Energy Savings Calculations for selected end use technologies and existing evaluation practices in Spain

A report produced for the IEA DSM Agreement, Task 21
Harmonisation of Energy Savings Calculations

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In the IEA DSM Agreement, Task 21 Harmonisation of Energy Savings Calculations, the following countries are participating:

France,
Republic of Korea
Netherlands
Norway
Spain
Switzerland
USA

Each country prepared a report on the Energy Savings Calculations for selected end use technologies and existing evaluation practices. These reports are available at www.ieadsm.org

The report holds information on selected case applications. These cases are selected with a view to present information on the energy savings calculations that are or could be done for the selected end use technologies. The case applications are not selected as best practice examples, but are good examples for common practise.

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1. CASE APPLICATION

1.1 Introduction

The country experts discussed during the project how an overview could be created for the methods that are used for calculating or estimating (ex-post) energy savings. It was decided to use case applications in selected technology areas and energy end-users. For this project the selection of case applications is to illustrate what is or could be used for estimating energy savings from programme or project implementations. The case applications show the practise in a participating country, without suggesting that these are ‘best practises’. They are a snapshot and sometimes also one of the applications that are in use in a country, but they clearly illustrate what key elements in the energy savings calculations are, how problems in data collections are handled and how default or standard values are used.

The case applications are selected for the following technologies and energy end-users:

a. Industry; Variable Speed Drive and High Efficient motor
b. Commercial Buildings; Heating system
c. Commercial Buildings; Integrated Air conditioning system
d. Households; Retrofit wall insulation
e. Households; Lighting

For Spain, the following case applications are selected:

- Efficient lighting in households
- Retrofit wall insulation in households
- Centralized AC systems in the services sector
- Efficient boilers in the services sector
- Installation of VSDs in electric motors

These case applications are presented from section 1.2 onwards with additional information in Annex B.

Each of the case applications presents the information in a common format, a template. There are four groups:

- Summary of the program
- Formula for calculation of annual energy savings
- Input data and calculations of energy savings
- Greenhouse gas savings

Additional information is provided in references, one or more annex and on definitions

The template was improved during the project, based on experiences to present the information for case applications and discussions during the experts meetings. A workshop was held in April 2011 in Korea to get feedback on the final draft of the template. During the workshop three different case applications were presented to illustrate the use of the template and to discuss future application.

In Annex A the final version of the template with instructions is enclosed.

Additional to the case application on energy savings, in Annex C one case application on the Demand Response programme “Interruptible service” is included. The information on the

Demand Response programmes is used to gain knowledge on the role energy savings play in such programs.

1.2 Efficient lighting in the households

1 Summary of the program.

1.1 Short description of the program

1.1.1 Purpose or goal of the program

The goal of this program is to save energy through the reduction of the installed and consumed power in the **lighting** systems of the **domestic sector**. The expenditure is recovered in less than ten years, which is a significantly lower figure that the useful life of the replacing lamps. This is one of the main measures included in the E4 Strategy and **aims to impact in a 21% of the existing buildings**, although the plan does not elaborate on how to measure the savings or the impact of the program.

The energy efficiency calculations presented in this study represent regular methods in use in Spain due to the non-existence of accepted M&V standards

1.1.2 Type of instrument(s) used

There is an ongoing awareness and information campaign to promote usage of low consumption lamps.

1.2 General and specific user category (economic sector and subgroups)

The entire household sector can be reached by the program.

1.3 Technologie(s) involved

The measure for energy saving described in this paper involves **the substitution of old existent lamps for more efficient, new lamp types** in the domestic sector. The lighting levels as well as the location of lamps within the house are assumed to remain constant.

The main types of lamps that can be used are:

- CFL: Compact Fluorescent.
- Metal halide lamps.
- **LED (Light Emitting Diode)**

1.4 Status of the evaluation and energy savings calculations

This case application holds a way how to calculate the energy savings of lighting in households in an aggregated way.

1.5 Relevant as a Demand Response measure

This measure cannot be considered an active Demand Response measure, beyond its impact in levelling the load curve

2. Formula for calculation of Annual Net Energy Savings

2.1. Formula used for the calculation of annual energy savings

The formula used for the calculation of annual net energy savings for a single house is:

$$ES = \sum^{Unit.}(Pold - Pnew)\ x\ t$$

For the entire Spain, these savings would be:

$$ES = \sum^{Unit.}(Pold - Pnew)\ x\ t\ x\ H\ x\ S$$

2.2. Specification of the parameters in the calculation

The parameters are:

H is the number of households in Spain[1]

MINISTERIO DE VIVIENDA

Tabla 1.
Estimación del Parque de Viviendas.
***Total de viviendas* por comunidades autónomas y provincias*. Serie 2001-2008**

Unidad: vivienda

	2001	2002	2003	2004	2005	2006	2007	2008
TOTAL NACIONAL	21.033.759	21.551.426	22.059.220	22.623.443	23.210.317	23.859.014	24.495.844	25.129.207

*Total viviendas= vivienda libre+ vivienda protegida

S is the number of lamps per house substituted.
t is the annual number of hours of lighting usage, around 700 in Spain[2], possibly higher in countries like Germany, France, etc.
Pold is the installed power before the measure, it can be determined as:

$$Po = \sum ni * Pi$$

[1] Number of households. Source: Ministry of Housing - (Last update: 2008)- Link: http://www.mviv.es/es/index.php?option=com_content&task=view&id=1612&Itemid=526
[1] Hypothesis based on everis/exeleria energy auditing experience.

