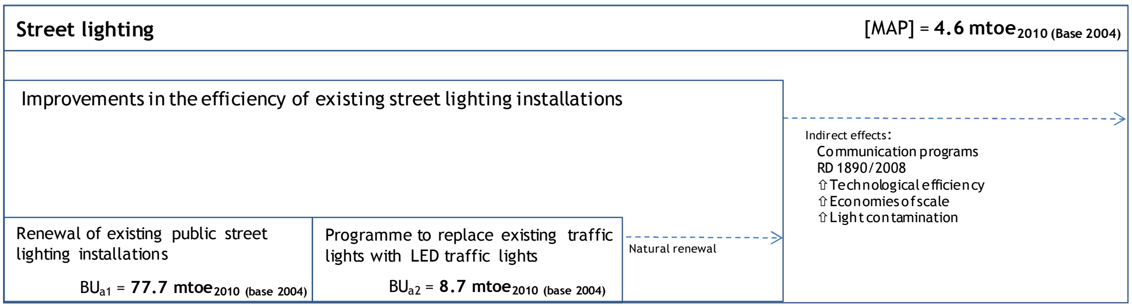
The final energy savings associated with the use of public street lighting within the public services sector in the period 2004—2010 were 4.6 ktoe.

The calculate the external perimeter a top-down indicator similar to that proposed by the European Commission for other sectors was adapted specifically for the street-lighting segment. With regard to the specific usage, “Improvement in the energy efficiency of existing public street lighting”, this was measured using bottom-up indicators to measure the effect of the street-lighting renewal plan promoted by the IDAE by means of the “Renove” plans and the “Programme to replace existing traffic lights with lights using LED technology”.

Results obtained

		Final energy savings 2010 [ktoe]	
		Base 2004	Base 2007
MAP	Street lighting consumption per house	4.6	11.3
BUa1	Renewal of existing public street lighting installations	77.7	55.0
BUa2	Programme replace existing traffic lights with LED	43.3	8.7
TOTAL STREET LIGHTING USE *(MAP)*		**4.6**	**11.3**

Savings diagram



Conclusions

According to top-down indicator *M*, savings of 4.6 ktoe were achieved in the period, more if we go back to 2007 (11.3 ktoe) given that the promotional mechanisms were introduced in that year.

The bottom-up indicators show that the initiative achieved direct savings of 121 ktoe. This began in the main in 2007, when the trend towards energy savings in this sector was improved.

Thanks to the differences between the external and internal savings perimeters (—116.4 ktoe) we can distinguish two indirect effects. Despite the fact that the sector has improved in efficiency, urban development in Spain up to 2008 increased considerably the consumption of street lighting. At the same time, the improvement in street lighting installations and their relatively reduced cost could give rise to light contamination.

WATER SUPPLY

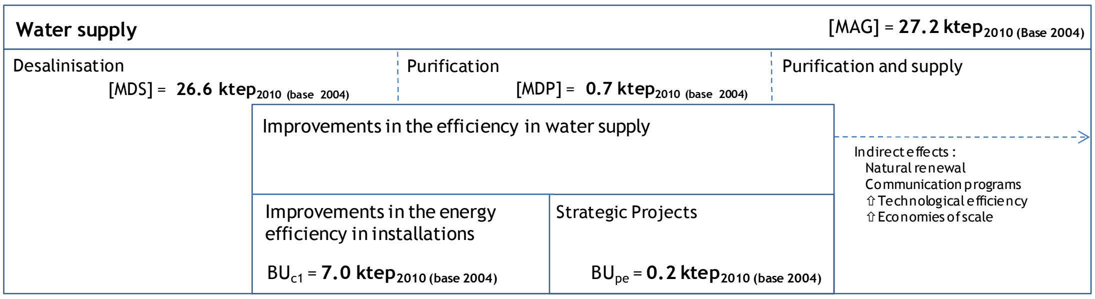
The final energy savings relating to the water supply within the public services sector were 27.2 ktoe in the period 2004—2010.

In order to calculate the external perimeter usage was divided into two main activities, desalination and treatment. As the catalogue of indicators of the European Commission makes no reference to this concept, it was decided to use the top-down indicator *M* for each activity. The sum of the savings according to these indicators returns the totals for the water supply. Finally, using a bottom-up indicator we were able to calculate the savings obtained by means of the Action Plan and the "Strategic Projects" scheme initiated by the IDAE.

Results obtained

		Final energy savings final 2010 [ktoe]	
		Base 2004	Base 2007
MAG	Energy savings desalinisation and de-sluging	27.2	17.3
MDS	Energy savings desalinisation	26.6	15.2
MDP	Energy savings de-sluging	0.7	2.1
BUc1	Improvements in installations for treatment and supply of drinking water and the desalinisation and de-sludging of waste water	7.0	3.8
BUpe	Strategic projects	0.2	0.2
TOTAL WATER SUPPLY USE *(MAG)*		27.2	17.3

Breakdown of savings



Conclusions

According to the top-down indicator *M* savings of 27.2 ktoe were achieved in the water supply in the period under study. Of the two activities analysed, desalination produced all the positive savings (26.6 ktoe), given that de-sludging produced practically no savings.

The bottom-up indicators show the savings resulting from the IDAE's Action Plan and Strategic Projects in this usage category (7.2 ktoe).

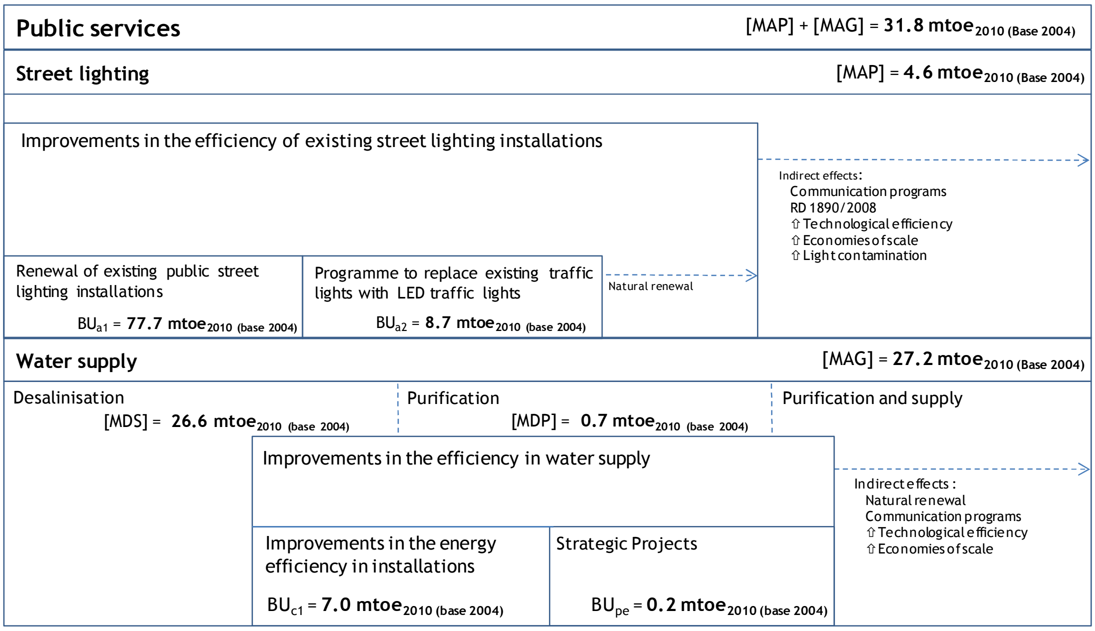
Lastly, on the basis of the difference between the external and internal savings perimeters (20 ktoe) it is possible to distinguish certain indirect effects. A concentration in the demand for more efficient water-supply installations favoured economies of scale by the producers and cheaper unit costs, resulting in an unquantifiable improvement.

2. Scope of the savings

The public sector has made savings in energy consumption thanks to improvements in street lighting and the water cycle.

Figure 47 provides a breakdown of the energy savings obtained in the public service sector using values of 2010 versus 2004, arranged by usage (street lighting and water cycle) and covering the initiatives taken by the public authorities and their possible indirect effects.

Figure 47. *Breakdown of energy saving in the public services sector in 2010 with respect to 2004*



In the following sections this report details the calculation methods used to ascertain what energy savings were achieved in the two public services concerned: street lighting and the water supply.

2.1. Street lighting

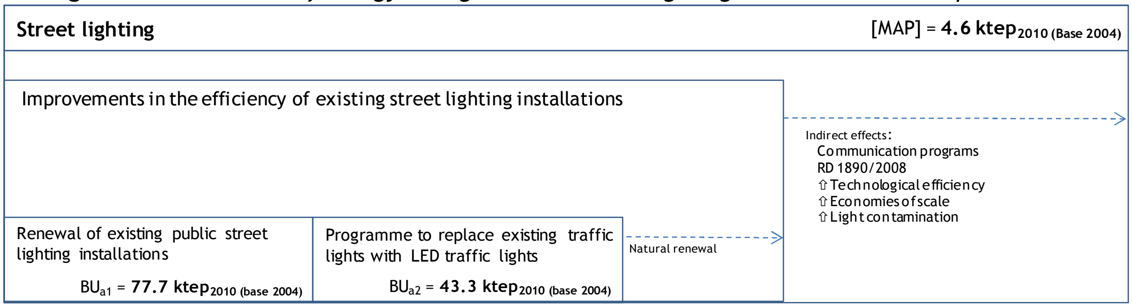
The measures relating to this energy use are designed to improve all public street lighting in cities, infrastructures and roads. The measures extend beyond improving the efficiency of the lighting itself to conducting energy audits and training the employees responsible for energy management.

Method used

In the first place the final energy savings given by the top-down indicator *M* were calculated using the method proposed by the European Commission.

Subsequently a calculation was made of the savings obtained by different measures adopted by the authorities pursuant to the cooperation agreements between the IDAE and the regional administrations and articulated by means of “Street Lighting Renewal” plans and a scheme to replace conventional traffic lights with lights using LED technology, two initiatives generating energy savings that can be measured using the bottom-up indicators BU_{a1} and BU_{a2}.

Figure 48. *Breakdown of energy saving in the external lighting use in 2010 with respect to 2004*



To calculate the resulting savings it is necessary to know how much energy is consumed in this usage. An appropriate variable must also be found to adjust the energy consumption in order to ascertain the energy efficiency obtained, i.e. the difference between the two unitary rates of consumption, before and after.

