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Energy Savings and Carbon Emission Reduction of Smart Lighting Installation in a Multipurpose and Residential Building in Santiago de Compostela, Spain

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ABSTRACT

The excessive emissions of greenhouse gases into the atmosphere has increased the global average temperature resulting to a phenomenon known as global warming. One of the major greenhouse gasses is CO_2 and the various efforts are focused on curbing its emissions. Using the case of a multipurpose and residential building at the University of Santiago de Compostela in Northwestern Spain, this study assessed the environmental impact of installing smart lighting. This study quantifies the CO_2 emission reduction, and economic cost associated to the technical improvement. Such action resulted to saving 126 MWh and a reduction of carbon emissions of 25 T annually, with a return period of six years.

Key words: *Efficient lighting, energy saving, greenhouse effect, residential lighting*

INTRODUCTION

In 1988, the United Nations held a meeting to establish the first Intergovernmental Panel for Climate Change (IPCC), with the aim of studying the causes of the increasing average temperature on Earth, commonly known as global warming (*Pachauri et al. 2007; Meinshausen et al. 2009*). This meeting was instrumental for the signing of the Kyoto Protocol eleven years later. Developed countries, including all belonging to the European Union, ratified a commitment to decrease the release of greenhouse gasses (CO_2, CH_4, SF_6 and others) , with the main objective of curbing CO_2 emissions below 1990 levels (**Figure 1**) by 2008-2012, through the achievement of a worldwide reduction of 5.2 % (*European Council 1997*).

On the whole, the European Union-15 established a cut down of 8 % in the period between 2008-2012, to achieve the set 1990 level. For instance, Luxembourg, Germany and Denmark's 28%, 21% and 21% targeted reduction respectively were perceived to have required more efforts to be realized. Spain, Portugal, Ireland, and Greece were allowed to increase emissions considering their lower industrialization level in 1990. Reduction of emissions of greenhouse gases was to be considered after 2012 (**Table 1**).

Carbon dioxide emissions are strongly associated to energy consumption these originated from the combustion of hydrocarbons (oil, natural gas and coal) either directly burned (transport and heating) or for generation of electricity in power plants (*Smale et al. 2006*). Therefore, the Spanish Government through the Ministries of Industry and Environment and the different regional Industry or Environment departments approved new regulations and programs in order to decrease the greenhouse gases, specifically CO_2.

In spite of the efforts undertaken by the different government agencies, the progress in the period 1990-2000 suggested that the objectives were not accomplished. Some countries such as Sweden, Luxembourg, Greece, France, and Finland were fulfilling the goals while many countries were releasing more CO_2 than what has been set (**Figure 2**).

In 2002, Spain was the European country with the worst results as no measures were undertaken to significantly lessen its emission such as in year 2004 when the country exceeded about 50% than what has been established in Kyoto. Since then, both central and regional governments approved different programs with the aim of reducing emissions. In the evolution of CO_2 emissions in Spain a declining trend from 2007 can be observed which could be due to the economic crisis and the effect of earlier-instituted environmental policies.

Another relevant issue is that Spain has a huge energy deficit. Over 80 % of the primary energy consumption comes from abroad. Among the national sources, coal is scarce and expensive, while fossil fuels produced nationally are insignificant and the construction of new nuclear power