Rolling out the new street lighting system and its associated savings is closely related to urban development. For this reason it is considered that the number of houses is the most appropriate objective variable for tracking the savings obtained. From the link between these two variables the indicator *MAP* was devised.

The *MAP* indicator, "unitary electric power consumption of street lighting per house" expresses the quotient between the power consumption and the number of houses in Spain. Its application gives the mean per-unit consumption of street lighting per house.

$$MAP = \left(\frac{E^{EA}}{V} \right).$$

where:
- E^{EA}: Power consumption of street lighting
- V : Number of houses

The saving obtained with respect to the scope of the street lighting improvements is given by multiplying the difference in the values of per unit consumption for the base year (2004 or 2007) and the year of calculation (2010) and the activity variable with respect to the indicator (number of houses in 2010).

For the *MAP* indicator the result would be:

$$\text{Energy savings} \;\; MAP = \left[\left(\frac{E^{EA}_{2004}}{V_{2004}} \right) - \left(\frac{E^{EA}_{2010}}{V_{2010}} \right) \right] \cdot V_{2010}$$

where:
- E^{EA}: Power consumption of street lighting
- V : Number of houses

Key variables

Table 90 gives all the variables having a direct bearing on the calculations of savings produced by this energy use.

Table 90. ***Evolution of specific variables related to the "M" indicators in the external lighting use in the period 2004-2010***

	2004	2007	2008	2009	2010
Electric power consumption in street lighting [ktoe]	290	320	330	323	326
Houses [thousands]	22,623	24,496	25,129	25,557	25,789

Source: INE, IDAE

Figure 49. *Evolution of electric power consumption in the external lighting use and number of houses in the period 2004-2010*

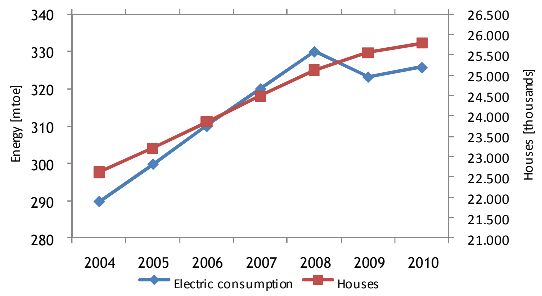


Figure 49 shows how the consumption of electricity in street lighting shows a marked increase in the early years of the series, in parallel to the growth in housing. However, as from 2008 this trend begins to level out, given that the street-lighting spend slows in line with the number of new houses.

This situation is the result of setting in train measures aimed at this subsector to significantly improve its efficiency.

Total savings achieved in street lighting

The total savings achieved in this usage include both direct and indirect savings.

In order to calculate the energy savings obtained in the period, the MAP indicator described above is used, applying the variables of the sector and the economic factors given in Table 90. The results are shown in Table 91 and the changes in the indicator in Table 92 and Figure 50.

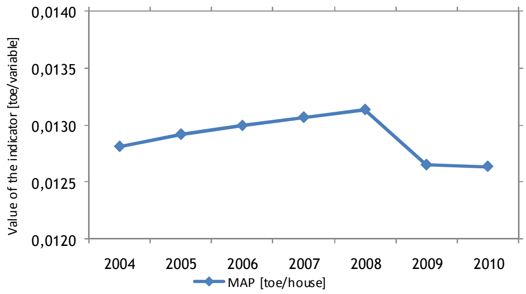
Table 91. *Energy saving in the external lighting use in 2009 y 2020 with base 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Street lighting	*MAP*	4.1	4.6
Base 2007 [ktoe]	Street lighting	*MAP*	10.7	11.3

Table 92. *Evolution of "MAP" indicator related to street lighting use in the period 2004-2010*

Description		2004	2007	2008	2009	2010
MAP	Consumption of street lighting per house [toe/house]	0.0128	0.0131	0.0131	0.0126	0.0126

Figure 50. *Evolution of “MAP” indicator related to street lighting use in the period 2004-2010*



The results of the top-down indicator *M* in Figure 92 show an energy saving in the period of 4.6 ktoe (14% of the total savings of the sector). Despite the improvement in efficiency in the use of street lighting and the efforts of the authorities, the savings were largely offset by the expansion of urban development in the period.

2.2. Water supply

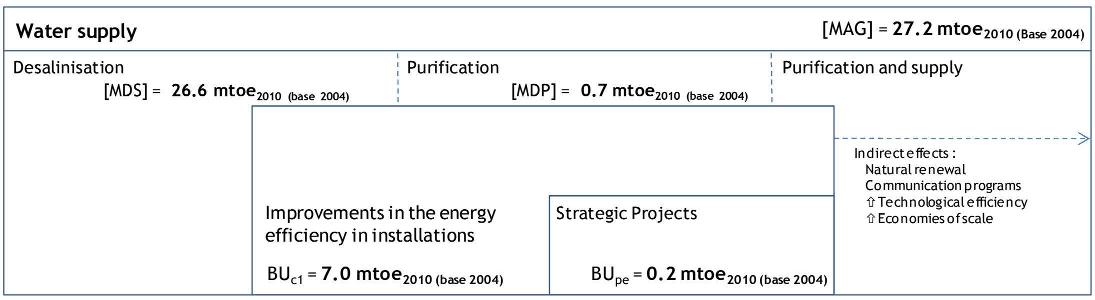
The measures associated with the water supply are aimed at improving energy efficiency both in the processes employed and in the present installations for purifying and storing tap water and for de-sludging and desalinating waste water.

Method used

In the first place, use was structured according to the activities of desalination, filtering, treatment and distribution as shown in Figure 51.

Next, with respect to the calculation methods used, the savings attributed to the measures of the Action Plan and the “Strategic Projects” sponsored by the IDAE by means of bottom-up indicators BU_{c1} and BU_{pe} and documented in the yearly reports drawn up by the regional administrations and contractors are quantified.

Figure 51. *Breakdown of energy saving in the water cycle in 2010 with respect to 2004*



In order to estimate the energy savings obtained in managing the water supply it is necessary first to establish the energy consumed and, secondly, to find a variable that allows energy consumption to determine the relative energy efficiency in the form of different per unit rates of consumption.

To this end two *M* indicators were arrived at, in a manner similar to that used in the case of street lighting, to cater for the twin activities of treatment and desalinisation.

- In the first place, with respect to desalinisation, energy consumption over use is directly proportional to the volume of water treated, with the consequence that care was taken to obtain all past records. This indicator, *MDS*, “Unitary consumption of electricity in the desalination of water per cubic hectometre treated”, is given by the quotient between the electrical energy employed and the total volume of water desalinated.

$$MDS = \left(\frac{E^{DS}}{A} \right)$$

where:
- E^{DS}: Power consumption in desalination
- A: Volume of water desalinated

- Similarly, for the activity of purifying drain water the *MDP* indicator “Per-unit power consumption for waste-water treatment per inhabitant” was created, this being the quotient between the electric power employed and the number of inhabitants, given that population is a variable that is directly proportional to the volume of drain water purified.

$$MDP = \left(\frac{E^{DP}}{H} \right)$$

where:
- E^{DP}: Power consumed in treatment
- H: Number of inhabitants

The savings made on the basis of these indicators are obtained by multiplying the difference between the figures for the base year (2004 or 2007) and the calculation year (2010) by the activity variable with respect to the indicator.

For example, for the *MDS* indicator, using 2004 as the base year, the result would be:

$$\text{Energy savings } MDS = \left[\left(\frac{E^{DS}_{2004}}{A_{2004}} \right) - \left(\frac{E^{DSI}_{2010}}{A_{2010}} \right) \right] \cdot A_{2010}$$

where:
- E^{DS}: Power consumed in desalination
- A: Volume of water desalinated

The sum of the savings reckoned according to the two indicators gives the total energy savings obtained in managing the water supply, as shown by the *MAG* indicator.

$$MAG = MDS + MDP$$

Key variables

Table 93 gives all the variables having a direct bearing on calculating the savings resulting from this activity.

Table 93. *Evolution of specific variables related to “M” indicator in the water cycle in the period 2004-2010*

	2004	2007	2008	2009	2010
Consumption of electric power in desalination [ktoe]	113	163	186	208	209
Consumption of electric power in treatment [ktoe]	211	223	225	226	230

	2004	2007	2008	2009	2010
Volume of treated water for desalination [hm3]	233.6	355.9	419.7	483.6	489.4
Number of inhabitants [thousands]	43,198	45,201	46,158	46,746	47,021

Source: OCC, IDAE

The activity variables used to calculate the top-down indicator *M* show a steady increase. The volume of water treated for desalination rose by 210% between 2004 and 2010, indicating an increase in power consumption in this activity, moderated to some extent by periods of drought.

Figure 52. *Evolution of electric power consumption related to desalination and volume of treated water in the period 2004-2010*

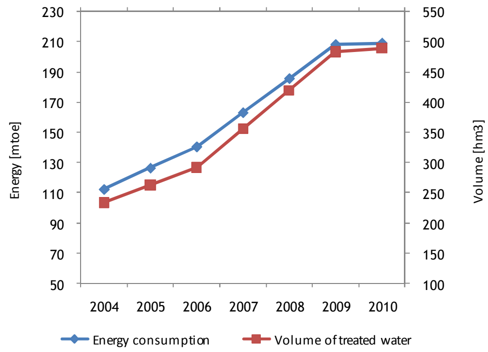
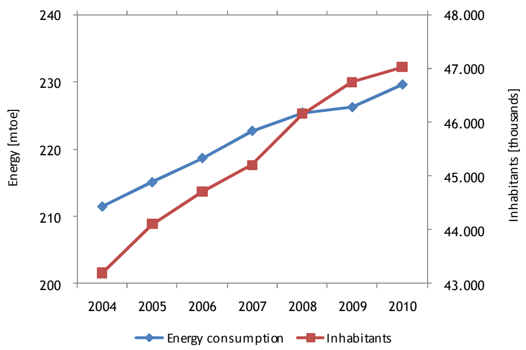


Figure 53. *Evolution of electric power consumption related to treatment and number of inhabitants in the period 2004-2010*



Total savings achieved in the water supply

The total savings obtained in this usage include the savings achieved both directly and indirectly.