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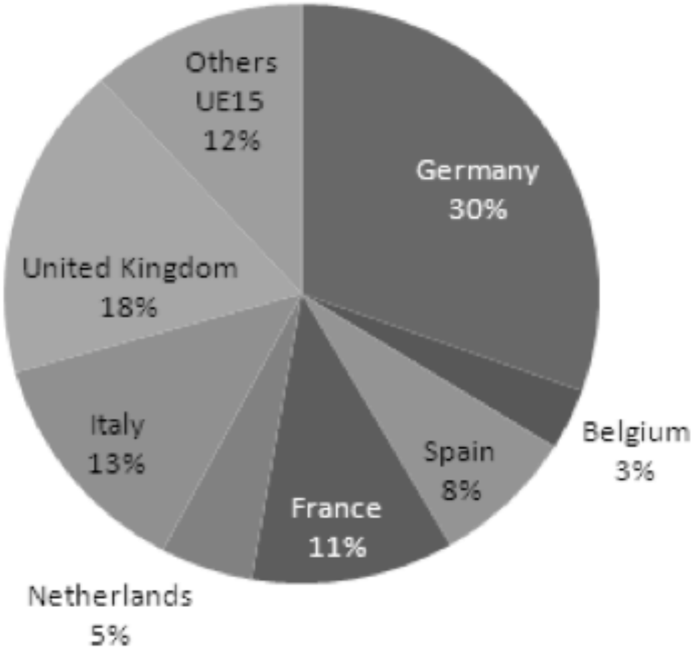

Figure 1. Emissions of CO_2 in the EU-15 (1990).
Source: Ministry of Environment of Spain (2005).

plants has been discarded. Therefore, the only energy source with a promising future is renewable energy, however, only if coupled with a higher energy efficiency (*Energy Saving Institute 1999*; *Dincer 2002*). For the renewable energy sources, efforts were made by the Spanish Ministries of Industry and Environment the country as one of the international leaders of wind and solar power. Both types of energy were favored by a new economical regime established in the Law 54/1997 of regulation of the electric system. This

Table 1. Emissions of CO_2 and objectives 2008-2012.

Country	CO^2 objetive in 1990 (Mton)	Objetive 2008-2012
Australia	289	8%
Belgium	113.4	-8%
Canada	457	-6%
Denmark	52.1	-21%
Finland	53.9	0%
France	366.6	0%
Germany	1012.4	-21%
Greece	82.1	25%
Ireland	30.7	13%
Italy	429	-7%
Japan	1173.4	-6%
Luxembourg	11.3	-28%
Netherlands	167.6	-6%
New Zealand	25.5	0%
Norway	35.5	1%
Portugal	42.1	27%
Russian Federation	2388.7	0%
Spain	260.7	15%
Sweden	61.3	4%
Ukraine	919.2	0%
United Kingdom	584.1	-13%
USA	4957	-7%
UE 15	3325.8	-8%

Source: Ministry of Environment of Spain (2005).