To calculate the energy savings obtained in the period the indicators described above (MDS and MDP) were used, applying the requisite sector variables contained in Table 93. The results are given in Table 94 and the rate of progress of the indicators in Table 95 and Figure 54.

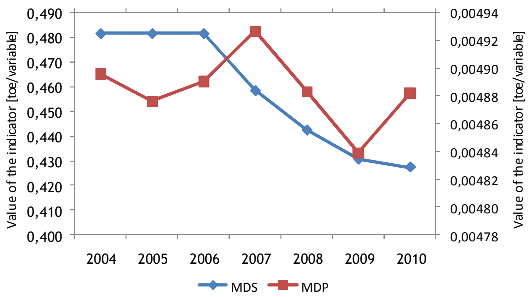
Table 94. *Energy saving in the water cycle use in 2009 y 2020 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Water cycle subsector	*MAG=MDS+MDP*	**27.4**	**27.2**
	Desalination	*MDS*	24.7	26.6
	Treatment	*MDP*	2.7	0.7
Base 2007 [ktoe]	Water cycle subsector	*MAG=MDS+MDP*	**17.6**	**17.3**
	Desalination	*MDS*	13.5	15.2
	Treatment	*MDP*	4.1	2.1

Table 95. *Evolution of M indicators in the water cycle use in the period 2004-2010*

	Description	2004	2007	2008	2009	2010
MDS	Consumption of desalination of treated water per volume [toe/hm3]	0.482	0.458	0.442	0.430	0.427
MDP	Consumption of treatment consumption per inhabitant [toe/inhabitant]	0.005	0.005	0.005	0.005	0.005

Figure 54. *Evolution of M indicators in the water cycle use in the period 2004-2010*



In the energy usage associated with the water supply, the savings achieved in 2010 with respect to the position six years earlier, savings of 27.2 ktoe, account for 86% of the savings achieved in the public services sector.

The greatest relative savings achieved were in desalination, given that treatment did not achieve significant savings in the period. This was due to the fortuitous circumstance that the construction of new plants for desalinating seawater improved the technology employed (see Table 95).

3. Improvement in the efficiency of existing street lighting installations

The main purpose of this measure was to foster the replacement of existing street lighting installations, based on obsolete technology, with more efficient up-to-date installations. The same purpose extended to all new street lighting installations.

As the savings obtained as a consequence of either the normal rotation of the stock of street lights or occasional technological improvements could not be extrapolated, the savings shown below are those obtained from targeted initiatives undertaken by the IDAE.

3.1. Renewal of existing public street lighting installations

The "Renewal of existing street lighting installations" is a scheme forming part of the measure, "Improving the efficiency of existing street lighting installations" articulated by means of the cooperation agreements reached between the IDAE and the regional administrations.

Method used

To calculate the effects of the measure, the annual reports on the savings achieved from the public grants earmarked for this purpose were used.

The savings obtained in 2010 are the sum of the annual savings achieved from 2004 or 2007, depending on the base year chosen.

$$BU_{et} = \sum_{t=2004-2007}^{2010} Ah_{et}$$

where:

- Ah_{et} : Annual savings reported by regional administrations with respect to the "Renewal of existing street lighting installations"

3.2. Programme to replace existing traffic lights with LED traffic lights

The "Programme to replace traffic lights with lights based on the new LED technology" was undertaken in 2009 to help municipal councils replace their conventional traffic lights with lights employing LED technology.

Method used

To calculate the savings resulting from this initiative a bottom-up indicator that allows the mechanism to be itemised in greater detail was established.
The main variables with this indicator are the number of LED optic components that were replaced per annum under the programme within the programme time period, multiplied by the different per unit consumptions of conventional and LED technology.

$$BU_{il} = \sum_{t=2004-2007}^{2010} \left(C^{T} - C^{LED}\right)_{t} \cdot O_{t}$$

where:

- C^{T} : Annual consumption of conventional traffic lights
- C^{LED} : Annual consumption of LED traffic lights
- $Ó_{t}$: Number of lights replaced

Key variables

Table 96 gives all the variables having a direct bearing on calculating the direct savings obtained from this mechanism.

Table 96. *Evolution of specific variables related to mechanism "Programme to replace existing traffic lights with LED technology" in the period 2004-2010*

	2004	2005	2006	2007	2008	2009	2010
Number of optical LED replaced [unit]	-	-	-	-	-	461,791	-
Consumption of conventional lights [kWh/year]	-	-	-	-	-	1,226	-
Consumption of LED technology lights [kWh/year]	-	-	-	-	-	135	-

Source: IDAE

3.3. Summary of the direct savings achieved by the improvements to existing street lighting installations

This summary covers the direct savings resulting from either specific measures taken to reduce usage consumption or from the facilitating mechanisms set up by the public authorities.

Table 97 gives the savings obtained by each of these mechanisms in the period under study.

Table 97. *Energy saving achieved by mechanisms in the street lighting use in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Renewal street lighting installation	BU_{a1}	58.6	77.7
	Replace existing traffic light with LED	BU_{a2}	8.7	8.7
Base 2007 [ktoe]	Renewal street lighting installation	BU_{a1}	35.9	55.0
	Replace existing traffic light with LED	BU_{a2}	8.7	8.7

Table 98. *Subvention to mechanisms related to external lighting use in the period 2006-2010*

	2004	2005	2006	2007	2008	2009	2010
Renewal street lighting installation [k€]	-	-	17,185.3	17,892.7	26,320.8	28,900.6	25,622.8
Replace existing traffic light with LED [k€]	-	-	-	-	-	31,794.0	-

Source: IDAE

The results obtained from the different mechanism analysed show that in 2010 the IDAE-regional administrations cooperation agreements generated energy savings of 77.7 ktoe, while the programme to replace conventional traffic lights by LED-technology traffic lights obtained savings of 8.7 ktoe.

The total savings obtained in the use of street lighting between 2004 and 2010 (4.6 ktoe) are much smaller than the direct savings achieved by the two administrative initiatives carried out in this subsector (86.4 ktoe). This is due to the somewhat uneven implementation of the administrative initiatives, although as a result of their useful life their effects endured until the end of the period. However, the total savings of this subsector include the negative figures of the initial years that penalise the final result, given that the per-unit consumption of street lighting per house shows a sharp upward trend.

4. Improvement in energy saving and efficiency in the water supply

The purpose of this measure was to replace the existing technologies employed for the treatment and desalinisation of water with more efficient technologies.

As it was not possible to extrapolate the savings obtained from either the normal rotation of water-supply equipment stock or non-induced technological improvements, the figures shown below are those obtained as the result of specific measures carried out by the IDAE.

4.1. Improvements in the energy efficiency in installations for the treatment and supply of drinking water and the desalinisation and de-sludging of waste water

The "Improvement in energy efficiency of installations for the treatment and supply of drinking water and the desalinisation and de-sludging of waste water" is one of the schemes forming part of the Action Plan implemented further to the cooperation agreements signed by the IDAE and the regional administrations.

Method used

To calculate the effects obtained from the scheme the annual reports provided by the regional administrations on the savings obtained by means of their public funding were used.

The savings obtained in 2010 result from the sum of the annual savings from 2004 or 2007 depending on the base year chosen.

$$BU_{c1} = \sum_{t=2004-2007}^{2010} Ah_{et}$$

where:

- Ah_{et} : Annual savings reported by the regional administrations with respect to the "Improvements in the energy efficiency of the treatment and supply of drinking water and the de-sludging and desalination of waste water"

4.2. Strategic projects

With regard to the encouragement of "Strategic Projects" on behalf of the IDAE, mention must be made of the improvement schemes covering all the structural components of buildings.

A key requirement of successful applications for funding under these initiatives is presentation to the IDAE of a report on the measures taken and the savings made.

Method used

To calculate the effects of the "Strategic Projects" scheme, we used the annual reports on the savings drawn up by the companies in receipt of funding.

$$BU_{et} = \sum_{t=2004-2007}^{2010} Ah_{pe}$$

where:

- Ah_{pe} : Annual savings reported by the companies funded under the "Strategic Projects"

4.3. Summary of the direct savings achieved in the water supply

The savings resulting from the introduction of specific measures to reduce energy consumption in managing the water supply, together with the savings obtained from the initiatives sponsored by the administrations authorities, were considered as direct savings.

Table 99. *Energy saving achieved by mechanisms in the water cycle in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Strategic projects	BU_{pe}	0.0	0.2
	Improvements in installations for treatment and supply of drinking water and the desalinisation and de-sludging of waste water	BU_{c1}	6.0	7.0
Base 2007 [ktoe]	Strategic projects	BU_{pe}	0.0	0.2
	Improvements in installations for treatment and supply of drinking water and the desalinisation and de-sludging of waste water	BU_{c1}	2.8	3.8

Table 100. *Subvention to mechanisms related to water cycle use in the period 2006-2010*

	2006	2007	2008	2009	2010
Improvements in installations for treatment and supply of drinking water and the desalinisation and de-sludging of waste water [k€]	2,718.6	2,158.8	1,920.0	2,426.0	1,571.7
Strategic projects [k€]	-	-	-	-	355.9

Source: IDAE

5. Savings obtained in the public services sector as at 2010

The public services sector achieved energy savings of 31.8 ktoe in the period 2004—2010. 86% of these savings related to management of the water supply. Within the cycle, desalination was the activity that generated the highest amount of saving, 26.6 ktoe.

Table 101. *Energy saving in public services sector in 2009 and 2010 with respect to 2004 y 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Public services sector	*MAP+MAG*	**31.5**	**31.8**
	Street lighting	*MAP*	4.1	4.6
	Water cycle	*MAG = MDS+MDP*	27.4	27.2
	Desalination	*MDS*	24.7	26.6
	Treatment	*MDP*	2.7	0.7
Base 2007 [ktoe]	Public services sector	*MAP+MAG*	**28.3**	**28.6**
	Street lighting	*MAP*	10.7	11.3
	Water cycle	*MAG = MDS+MDP*	17.62	17.35
	Desalination	*MDS*	13.52	15.25
	Treatment	*MDP*	4.09	2.10

Analysing the savings achieved between 2007 and 2010 it will be noted that the savings resulting from street lighting increase in relative terms with respect to the total (from 14% to 39%) due to the slowdown in urban development and the introduction of measures to improve energy efficiency.

5.1. Indirect effects

Using the difference between the savings perimeters obtained from the applicable indicators it is possible to detect a number of indirect effects. In the case of public services we would highlight the following effects, according to the energy use studied:

***Street lighting*.**

With regard to street lighting, between the external perimeter and those relating to the schemes, we estimate a negative saving of —116.4 ktoe, as explained below.

- In the first place, the improvement in the efficiency of street lighting may lead to an increase in use, resulting in an increase in light contamination in urban environments. Also, the improvement in efficiency resulting in reduced levels of consumption is sometimes offset by an extension of the hours of operation.
- Secondly, urban development has played a major role in achieving the savings given that street lighting installations have been proportional to the number of new buildings, although as from 2008 the results have improved.
- Lastly, the savings resulting from schemes that could not be quantified, such as the information and awareness campaigns conducted by the IDAE and Decree Law 1890/2008 on the energy efficiency of street lighting installations and their technical complementary instructions, are considered as unquantified effects.

Water supply

In the energy use associated with the water supply a number of indirect effects were detected, quantified at 20.0 ktoe. The difference is the result of the savings produced by the rest of the mechanisms for which the actual savings could not be quantified precisely. However, they can be justified in part as the normal rotation of installation assets and the presence of public programmes promoting economies of scale and technological efficiency.

No risk of incurring in double accounting was detected in calculating the savings obtained in this sector.

VI.AGRICULTURE AND FISHERIES SECTOR

1. Summary of energy savings in agriculture and fisheries

AGRICULTURE AND FISHERIES

The energy savings obtaqined in the period 2004—2010 in the agriculture and fisheries sector were due in the main to the improvements undertaken in arable and livestock farms and fruit & vegetable farms, in irrigation systems and in the fishing fleet. The final energy consumption in this sector in 2010 was 3,313.7 ktoe, 3.7% of the national total.

Breakdown of savings

The savings obtained in the agriculture and fisheries sector were structured into two main subsectors: agriculture, livestock, hunting and forestry on one hand, and fishing and aquiculture on the other.

Agriculture and fisheries [M8'] = **425.5 ktep** 2010(Base 2004)

Agriculture, livestock, hunting and agricultural services
[$M8_1$] = **240.1 ktep**

- Cultivation & farms: [PMa + PCl] = **-65.63 ktep** 2010(B 2004)
- Irrigated: [PRe] = **73.5 ktep** 2010(B 2004)
- ⇧ Climatization ⇧Tech. efficiency ⇩ Production: 339.8 ktep 2010(Base 2004)

Fisheries and aquaculture
[$M8_2$] = **146.4 ktep**

- Fisheries: [PPe] = **38.8 ktep** 2010(B 2004)
- ⇧Tech. efficiency ⇩ Production: 107.6 ktep 2010(B 2004)

Change in the relative weighting in overall energy consumption: 39.1 ktep

Sector consumption

	Final energy 2010 [ktoe]
TOTAL CONSUMPTION AGRICULTURE AND FISHERIES	3,313.66
AGRICULTURE, LIVESTOCK, HUNTING AND FORESTRY	2,829.80
FISHERIES AND AQUICULTURE	483.87

Savings results obtained

	Final energy saving 2010 [ktoe]		Primary energy saving 2010 [ktoe]		CO_2 emissions avoided 2010 [$ktCO_2$]	
	Base 2004	Base 2007	Base 2004	Base 2007	Base 2004	Base 2007
TOTAL SAVINGS SECTOR	425.5	466.7	535.5	580.4	1,526.3	1,673.2
AGRICULTURE, LIVESTOCK, HUNTING AND FORESTRY	240.1	359.7	374.7	544.5	947.1	1,417.1
FISHERIES AND AQUICULTURE	146.4	121.6	163.9	136.2	501.0	416.1

Conclusions

According to the top-down indicators energy savings of 425.5 ktoe were achieved in the period, due in the main to the fall in production and technological improvements in agriculture, livestock, hunting and forestry (62% of total savings) and in fishing and aquiculture (38%).

From the difference betwee the sum of the external perimeters of each subsector (240.1 ktoe and 146.4 ktoe) and the external perimeter of the sector as a whole (425.5 ktoe) we see an energy saving resulting from the change in the weighting of consumption of the subsectors of livestock and fishing (39.1 ktoe).

In the subsector of agriculture positive savings were obtained from energy improvements in farm machinery (146.8 ktoe) and changes to irrigation systems (73.5 ktoe). However, the increase in the degree of sophistication of air-conditioning systems in livestock and fruit & vegetable farms resulted in a more intensive use of energy resulting in negative savings of —212.4 ktoe. As a result, overall there were no savings in arable, livestock and fruit and vegetable farms. On the contrary, there were negative savings of —65.6 ktoe.

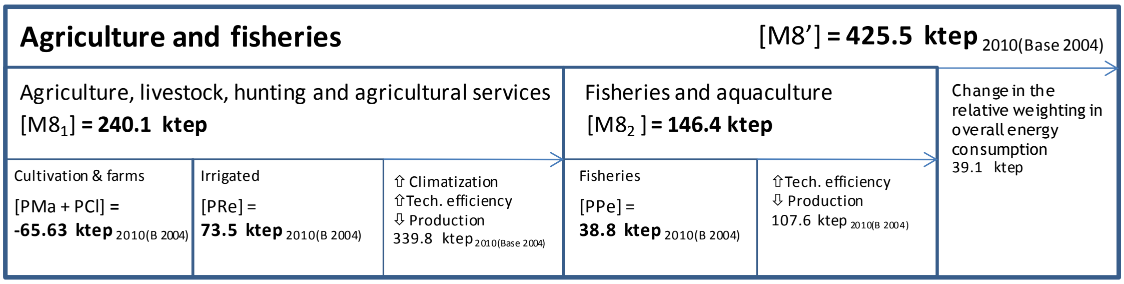
The savings obtained in the subsector of fishing and aquiculture correspond to direct action taken to reduce the consumption of electricity in the different types of vessel employed (38.8 ktoe), the economic downturn and the natural technological development of the fishing fleet (107.6 ktoe).

2. External perimeters

Despite its reduced share in national energy consumption, the agriculture and fisheries sector has a strategic value and measures affecting the efficient use of energy contribute significantly to its sustainability and competitiveness.

The breakdown of energy savings within the sector is shown in Figure 55, which gives the values obtained in 2010 with respect to the base year 2004 and where we can see that the sector is divided into two main subsectors.

Figure 55. *Breakdown of energy saving in the agriculture and fisheries sector in 2010 with respect to 2004*



In the following paragraphs we give the methods employed to calculate each of the energy-saving boundaries.

Method used

As an approximation, we can measure the efficiency of an economic activity as the change in consumption with respect to its broadest measurement, gross value added (GVA).

On this basis to determine the total savings achieved in the sector we employed an adapted version of the indicator *M8* recommended by the European Commission in its document *"Recommendations on Measurement and Verification Methods"*. For each branch of activity, this indicator is defined as the ratio between the final energy consumed by the subsector and the basic value added of the subsector, understood as net production at basic prices less intermediate consumption, as shown in the following expression:

$$M8' = \left[\left(\frac{E_t}{GVA_t} \right) \right]$$

where:
- *E*:Energy consumed
- *GVA* :Gross Value Added at basic prices

Thus the energy saving is calculated as the difference between the result of the *M8* indicator for the base year (2004 or 2007) and the calculation year multiplied by the gross value added of the calculation year (in this case 2010) according to the expression:

$$\text{Energy savings } M8' = \left[\left(\frac{E_{2004}}{GVA_{2004}} - \frac{E_t}{GVA_t} \right) \right] \cdot GVA_t$$

where:
- *E*:Energy consumed
- *GVA* :Gross Value Added at basic prices

In addition and on the same basis, the energy savings were calculated for each of the four main subsectors: agriculture, livestock, hunting and agricultural services (also known as "serviculture") — hereinafter collectively "agriculture" — by means of the new indicator *M8'*$_1$, while fisheries and aquaculture (hereinafter "fisheries") were calculated with the new indicator *M8'*$_2$.

$$M8'_{\text{Subsector}} = \left[\left(\frac{E_t^{\text{Subsector}}}{VAB_t^{\text{Subsector}}}\right)\right]$$

where:
- $E^{Subsector}$: Energy consumed by the subsector
- $VAB^{Subsector}$: Gross Value Added at the basic prices of the subsector

Key variables

Table 102 shows the variables having a direct bearing on calculation of the savings generated in this sector by means of the top-down indicators *M8, M8*$_1$ *and M8*$_2$.

Table 102. *Evolution of specific variables related to "M" indicators in the agriculture and fisheries sector in the period 2004-2010*

	2004	2007	2008	2009	2010
Total energy consumption in the sector [ktoe]	3,681.1	3,877.9	3,381.6	3,094.5	3,313.7
Energy consumption Agriculture [ktoe]	3,007.5	3,278.2	2,817.5	2,597.0	2,829.8
Energy consumption Fisheries [ktoe]	673.6	599.8	564.0	497.5	483.9
GVA total sector [M€]	23,896.7	24,900.5	24,370.9	24,597.2	24,273.7
GVA agriculture [M€]	22,505.5	23,611.1	23,167.4	23,224.0	22,972.1
GVA fisheries [M€]	1,391.2	1,289.4	1,203.5	1,373.2	1,301.6

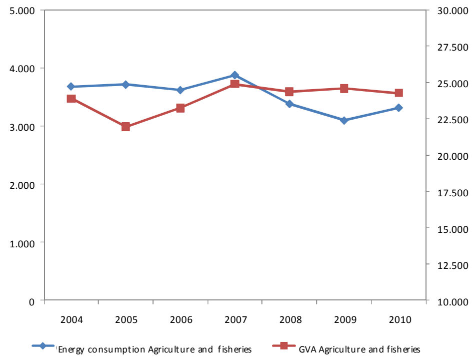
Source: MINISTERIO DE INDUSTRIA, TURISMO Y COMERCIO, MINISTERO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

The consumption of final energy in the period shows a downward trend (—10% between 2004 and 2010) due to the technological improvements in equipment in the two main subsectors plus a decline in production.

On the other hand, GVA moved upwards until 2007 (an increase of 4%) before falling in the last four years (—2.5%) as shown in Figure 56.