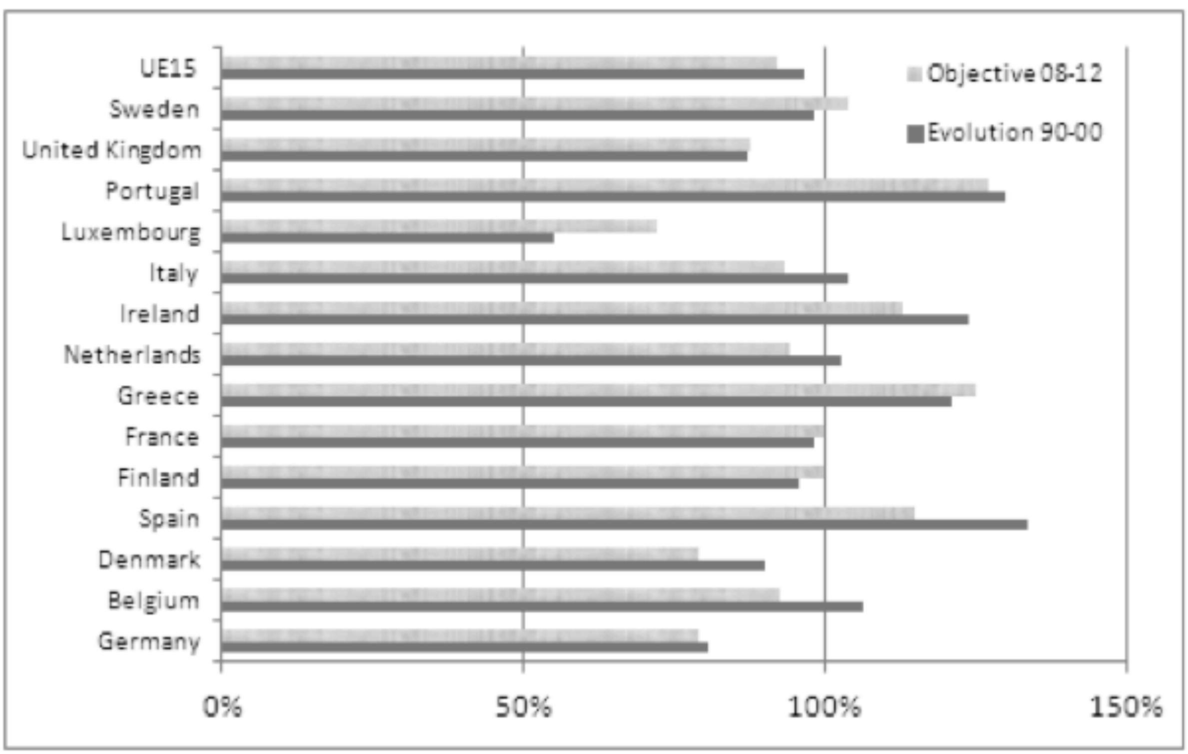

Figure 2. Emissions of CO_2 in1990-2000 and the Kyoto's objectives in 2008-2012.
Source: *European Environmental Agency* (*2002*), *Sánchez-Chóliz et al.*(*2008*).

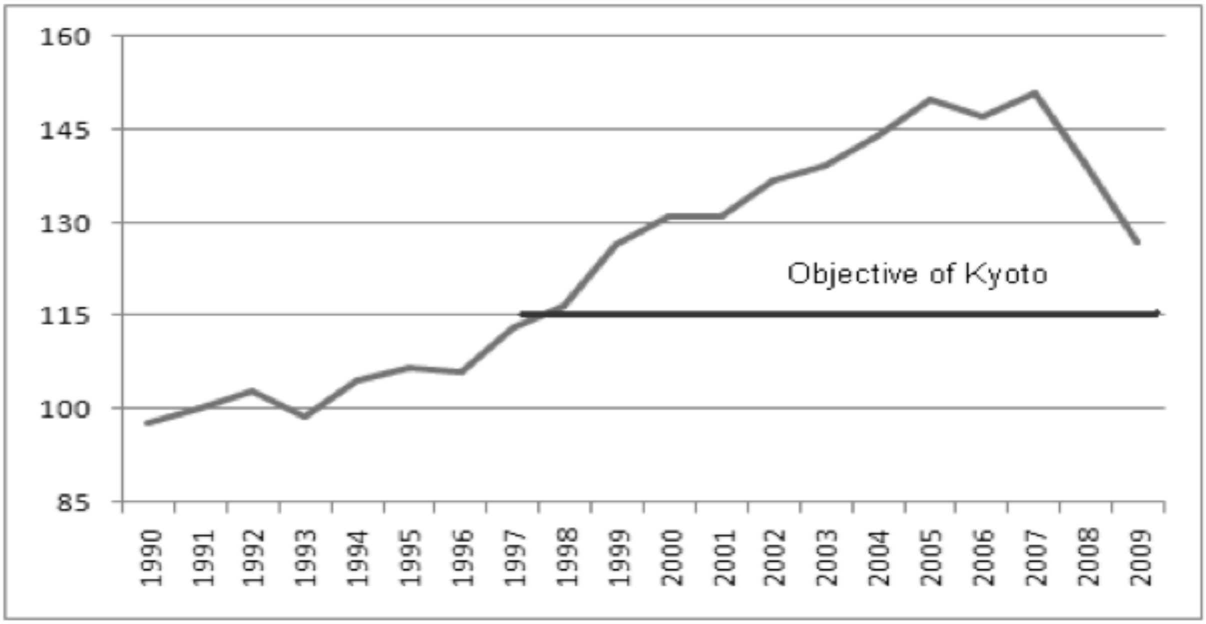

Figure 3. Evolution of emissions of CO_2 equivalent in Spain (%).
Source: (*Ministry of Environment of Spain 2010*).

law established an Ordinary Regime (for electricity produced by traditional means) and a Special Regime for renewable energy (wind, solar both photovoltaic and thermoelectric, and geothermal) as well as for cogeneration and burning of municipal solid waste, sewage sludge and forest biomass in high efficiency systems. Special regimes resulted to price premiums depending on the energy source, age, and efficiency of the facility, which reassured the profitability of the installation. On top of this, subsidies are given for construction of renewable energy facilities (*Menéndez Pérez 2004*). The other way of achieving the objectives of Kyoto is by improving energy efficiency. The Spanish Government has signed many regulations with aim of promoting energy efficiency such as the "Strategy for energy saving and efficiency in Spain 2004-2012 (E4)" approved in November 2003 as transposition of the European Directive 2002/91/CE in Spain. The Strategy E4 is a general document, which is concreted in the Action Plan 2005-2007. The Action Plan 2005-2007 identified some specific measures to decrease the emissions across several sectors. Among these are the buildings, thermal isolation improvement and heating efficiency of boilers and lightings. All these measures can be considered in the initial design particularly for new buildings or in successive refurbishments. This plan proposes different mandatory and voluntary measures that are financed with non-recoverable subsidies. Though, applicants may shoulder most of the initial investments.

Competences for decreasing CO_2 emissions (regulations, subsidies, etc.) are shared between central and regional governments in Spain. The Ministries of Industry and Environment and the regional governments have granted subsidies until 2007. From this year on, only regional governments maintained such function, though

Figure 4. Monte da Condesa building in Santiago.

occasionally local councils are also involved. In Galicia, a region in the Northwest of Spain, subsidies are given by the Galician Institute for Energy (Instituto Enerxético de Galicia, I.N.E.Ga) to promote the reduction of GHG emissions (*Institute of Energy of Galicia 2007*).

BUILDING HISTORY

This study focused on Monte da Condesa (**Figure 4**), which is a huge multipurpose building where a university residence, the Optical College of the Electronic Physics Department, the Institute of Orthopedics and the Laboratory of Archeology, are all located. The total built surface area is 27,000 m^2 which 10 % are corridors and halls. It was designed as a maternity hospital based on a project from the 80's. Once the building was completed an administrative problem hampered its use until the University of Santiago de Compostela (USC) bought it in the 90s. To save money, the original facilities (electricity, heating, and plumbing) were used, although aging and may have problems on energy efficiency.

Regarding the lighting, the original project was designed for a hospital building with facilities working 8,700 hr yr^{-1} and ensuring a high illuminance in halls, corridors and rooms. For higher efficiency while taking into account the current use as a university residence, a reduction of illuminance in seldom used areas, specifically switching off luminaries next to windows with enough daylight was recommended. The demand to implement new lighting installation has been raised by various building users particularly the residence staff.

MATERIALS AND METHODS:

Description of the new lighting facility

The new lighting facility is based on the discrimination of common lighting in the residence (corridors, halls) in three groups: 24 hr, Morning, and Evening-Night. The first group of luminaries would be switched on continuously all day long in highly-frequented and used areas (main hall, library, TV rooms), while the other two categories would be connected alternatively depending on the solar light from outside: "Morning" lights would be switched on with the daylight, while when it is not enough, "Evening-Night" lights would take the turn. These two categories would be installed in common areas, specifically in corridors.

Also the illuminance was too high for the final use, as the building was designed like a hospital. With the aim of decreasing the illuminance, the 2 x 36 W recessed luminaries were replaced by a unique superficial 1 x 36 W. Also, some of the 4 x 36 W luminaries were replaced by 1 x 36 W, while the reflector was renovated in some. Reduction of illuminance would not pose a problem for residential use as visual demands are lower than for sanitary use.