The fact that consumption fell while activity rose, generated savings in this subsector.

Figure 56. *Evolution of consumption and GVA in the agriculture and fisheries sector in the period 2004-2010*



Total savings achieved

To calculate the energy savings obtained in the period (Table 103) the *M8, $M8_1$ and $M8_2$* indicators were used, combined with the economic variables for the agriculture and fisheries sector shown in Table 102 necessary for purposes of calculation.

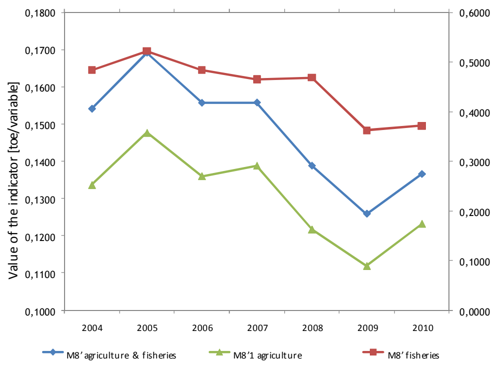
Table 103. *Energy saving in agriculture and fisheries sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Agriculture and fisheries	*M8'*	694.5	425.5
	Agriculture, livestock, hunting and forestry	*$M8'_1$*	506.5	240.1
	Fisheries and aquiculture	*$M8'_2$*	167.4	146.4
Base 2007 [ktoe]	Agriculture and fisheries	*M8'*	736.2	466.7
	Agriculture, livestock, hunting and forestry	*$M8'_1$*	627.4	359.7
	Fisheries and aquiculture	*$M8'_2$*	141.2	121.6

Table 104. *Evolution of M8´ and $M8_1$' and $M8_2$' indicators in the period 2004-2010*

		2004	2007	2008	2009	2010
M8'	Energy consumption agriculture and fisheries sector per GVA unit [ktoe/M€]	0.1540	0.1557	0.1388	0.1258	0.1365
$M8_1$'	Energy consumption livestock, hunting and forestry per GVA unit [ktoe/M€]	0.1336	0.1388	0.1216	0.1118	0.1232
$M8_2$'	Energy consumption fisheries and aquiculture per GVA unit [ktoe/M€]	0.4842	0.4651	0.4686	0.3623	0.3717

Figure 57. *Evolution of M8' and $M8_1$' and $M8_2$' indicators in the period 2004-2010*



According to readings within the study period 2004—2010 of the top-down *M8'* (Table 104) indicators savings of 425.5 ktoe were obtained. The subsector achieving most savings was agriculture, livestock, hunting and serviculture (240.1 ktoe) as opposed to fisheries and aquaculture (146.4 ktoe).

The following sections give the energy savings obtained by means of specific measures introduced by means of the Energy Savings Action Plan in the agriculture and fisheries sector:

- Improvement in irrigation systems by means of the switch from sprinkler systems to drip systems.
- Improvements in energy savings in the fisheries sector by means of energy audits, and subsidies to encourage the replacement of engines, propellers and other mechanical components of fishing vessels.
- Modernisation, by means of "Renove" schemes and energy labelling of farm tractors and improvements in the energy efficiency of farms.

3. Switch from sprinkler irrigation to drip irrigation

The purpose of this measure was to reduce the consumption of energy in those crops permitting a changeover from sprinkler irrigation to drip irrigation. To achieve this, measures such as amendment of the rules governing water use and technical and financial support for changing over to drip irrigation were introduced.

Method used

To calculate the savings obtained in this area the indicator *PRe* was developed. This indicator tracks the unit consumption employed in surface irrigation, understood as the relationship between total energy consumption and the number of hectares irrigated.

$$PRe = \left(\frac{E^{Reg}}{Has} \right)$$

where:
- E^{Reg} : Energy consumed in irrigation
- *Has:* Total hectares irrigated

Key variables

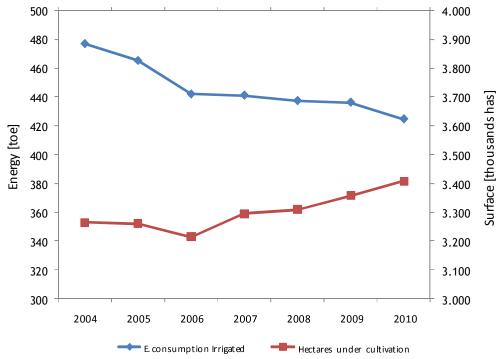
Energy consumption devoted to irrigation in the period showed a downward trend (—11% from 2004 and —4% between 2007 and 2010) as a result of the technological improvements in the irrigation systems. Meanwhile the trend in the number of hectares under cultivation was upward, moving from 3.26 million hectares in 2004 to 3.41 million in 2010, an increase of 4%, as shown in Figure 58.

Table 105. *Evolution of activity variables used in the irrigation use in the period 2004-2010*

	2004	2007	2008	2009	2010
Energy consumption irrigation [ktoe]	477	441	437	436	425
Surface under cultivation [has]	3,264,149	3,294,685	3,308,643	3,357,970	3,407,953

Source: IDAE

Figure 58. *Evolution of activity variables used in the irrigation use in the period 2004-2010*



Direct savings achieved

The total savings achieved in crop irrigation in terms of both direct savings and indirect savings was obtained by multiplying the difference in the values of the indicator for the base year (2004 or 2007) and the calculation year (2010) by the relative activity variable.

By way of example, for the *Pre* indicator the savings were:

$$\text{Energy savings } \ PRe = \left[\frac{E_{2004}^{Reg}}{Has_{2004}} - \frac{E_{2010}^{Reg}}{Has_{2010}} \right] \cdot Has_{2010}$$

To calculate the energy savings in the period (Table 106) the *PRe* indicator was used, applying the specific variables of the irrigated crop subsector, shown in Table 105.

Table 106. *Energy saving in the irrigation use in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Irrigation	*PRe*	54.6	73.5
Base 2007 [ktoe]	Irrigation	*PRe*	13.3	31.7

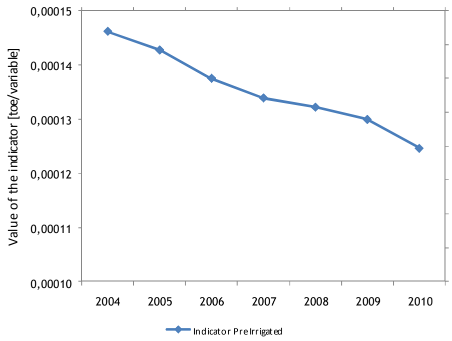
Thus, both for 2009 and 2010, for base years 2004 or 2007, we see final energy savings determined in the main by an improvement in the ratio of the energy consumption of irrigation and the land surface irrigated, expressed in hectares.

It should be noted that despite having extended by a small amount the land surface under irrigation in the period, the improvement in associated final energy consumption remained positive, particularly in the driest regions, such as Old and New Castille (a decline of —18% between 2004 and 2010) and Valencia (a decline of —13%).

Table 107. *Evolution of "Pre" indicator in the period 2004-2010*

		2004	2007	2008	2009	2010
PRe	Energy consumption related to irrigation per hectare [ktoe/ha]	0.000146	0.000134	0.000132	0.000130	0.000125

Figure 59. *Evolution of "Pre" indicator in the period 2004-2010*



The IDAE, using the funds of the Energy Efficiency Action Plan, supported replacement of sprinkler irrigation by drip irrigation with a total of 6.52 million euros in the period.

Table 108. *Subvention to the irrigation use in the period 2006-2010*

	2006	2007	2008	2009	2010
Switch from sprinkler irrigation to drip irrigation [k€]	-	2,800	946	1,391	1,749

Source: IDAE

4. Improvements in energy savings and efficiency in the fisheries sector

The energy efficiency improvements in the fisheries sector were articulated by means of investment in efficient technologies on board fishing vessels and in the technical and financial support for the economic studies and audits required for implementation.

To this end initiatives were implemented at various levels, such as with respect to deep-sea fishing gear, the routes taken by fishing vessels, plus the associated logistic, technical and technological aspects. On the technological side, improvements in power systems, such as the use of electric and hybrid marine engines, exhaust systems and propellers, were introduced, while there were parallel improvements in energy management, alternative fuels and other energy sources.

Method used

To estimate the savings obtained by the measure, "Improvement in energy savings and efficiency in the fisheries sector" it is necessary to know the rate of consumption of the "B" type diesel assigned to the fishing fleet. Also, it is necessary to find an appropriate variable to measure that consumption and thus determine the improvement in energy efficiency as the difference between the two pertinent unit consumptions.

To this end, the overall savings obtained by improvements to the energy efficiency of the fishing fleet were calculated by means of the indicator *PPe*, understood as the relationship between "B"-type diesel used by the fleet and the number of active fishing vessels, encompassing the three main categories of Spanish fishing vessels:

deep-sea, coastal and “artisan” or specialist vessels, the last mentioned being vessels fishing for specific species using purpose-made tackle.

$$PPe=\left(\frac{E^{Pesca}}{B}\right)$$

where:
- E^{Pesca} : Energy consumed in the fishing subsector
- *B*: Number of Spanish-flag fishing vessels

Key variables

The fuel consumption of the fishing fleet has been ascertained by a series of audits conducted by different administrative bodies on the deep-sea, coastal and specialist fleets.

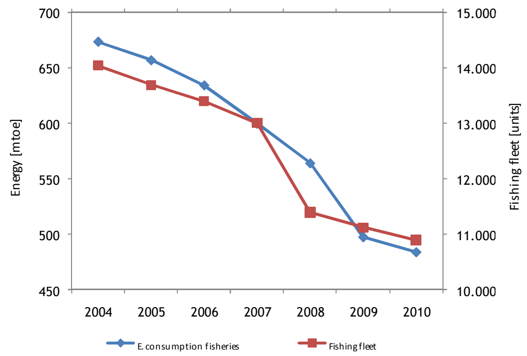
As Table 109 shows, the consumption of “B”-type diesel in the period analysed suffered a marked decline (—28% since 2004 and —18% since 2010), mainly as the result of the general downturn in the activity. This was reflected in the number of active vessels, which has fallen (—22%) over the last four years.