These measures were aimed to decrease the installed power, due to the substitution of luminaries as well as the reduced operating hours ("Morning" and "Evening-night" discrimination would allowed for 50 % reduction in these groups of luminaries). On top of the obvious economical and environmental benefits, a reduction in the time consumed by maintenance staff changing luminaries would be achieved due to the low number of luminaries, their lower use and the ease of substitution after changing recessed luminaries by superficial ones. This action was raised in two phases:

Phase 1. Ground, First and Second floors were made in 2008: This includes the changing of the lights that were initially switched on 24 hours a day to three groups (24 hours, Morning and Evening-Night). The new lighting set up are 1 x 36 W on the surface (previously some were recessed, 2 x 36 W and 4 x 36 W).

Phase 2. This second task included the Third, Fourth and Fifth floors and was held in 2009. These luminaries worked on continuously in two groups (Morning and Evening-Night). In these floors, it is not necessary to maintain a lighting 24 hours in any area. Originally, these luminaries were recessed 2 x 36 W and now they are 1 x 36 W on surface.

The total estimated cost of the two phases was € 110,000.00 (US $ 146,300.00). The real cost was € 95,000.00

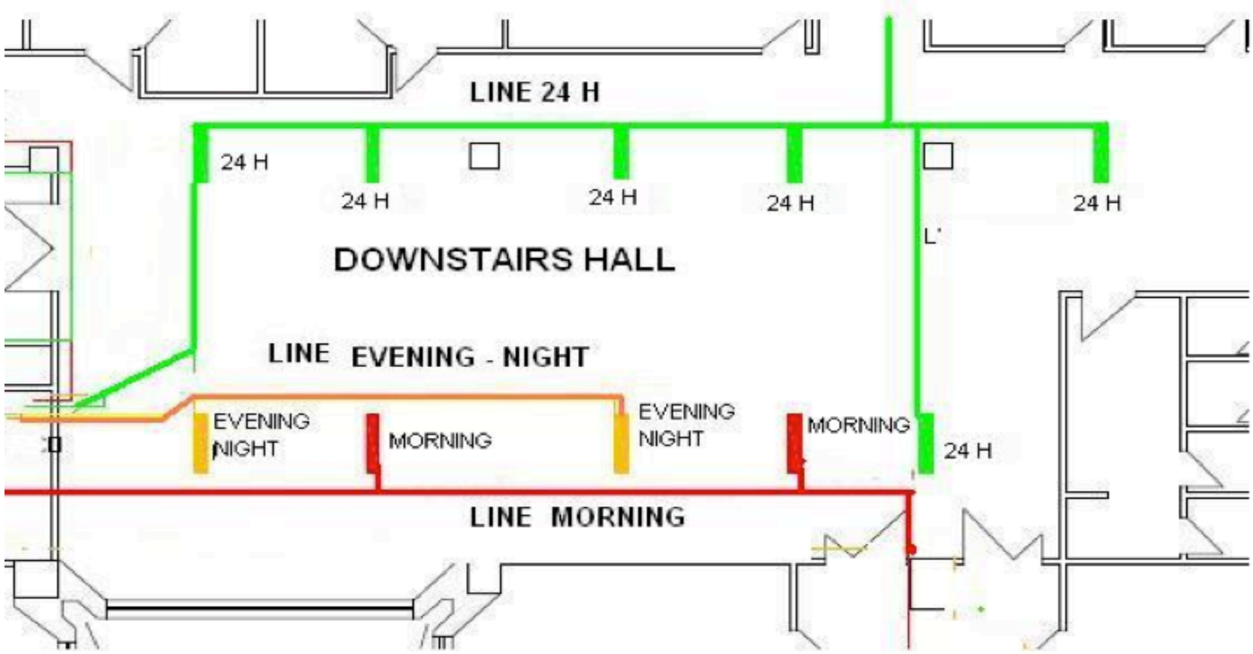

Figure 5. Discrimination lights in the hall downstairs

(US $ 125,000.00) and the other cost amounting to € 15,000.00 (US $ 20,000.00), are the Value Added Tax.