Table 109. *Evolution of activity variables related to fishing fleet use in the period 2004-2010*

	2004	2007	2008	2009	2010
Consumption of diesel B related to fishing fleet [ktoe]	673.6	599.8	564.0	497.5	483.9
Deep-sea, coastal and artisanal fleet [number of vessels]	14,041	13,006	11,394	11,116	10,893

Source: MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO, CETPEC, ICAEN, IDAE

Figure 60. *Evolution of activity variables related to fishing fleet use in the period 2004-2010*



Direct savings achieved

The total savings achieved in the fisheries sector includes both direct saving and indirect savings in terms of final energy consumption.

To calculate the energy savings obtained in the period (Table 110) the *PRe* indicator was applied to the relevant variables of the fisheries subsector, as stated in Table 109.

Table 110. *Energy saving in the fishing fleet use in 2009 and 2010 with respect to 2004 and 2007*

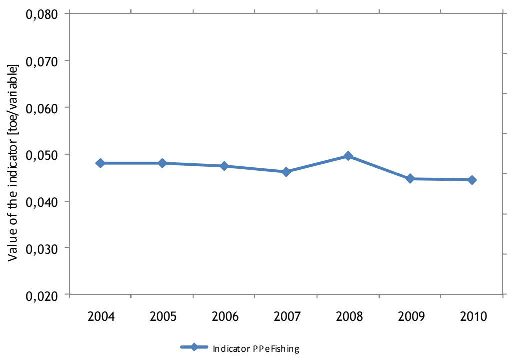
		Indicator associated	2009	2010
Base 2004 [ktoe]	Fisheries	*PPe*	35.8	38.7
Base 2007 [ktoe]	Fisheries	*PPe*	15.1	18.5

Thus in both 2009 and 2010, in comparison with 2004 or 2007 we find final energy savings determined in the main by an improvement in the ratio (see Table 111) relating to the relative consumption of "B"-type diesel with respect to fishing vessels.

Table 111. *Evolution of the "PPe" indicator in the period 2004-2010*

		2004	2007	2008	2009	2010
PPe	Energy consumption related to fisheries per vessel [ktoe/vessel]	0.04797	0.04611	0.04950	0.04476	0.04442

Figure 61. *Evolution of the "PPe" indicator in the period 2004-2010*



The IDAE, using the funds of the Energy Efficiency Action Plan, has funded the use of efficient technologies aboard fishing vessels, providing a total of 2.73 million euros in the period.

Table 112. *Subvention to the fishing fleet use in the period 2006-2010*

	2006	2007	2008	2009	2010
Improvements in energy savings and efficiency in the fisheries sector [k€]	-	-	1,003	459	611

Source: IDAE

5. "Renove" plan for tractors and energy efficiency on arable, livestock and fruit & vegetable farms

The main purpose of the "Renove" tractor action plan was to modernise the fleet of farm tractors. To this end measures were introduced via the Decree Law 1539/2006 governing grants obtainable under the "Tractor Renovation Plan" between 2007 and 2009 using objective energy efficiency criteria. However, to complete this analysis on the use of farm machinery, the study was extended to include all tools employed on a regular basis on crop and livestock farms.

It was also considered useful to analyse the energy consumption of air conditioning in livestock sheds and greenhouses as a means of completing the study on agriculture and fisheries.

Method used

To calculate the overall savings obtained from the "Renove" campaign for tractors and farm machinery, two indicators were used. The first is the *PMa,* which takes into account on the one hand the consumption of energy in powering machinery for crop, forestry or livestock farms and, on the other, the number of active farms, encompassing the full range of crop, livestock and fruit and vegetable farms.

$$PMa = \left(\frac{E^{\text{Maq.}}}{Ex_{\text{Ar.liv.\& farms.}}} \right).$$

where:

- $E^{Maq.}$: Energy consumption associated with farm machinery
- $Ex_{Ar.\ liv\ \&\ farms.}$: Number of arable, livestock and fruit & vegetable farms

Secondly, in order to assess the savings made in conditioning the temperature of livestock sheds and greenhouses the indicator *PCl* was used to relate on the one hand the energy consumed and, on the other, the number of livestock and fruit & vegetable (greenhouses) farms in operation.

$$PCl = \left(\frac{E^{\text{Climat.}}}{Ex_{\text{Liv\&farms.}}} \right).$$

where:

- E^{Climat}: Energy consumption of farm air conditioning
- $Ex_{Liv\ \&\ farms.}$: Number of livestock and fruit & vegetable farms

Key variables

According to the data referred to in Table 113 the energy consumed by farm, forestry and livestock machinery in the period concerned fell considerably, due in the main to the downturn in activity. This decline was similarly reflected in the numbers of farms now in use, the figures for which show a decline of —13% over the last four years (see Figure 62).

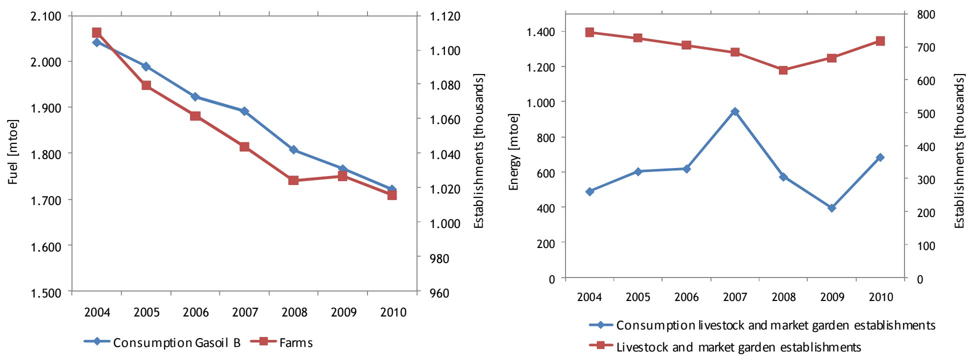
With respect to the second calculation, that of the energy consumed by livestock and fruit & vegetable farms, it increased by 40% between 2004 and 2010 to satisfy the energy requirements needed to boost production. The increase in relative consumption is reflected in the comparison with the number of livestock and fruit & vegetable farms, which in the last few years underwent a small decline,—4% (see Figure 62).

Table 113. *Evolution of activity variables related to exploitations use in the period 2004-2010*

	2004	2007	2008	2009	2010
Energy consumption related to farm machinery [ktoe]	2,041.3	1,891.7	1,807.5	1,765.4	1,720.9
Crop and livestock farms, greenhouses [number]	1,110,050	1,043,900	1,024,282	1,026,784	1,015,648
Energy consumption related to exploitations [ktoe]	489.22	945.42	572.78	395.39	684.41
Farms and greenhouses [number]	743,739	683,913	628,920	666,424	717,510

Source: IDAE

Figure 62. *Evolution of activity variables related to exploitations use in the period 2004-2010*



Direct savings obtained

To calculate the energy savings obtained in the period (Table 114) the indicators *PMa* and *PCl* were used, applying the required usage variables for farms given in Table 113.

Table 114. *Energy saving in the exploitations use in 2009 and 2010 with respect to 2004 and 2007*

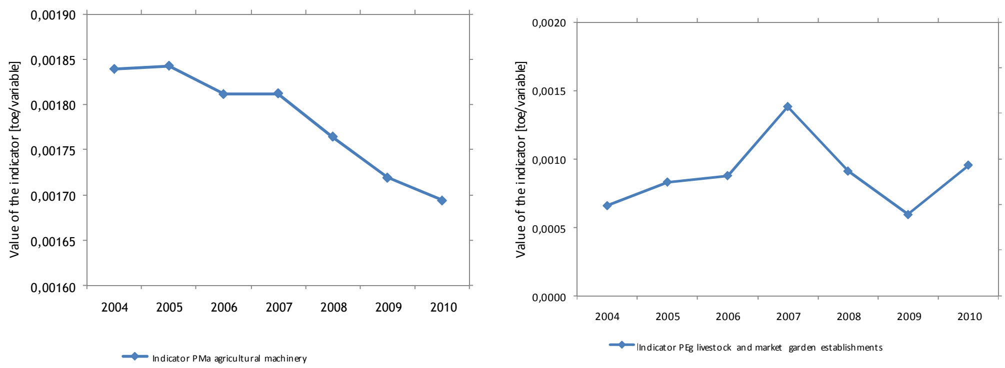
		Indicator associated	2009	2010
Base 2004 [ktoe]	Crop and livestock farms, plus market gardens	*PMa +PCl*	165.7	-65.6
	Machinery	*PMa*	122.7	146.8
	Air conditioning	*PCl*	43.0	-212.4
Base 2007 [ktoe]	Crop and livestock farms, plus market gardens	*PMa +PCl*	621.1	427.1
	Machinery	*PMa*	95.3	119.6
	Air conditioning	*PCl*	525.8	307.5

Thus in 2010, in comparison with either 2004 or 2007, positive energy savings were achieved, thanks in the main to an improvement in the ratio (see Table 115) between the consumption of “B”-type diesel fuel and the surface area, in hectares, under cultivation.

Table 115. *Evolution of “PMa” and “PCl” indicators in the period 2004-2010*

		2004	2007	2008	2009	2010
PMa	Energy consumption in machinery per exploitation [ktoe/exploit.]	0.001839	0.001812	0.001765	0.001719	0.001694
PCl	Energy consumption in air condition per exploitation [ktoe/exploit.]	0.000658	0.001382	0.000911	0.000593	0.000954

Figure 63. *Evolution of "PMa" and "PCl" indicators in the period 2004-2010*



As stated at the beginning of this section, the IDAE, using the powers provided under the Energy Efficiency Action Plan, has helped fund improvements on arable, livestock and fruit & vegetable farms, with a sum of 118.2 million euros, which includes the cost of the "Renove" tractor replacement scheme.

Table 116. *Subvention to mechanisms related to exploitations use in the period 2006-2010*

	2004	2005	2006	2007	2008	2009	2010
Training for efficient use of energy [k€]	-	-	935	1,355	956	-	859
Energy audits of farms [k€]	-	-	362	308	982	1,522	2,138
"Renove" tractor replacement scheme and improving energy efficiency [k€]	-	-	1,508	34,912	48,887	20,138	1,215
Migration to conservation agriculture [k€]	-	-	-	-	93	464	1,580

Source: MNISTERIO MEDIO AMBIENTE, MEDIO RURAL Y MARINO, IDAE

Table 117. *Number of replaced tractors in "Renove" scheme in the period 2006-2010*

	2004	2005	2006	2007	2008	2009	2010
"Renove" tractor replacement scheme and improving energy efficiency [tractors]	-	-	548	2,164	3,558	1,948	123

Source: MINISTERIO MEDIO AMBIENTE, MEDIO RURAL Y MARINO, IDAE

6. Energy savings obtained in agriculture and fisheries as at 2010

Thus the agriculture and fisheries sector achieved energy savings of 425.5 ktoe between 2004 and 2010. 62% of the savings were made in agriculture and 38% in fisheries.