The Institute of Energy of Galicia has awarded a grant of € 20,000 (US $ 26,600.00) [11], so the actual disbursement of the USC was about € 75,000 (US $ 110,000.00), since VAT was not included since USC is an education institution.

The corridors and halls has a combined area of 2,700 m^2 wherein 300 m^2 of which was subjected to 24-hour lighting while the remaining 2,400 m^2 area was subdivided in to two which received "Morning and Evening-Night" lighting, respectively. In these areas, the initial medium luminance is 180 lux.

Performance example

In the illustration of the downstairs halls (**Figure 5**), there are three groups: 24-hours where luminarieswere placed in area transiting more people, Morning and Evening-Night in area transiting less people but with greater illuminance (upper, 24 hours), and Morning and Evening-Night in area transiting less people but with lower illuminance (bottom, working luminaries alternatives). For the ground floor (**Figure 6**) has two areas: the top that is a highly transited hall and with lighting switched on for 24 hours, and the bottom that has lower illuminance and with alternative luminaries (Morning and Evening-Night).

The new luminaries are now installed in all the floors. The original lighting installation was recessed and on surface lighting. Aside from the recessed lighting design on the ground floor, the reflectors in its casing were also replaced (**Figure 7).**

RESULTS AND DISCUSSION

Energy saving calculation

In the Ground, First, and Second floors, the previous electric power consumption was 16 kW. With the replacement of two and four-lamps recessed with a single one on surface, the consumption decreased to 13.5 kW. Each one of the three groups (24 hours, morning and evening-night) has a power of about 4.5 kW. The new configuration has two switched-on groups so that consumption will always be around 9 kW.

In the energy savings calculation, the previous consumption was 16 kW on about 8,700 hr yr^{-1}. But now it is only 9 kW, thus the initial consumption was reduced from 138 MWh to 78 MWh, with an annual savings of 60 MWh (**Table 2**).

In the second phase, the previously installed power is 10 kW. Now it is just half, with all original lamps (2 x 36 W) were replaced by 1 x 36 W set up on surface. Further, the equivalent operating hours would be reduced to half (from about 8,700