For an economic sector such as agriculture and fisheries the most suitable indicator for measuring energy savings is probably the *M8'*. This is because although it encompasses a broad range of effects, its activity variables are more closely aligned with the sector than those of the *PRe*, *PPe*, *PMa* and *PCl* indicators.

Table 118. *Energy saving in agriculture and fisheries sector in 2009 and 2010 with respect to 2004 and 2007*

		Indicator associated	2009	2010
Base 2004 [ktoe]	Agriculture and fisheries	*M8'*	694.5	425.5
	Agriculture, livestock, hunting and forestry	*$M8'_1$*	506.5	240.1
	Fisheries and aquiculture	*$M8'_2$*	167.4	146.4
Base 2007 [ktoe]	Agriculture and fisheries	*M8'*	736.2	466.7
	Agriculture, livestock, hunting and forestry	*$M8'_1$*	627.4	359.7
	Fisheries and aquiculture	*$M8'_2$*	141.2	121.6

In addition it is possible to make a distinction between the total savings achieved within the sector's external perimeters and direct savings, whether occurring naturally or by design. Finally, in the last section, we give the indirect savings occurring within the sector.

6.1. Indirect effects

Between the external perimeter (425.5 ktoe) obtained by use of the indicator *M8'* and the internal perimeters (386.4 ktoe) obtained by adding together the results of indicators *M81'* and *M82'* we see a difference of 39.1 ktoe related to the change in the relative weighting of each subsector in overall energy consumption. The percentage consumption of the agriculture subsector moves from 82% in 2004 to 85% in 2010, showing a consumption per unit of GVA in 2010 (0.12 ktoe per GVA) which is lower than that of fisheries (0.37 ktoe/GVA).

Agriculture, livestock, hunting and agricultural services

In this subsector certain indirect effects between the external perimeter and the accounted for savings of 232.2 ktoe, due in the main to:

- A reduction in agricultural production (—2.2% in 2004—2007) due to the recession.
- An unquantifiable improvement in the efficiency of energy use as a consequence of technological improvements in farm machinery and irrigation systems.

Also, the savings resulting from other schemes implemented under the Action Plan may also be regarded as indirect effects:

- Sustainable rural development plan (PDRS in Spanish), implemented under Decree Law 752/2010.
- Information and awareness programmes (training programmes). Energy audits and action plans implemented on crop, livestock and fruit and vegetable (greenhouse) farms.
- Subsidies to promote sustainable farming.

Fishing and aquaculture

With respect to the indirect or unquantifiable effects on fishing and aquaculture, 131.1 ktoe of energy savings have been estimated, relating in the main to:

- A fall in catches resulting from legal restrictions to protect endangered species and from the present economic recession.

- An unquantifiable gradual reduction in energy consumption due to technological improvements in key components of fishing vessels such as propellers, hybrid electric-diesel engines, etc.

The savings may also be regarded as the indirect effects of other schemes whose results could not be accounted for directly:

- Encouraging the use of techniques designed to foster efficient energy use in the fisheries and aquaculture subsector.
- One-off campaigns having an impact on energy efficiency in the sector, such as subsidies for modernising engines and propellers, the use of alternative fuels, and the project known as “Peixe Verde” (“Green Fish” in Galician).

6.2. Double accounting

No risk of incurring double accounting was detected in calculating the savings obtained in the subsectors examined.

VII. ENERGY CONVERSION SECTOR

1. Summary of savings

ENERGY CONVERSION SECTOR

The *Energy Conversion* Sector covers all activities converting primary energy into final energy. It thus covers the generation of electricity, the refining of oil and co-generation.

The *Energy Conversion* Sector generated primary energy savings of 9,767 ktoe in 2010, using 2004 as the base year, resulting in the main from improvements in the efficiency of the electric power generating equipment.

Sector consumption

	Final energy 2010 [ktoe]	Primary energy 2010 [ktoe]
TOTAL CONSUMPTION SECTOR	**77,294**	**108,032**
ELECTRIC POWER GENERATION	22,861	49,249
PETROLEUM REFINING	54,433	58,783

Total savings

	Final energy saving 2010 [ktoe]		Primary energy saving 2010 [ktoe]		$C0_2$ emissions avoided 2010 [$ktCO_2$]	
	Base 2004	Base 2007	Base 2004	Base 2007	Base 2004	Base 2007
TOTAL SAVINGS SECTOR	**N/A**	**N/A**	**9,767**	**7,019**	**51,797**	**53,254**
ELECTRIC POWER GENERATION	N/A	N/A	9,482	6,909	51,466	52,947
PETROLEUM REFINING	N/A	N/A	72	39	38	186
CO-GENERATION	N/A	N/A	213	71	293	121

Conclusions

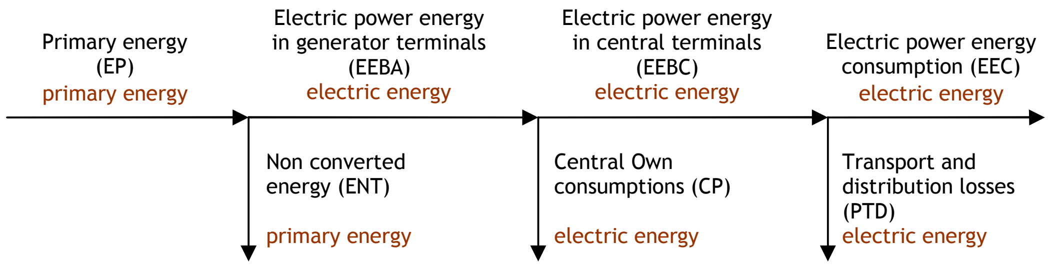
In 2010 of a total consumption in Spain of primary energy of 131,927 ktoe, 62,358 ktoe (47%) was oil, mostly refined in Spanish refineries, and 49,249 ktoes (37%) was consumed in the production of electricity for the domestic market. These volumes underline the importance of energy efficiency in the energy conversion sector.

In the period studied almost all the savings achieved resulted from improvements in the overall performance of electricity generation. Thus in 2010 the saivngs in electricity generation were 9,482 ktoe, with 2004 as base year. The oil refining sector achieved savings in 2010 with respect to 2004 of 72 ktoe, mainly from a reduction in losses. The power cogeneration sector achieved primary energy savings of 213 ktoe, resulting from the high efficiency of producing heat and electricity at the same time as opposed to separating these two energy flows.

2. Electric power generation

2.1. Method used

The method used to obtain the primary energy savings associated with electric power generation is detailed here in its component parts of the energy conversion itself, the inputs required by the power stations, and the transport and distribution of consumable power. The following diagram sets out the various energy formats.



In this way the total amount of primary energy saved in the generation of electricity is obtained by adding the three sources of potential savings as per the following formula:

$$AEP_{\mathrm{a}} = AEP_{ENT-\mathrm{a}} + AEP_{CP-\mathrm{a}} + AEP_{PTD-\mathrm{a}}$$

where:

- AEP_{a}: primary energy savings in electricity generation in the year 'a' with respect to the reference year
- $AEP_{\mathrm{ENT\text{-}a}}$:savings in primary energy resulting from efficiency in energy transformation in year 'a' with respect to the base year
- $AEP_{\mathrm{CP\text{-}a}}$:savings in primary energy resulting from effiency in own consumption in year 'a' with respect to the base year
- $AEP_{\mathrm{PTD\text{-}a}}$:savings in primary energy resulting from efficiency in transport and distribution networks in year 'a' with respect to the base year

Primary energy savings obtained by efficient energy conversion

The primary energy saved by making the process of transforming primary energy into electric energy can be expressed as follows:

$$AEP_{\mathrm{ENT-a}} = \frac{EEBA_{\mathrm{a}}}{\eta_{EEBA/EP-ref}} - EP_{\mathrm{a}}$$

where:

- $EEBA_{\mathrm{a}}$:total electric power in alternator terminals produced in year 'a'.
- EP_{a}: total primary energy employed in year 'a'
- $\eta_{EEBA/EP\text{-}ref}$: yield between EEBA and EP in the base year, calculated as follows:

$$\eta_{EEBA/EP-ref} = \frac{EEBA_{\mathrm{ref}}}{EP_{\mathrm{ref}}}$$

Savings of primary energy resulting from reduced consumption in the transformation process

The savings resulting from reduced power consumption within generating stations are estimated according to the following expression:

$$AEP_{\mathrm{CP-a}} = \frac{EEBC_{\mathrm{a}}}{\eta_{EEBC/EP-ref}} - \frac{EEBA_{\mathrm{a}}}{\eta_{EEBA/EP-ref}}$$

where:

- $EEBC_{\mathrm{a}}$: total electric energy at source in the year 'a'
- $EEBA_{\mathrm{a}}$: total electric energy at the alternator terminal in the year 'a'
- $\eta_{EEBA/EP\text{-}ref}$: yield between EEBA and EP in the base year
- $\eta_{EEBC/EP\text{-}ref}$: yield between EEBC and EP in the base year, calculated as:

$$\eta_{EEBC/EP-ref} = \frac{EEBC_{\mathrm{ref}}}{EP_{\mathrm{ref}}}$$

Savings of primary energy through reduced transport and distribution losses

Similarly, the savings resulting from reduced losses in transporting and distributing the generated electricity are expressed as:

$$AEP_{\mathrm{PTD-a}} = \frac{EEC_{\mathrm{a}}}{\eta_{EEC/EP-ref}} - \frac{EEBC_{\mathrm{a}}}{\eta_{EEBC/EP-ref}}$$

where:

- EEC_{a}: *total electric energy at source consumed in year 'a'*
- $EEBC_{\mathrm{a}}$: *total electric energy at the station terminals in year 'a'*
- $\eta_{EEBC/EP\text{-}ref}$: yield between EEBC and EP in the base year
- $\eta_{EEC/EP\text{-}ref}$: yield between EEC and EP in the base year, calculated as:

$$\eta_{EEC/EP-ref} = \frac{EEC_{\mathrm{ref}}}{EP_{\mathrm{ref}}}$$

2.2. Key variables in calculating savings

To assess the savings in primary energy obtained within the electricity generation sector in the period studied in a manner adapted to the methods given above, we use the list of activity variables shown in Table 119.