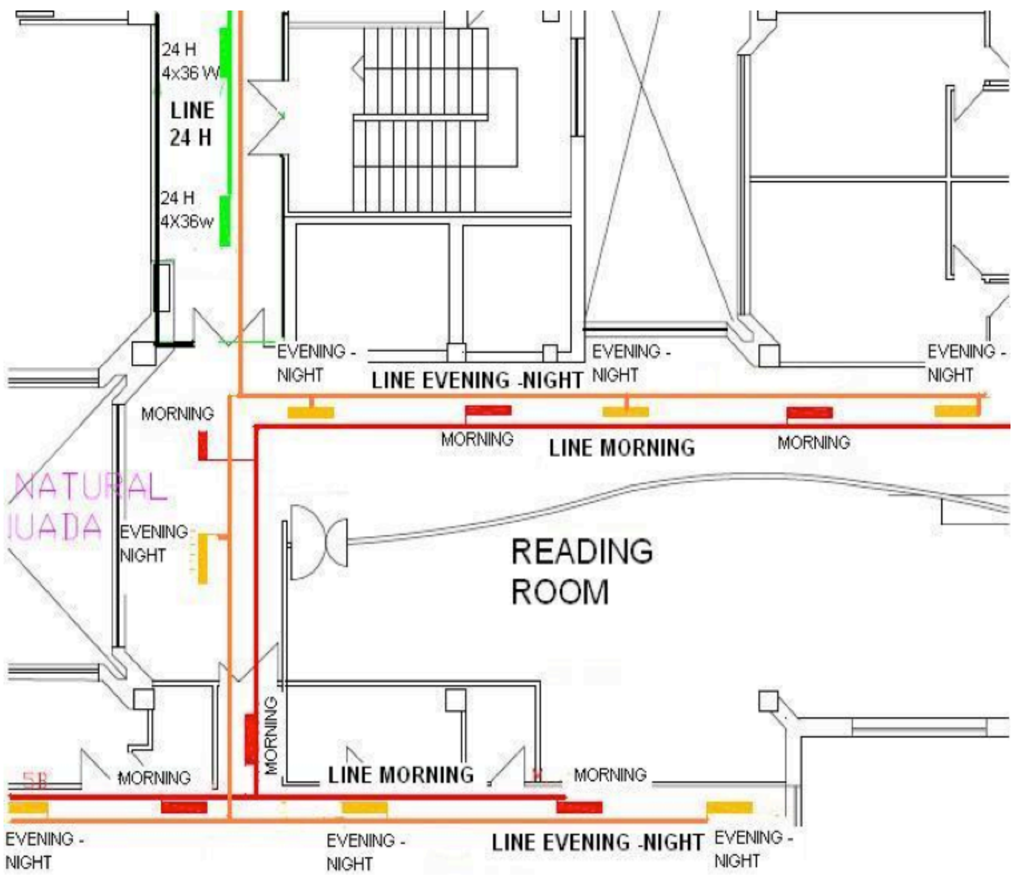

Figure 6. Example of discrimination of lights in one of the corridors on the ground floor.

Figure 7. Recessed luminaries on the ground floor.

hours a year to 4,350 hours); the savings is 66 MW (from 88 MW to 22 MWh). In "24 hours" area, the luminance was the same (about 180 lux) and in the others areas (morning and evening) the luminance decreased about a 10 % (between 150 to 160 lux) but the users didn´t complain on this reduction.

Decrease in Emissions

Each kWh of electrical consumed energy promotes about 200 g of CO_2, 0.3 g of sulfur oxides and 0.261 g of nitrogen oxides (*Spanish Electric Grid 2012*). Applying these relationships can determine the emissions savings achieved (**Table 3**). The first phase has saved 12 t of CO_2, 18 kg of sulfur and 16 kg of NOx; the second phase has achieved savings of 13.2 t of CO_2, 20 kg of sulfur and about 18 kg of NOx (**Table 3**).

Payback Calculation

In the economic analysis of the actions taken, a calculation of the return period for the improvements was included. As that the implementer (the University of Santiago de Compostela)- does not pay VAT, this tax was excluded in the calculations. The study considered that during the first year the average price of electricity is € 0.08 kWh^{-1} (€ 0.106 kWh^{-1}) before taxes (excluding VAT) and this price will increase annually by 4 %. The savings in maintenance should be added, which is estimated at about € 1,000 yr^{-1} (maintenance of lights on the surface is easier than the recessed one, US $1.335 yr^{-1}). The investment of € 75,000.00 was recovered after about six years (€ 75,000.00 is the subsidy, US$ 110,000.00) while, if there are no grants, the cost would be about € 90,000.00 (US$ 120,000.00) and the payback period would be 7.5 years (**Table 4**).

Table 2. Reduction of energy consumption with the improvements in the interior lighting of the University Residence Monte da Condesa.

Phase	Floors	Power				Energy		
		Initial power (kW)	Finished power installed (kW)	Maximun power demanded (kW)	Save of power (kW)	Initial energy (MWh)	Finished energy (MWh)	Save of energy (MWh)
First	Ground, First and Second	16	13,5	9	7	138	78	60
Second	Third, Fourth and Fifth	10	10	5	5	88	22	66
Total	Ground to fifth	26	23,5	14	12	226	100	126

Table 3. Emissions reductions achieved.

Phase	Save of energy (MWh)	Reduction CO_2 (ton)	Reduction SOx (kg)	Reduction NOx (kg)
Conversion factor	1	0.2	0.3	0.261
First:	60	12	18	16
Second:	66	13.2	19.8	17.6
TOTAL	126	25.2	37.8	33.6

Table 4. Financial table of the investment.

Year	Prize (€/MWh)	Economic savings (€)	Maintenance savings (€)	Total savings (€)	Cumulate savings (€)
1	80.0	10,080.00	1,000.00	11,080.00	11,080.00
2	83.2	10,483.00	1,000.00	11,483.00	22,563.00
3	86.5	10,903.00	1,000.00	11,903.00	34,466.00
4	90.0	11,339.00	1,000.00	12,339.00	46,804.00
5	93.6	11,792.00	1,000.00	12,792.00	59,597.00
6	97.3	12,264.00	1,000.00	13,264.00	72,860.00
7	101.2	12,754.00	1,000.00	13,754.00	86,615.00
8	105.3	13,265.00	1,000.00	14,265.00	100,879.00

CONCLUSIONS AND RECOMMENDATIONS

This study presented the increase in carbon dioxide emissions and the rest of greenhouse gases, which is causing global warming. In Spain, the attempt to reduce emissions of greenhouse gases have failed and the emissions are higher than expected, so the government has approved several programs to implement actions to reduce them. One of these actions is the improvement of lighting installations, such as the intelligent lighting system in the building "Monte da Condesa" in Santiago de Compostela.

This lighting system costs about € 90,000.00 (US$120,000.00) plus VAT and with an additional grant of 22 % from the Institute of Energy of Galicia. This action has generated savings of 126 MWh and a reduction of CO_2 emissions by 25 T annually, with a return period of about six years if the grant is considered and about 7.5 years without considering as such.

REFERENCES

Blanco Silva, F.1999. Guía para entender el Protocolo de Kioto. Club Universitario Dínamo. Santiago de Compostela (Spain)

Dincer, I. 2002. "Technical, environmental and exergetic aspectsof hydrogenenergysystems". *HydrogenEnergy*, vol.27:265–285.

Energy Saving Institute – IDAE & Ministry of Industry of Spain. 1999. Plan de Fomento de las Energías Renovables en España. Madrid.

European Council. 1997.Energy for the future: renewable sources of energy (White Paper). , COM (97) 599, 26 November, Brussels.

Institute of Energy of Galicia.2007. Resolución de 26 de abril de 2007 por la que se establecen las bases reguladoras para la concesión, en régimen de concurrencia competitiva, de las subvenciones y ayudas a proyectos de ahorro y eficiencia energética y proyectos de energías renovables correspondientes al ejercicio 2007. Diario Oficial de Galicia, 30 de march of 2007, Santiago de Compostela (Spain)

Meinshausen, M.; Meinshausen, N.; Hare, W. Raper, S.: Frieler, K.; Knutt, R. ; Frame, D.J.; Allen, M. R.2009. Greenhouse-gas emission targets for limiting global warming to 2ºC. *Nature*, Vol. 458: 1158-1163.

Menéndez Pérez, E. 2004. "Escenarios de evolución del sistema eléctrico español".Energía: *Ingeniería energética y medioambiental*, Vol. 177, 2004: 81-88.

Ministry of Enviroment of Spain. 2011: Inventario de Gases de Efecto Invernadero de España Edición 2011. Madrid

Pachauri, R. K. & Reisinger, A. 2007:Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change", Cambridge (UK)

Sánchez-Chóliz, J., Duarte, R. Mainar, A.2008. "Factores determinantes en la evolución de las emisiones de gases de efecto invernadero en la Unión Europea. Influencia de los patrones de consumo", Paper presented at the IX Congress of critical economy. Bilbao (Spain).

Smale, R.; Hartley, M.; Hepburn, C.; Ward, J.; Grubb, M.2006."The impact of CO2 emissions trading on firm profits and market prices", *Climate Policy*, Vol. 6, nº 1: 31-48.

Spanish Electric Grid. 2012. http://awsassets.wwf.es/downloads/oe_febrero_2012_01032012.pdf