Table 119. *Evolution of the activity variables related to the electric power generation sector in the period 2004-2010*

	2004	2007	2008	2009	2010
Primary energy used [ktoe]	53,096	57,352	56,172	50,995	49,249
Hydraulic	2,952	2,625	2,246	2,510	3,898
Nuclear	16,576	14,360	15,368	13,750	16,102
Coal and Ordinary Regime (OR)	17,839	17,298	11,109	8,218	5,977
Fuel and natural gas in OR (without CCGT)	4,115	3,704	3,178	3,153	2,342
Combined Cycle (CCGT) in OR	5,414	11,287	15,237	13,406	10,680
Coal, oil and NG in Special Regime (SR)	3,717	4,150	4,527	4,572	4,183
Biomass and Waste	1,079	1,512	1,487	1,560	1,497
Solar thermoelectric	0	3	6	40	271
Other renewable thecnologies	1,404	2,414	3,013	3,787	4,299
Electric power generator terminals [GWh]	276,358	311,125	317,862	296,457	300,241
Hydraulic	34,324	30,519	26,117	29,184	45,321
Nuclear	63,606	55,102	58,971	52,761	61,788
Coal and Ordinary Regime (OR)	80,097	74,203	49,018	36,106	24,730
Fuel and natural gas in OR (without CCGT)	17,912	11,731	11,309	11,227	10,544
Combined Cycle (CCGT) in OR	28,974	72,219	95,529	82,253	68,303
Coal, oil and NG in Special Regime (SR)	32,097	35,639	37,240	36,012	33,986
Biomass and Waste	3,023	3,635	4,625	4,781	4,891
Solar thermoelectric	0	8	16	103	691
Other renewable thecnologies	16,325	28,069	35,037	44,030	49,987
Own consumptions [GWh]	11,399	11,995	11,679	10,462	9,956
Transport and distribution losses [GWh]	24,635	27,649	27,438	25,830	24,456

Source: MITYC

2.3. Savings obtained

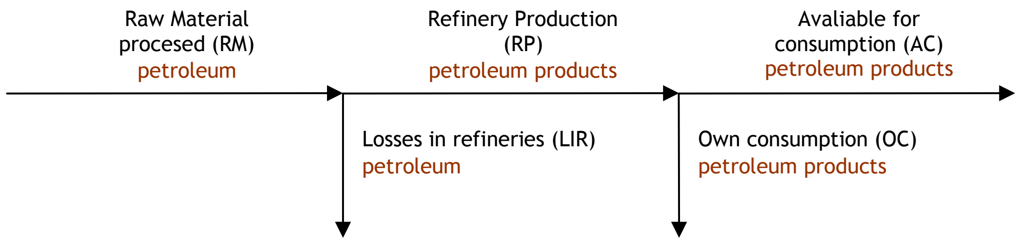
The total primary energy savings achieved in the process of generating electricity in 2010 in comparison with 2004 total 9,482 ktoe. This figure is obtained by adding together the improvement in efficiency in energy conversion (8,435 ktoe), the reduction in own consumables in the generating stations (487 ktoe) and the reduction in transport and distribution losses (560 ktoe).

With respect to the savings as from 2007, the total saving in primary energy was 6,909 ktoe. This breaks down into 6,097 ktoe in energy conversion, 310 ktoe in reduced consumables in the generating stations, and 502 ktoe from the reduction in transport and distribution losses.

3. Oil refining

3.1. Method used

The improvement in the efficiency of the refining sector is the result of having reduced refining losses and the changes in refinery inputs. The following diagram shows the relationship between primary energy, refinery production and the amount of oil-based products consumed in the process.



The savings in primary energy are calculated as follows:

$$AEP_a = \frac{DC_a}{\eta_{DC/MP-ref}} - MP_a$$

where:

- AEP_a: primary energy saving in refining oil in year 'a' with respect to the base year
- DC_a: energy of oil products produced in refineries for final consumption in year 'a'
- MP_a: energy of raw material (oil) consumed in refineries in year 'a'
- $\eta_{DC/MP-ref}$: yield between DC and MP in the base year, calculated as:

$$\eta_{DC/MP-ref} = \frac{DC_{ref}}{MP_{ref}}$$

3.2. Key variables in calculating savings

In order to calculate the savings in primary energy in the oil-refining sector in the period according to the method given, the list of activity variables set out in Table 120 is used.

Table 120. *Evolution of the activity variables related to the petroleum refining sector 2004-2010*

	2004	2007	2008	2009	2010*
Raw material processed [ktoe]	61,201	61,539	62,253	58,835	58,783
Losses in refineries [ktoe]	610	528	599	528	526
Refinery production [ktoe]	60,591	61,011	61,653	58,307	58,257
Own consumption [ktoe]	3,988	4,063	4,132	4,028	3,824
Available for consumption [ktoe]	56,603	56,948	57,521	54,279	54,433

Source: CORES

* 2010 has been estimated is based on information from MITyC (losses and own consumption) and AOP (available for consumption).

3.3. Savings obtained in oil refining

In 2010 with respect to 2004 a saving in primary energy of 72 ktoe was calculated; with respect to 2007 the saving was 39 ktoe.

4. Encouraging co-generation

4.1. Method used

In the case of cogeneration, the savings in primary energy are calculated by comparing its efficiency with that of conventional systems used for generating electric and thermal energy. The expression used is as follows:

$$AEP_a = \frac{E_a}{Ref\ E_{ref} \cdot FC_{ref}} + \frac{H_{CHP-a}}{Ref\ H_{ref}} - F_a$$

where:

- AEP_a: primary energy generated by new cogenerations in year 'a'
- E_a: electrical energy generated by new cogenerations in year 'a'
- $Ref\ E_{ref}$: electrical yield of conventional electrical generation in the base year
- FC_{ref}: convertsion factor for connection voltage in the base year[11],
- H_{CHP-a}: useful heat generated by new congenerations in year 'a'
- $Ref\ H_{ref}$: yield of conventional thermal generation in the base year
- F_a: consumption of primary energy from new cogenerations in year 'a'

4.2. Key variables in calculating the savings made in cogeneration

To calculate the savings obtained in the different measurements of cogeneration, according to the methods and criteria stated above, the activity variables shown in Table 121 are used.

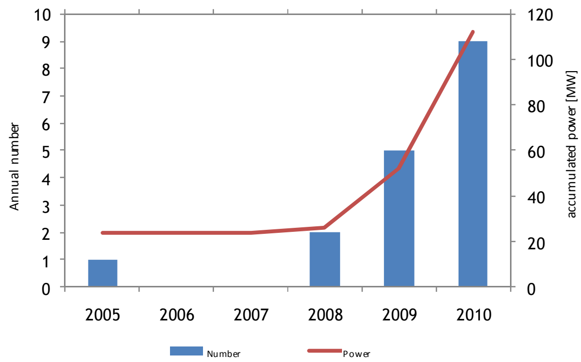
Table 121. *Evolution of the activity variables related to the cogeneration sector* in the period 2007-2010

		2007	2008	2009	2010
Promotion of small power plants					
Base 2004	Electric power energy generated (GWh)	-	-	0.29	0.29
	Total heat produced (Gcal)	-	-	502	502
	Total fuel consumed (TJ)	-	-	3.66	3.66
Base 2007	Electric power energy generated (GWh)	-	-	0.29	0.29
	Total heat produced (Gcal)	-	-	502	502
	Total fuel consumed (TJ)	-	-	3.66	3.66
Promotion of installations of non-industrial activities					
Base 2004	Electric power energy generated (GWh)	558	522	920	920
	Total heat produced (Gcal)	485,653	468,259	825,303	825,303
	Total fuel consumed (TJ)	5,628	5,321	9,407	9,405
Base 2007	Electric power energy generated (GWh)	-	-	229	316
	Total heat produced (Gcal)	-	-	299,271	283,831
	Total fuel consumed (TJ)	-	-	2,792	3,235
Promotion of installations of industrial activities					
Base 2004	Electric power energy generated (GWh)	1,285	1,614	2,312	2,331
	Total heat produced (Gcal)	1,368,838	1,450,098	2,447,601	2,467,562
	Total fuel consumed (TJ)	14,274	16,507	25,497	25,700
Base 2007	Electric power energy generated (GWh)	-	232	915	1,033
	Total heat produced (Gcal)	-	183,426	1,169,258	1,093,719
	Total fuel consumed (TJ)	-	2,255	11,129	11,391

[11] According to Annex IV of Commission Decision of 21 December 2006 in accordance with the Directive 2004/8/CE

As for substantial modification, 17 cogeneration plants renovated their installations between 2005 and 2010. The number and output rating of the renovated installations are given in Figure 64.

Figure 64. *Number of power substantive changes in co-generation plants in the period 2005-2010.*



Source: Ministerio de Industria, Turismo y Comercio

In order to quantify the savings obtained from substantial modifications, the increase in the electrical output of the renovated versus the original plant was taken into account, together with the runtime hours according to the technical specifications of the 17 plants concerned. In each case the technology of the plant and the subsector to which it belongs was taken into account.

4.3. Savings obtained in cogeneration

The savings in primary energy resulting from cogeneration in special regime in 2010 with respect to 2004 was 213 ktoe. This saving can be categorised by size of plant and by the sector to which the heat user belongs. Thus, the contribution of small-powered (< 150 kW) plants is 32 ktoe, that associated with non-industrial use is 49 ktoe, and that employed in industrial processing represents the greatest saving, 159 ktoe. In addition plant installations of up to 60 MW have conducted significant modifications, resulting in a contribution of 6 ktoe.

With respect to the primary energy savings in 2010 v. 2007, the total is 71 ktoe, 10 ktoe from small-powered plants, 10 ktoe from cogeneration with non-industrial activities, 55 ktoe from cogeneration with industrial activities, and 6 ktoe from plants that have undergone substantial modification.