With:

- n_i the number of lamps of one specific kind and Pi the power (in kilowatt) per lamp of that specific type.
- P the installed power (in kilowatt) after the retrofit, is determined as Po, using the new lamp characteristics.

2.3. Specification of the unit for the calculation

The (unitary) object of assessment is a lamp, more specific in the example LED.
In this case no (specific) action is taken into account.

2.4. Baseline issues

The baseline is the energy consumed before the application of the measure and is considered to be static; there are no factors of influence. This is acceptable in a system as domestic lighting.

2.5. Normalization

No normalisation is conducted.

2.6. Energy saving corrections

2.6.1. Gross-net corrections

There are no significant interactions to be considered

2.6.2. Corrections due to data collection problems

As all data (except the number of households) are based on assumptions, corrections due to data collection problems are not applicable.

3. Input data and calculations

3.1. Parameter operationalisation

The number of hours of usage is estimated upon a normal usage of two hours per day of the lighting system. Its accurate measurement would involve the usage of energy meters or other form of recording.

The installed power can be determined in two ways:

- Using the datasheet of lamps
- Measuring the power before and after with a wattmeter

The second method is more accurate and should be used. The calculation is already on an annual basis, so no correction in this regard is needed.

3.2. Calculation of the annual savings as applied

Assuming a house with **5** lamps of **40** Watts, substituted by **LED** with **4** Watt consumption, annual savings are:

$$(40-4)\,W/lamp \times 1\,kW/1000\,W \times 5\,lamps \times 700\,hours\ of\ lighting/year = 126\,kWh\ a\ year$$

3.3. Total savings over lifetime

3.3.1. Savings lifetime of LED

Efficient lamps often have a much longer lifetime than incandescence lamps. The useful life of a LED lamp, for example is around **50.000** hours, and the usage in a year approximates to **700** hours thus, the lifetime of the measures would be beyond 70 years.

$$Life\,(years) = \frac{50.000\ hours}{700\frac{hours}{year}} = 71{,}4\ year$$

3.3.2. Lifetime savings calculation of LED

The total lifetime savings are:

$$Savings(kWh) = 126\frac{kWh}{year} * 71{,}4\ year = H * S * 9.000\ kWh$$

4. GHG savings

4.1. Annual GHG-savings

4.1.1. Emission factor for energy source

The GHG savings are determined using the medium emission factor for the national electrical system. For Spain the value is **0,360** (using as reference data from REE, and evaluated in accordance to the European Commission Directive 2007/589/CE) **kg of CO_2 per kWh of electrical consumption.**

4.1.2. Annual GHG-savings calculation as applied

Using the medium emission factor, the annual savings of CO_2 are:

$$\text{GHG saving (kg/}CO_2 = H * S * 0{,}360 * N * (P_{old} - P_{new})$$

Particularizing this calculation for year **2008**, the annual savings of CO_2 are approximately to **1.140 Tons.**

4.2. GHG lifetime savings

4.2.1. Emission factor

No emission factor for GHG lifetime savings.

4.2.2. GHG lifetime savings as applied

N/A

References

CTE: TECHNICAL BUILDING CODE -HE1-
http://161.111.13.202/apache2-default/cte/CTE_DB-HE.pdf

IDAE: Institute for Diversification and Saving of Energy
http://www.idae.es/index.php

REE: Red Eléctrica de España, Electrical System Operator
http://www.ree.es/operacion/curvas_demanda.asp

MINISTRY OF INDUSTRY, TOURISM AND TRADE
http://www.mityc.es/energia/desarrollo/EficienciaEnergetica/Estrategia/Documentos/Documentos%20sectoriales/SectorEdificacion.pdf

MINISTRY OF HOUSING.
http://www.mviv.es/es/index.php?option=com_content&task=view&id=1612&Itemid=526

1.3 Retrofit wall insulation

1 Summary of the program.

1.1 Short description of the program

1.1.1 Purpose or goal of the program

The goal of this program is to save energy through the **reduction in the domestic sector heating system consumption**. This measure is included as one of the main actions of the E4 strategy. The goal is to promote the implementation in the **3,3%** of the existing buildings. The simulation method carried out in this document is more complex than the more simplified and common engineering calculations. However, this methodology achieves more accurate and flexible results.

The energy efficiency calculations presented in this study represent regular methods in use in Spain due to the non-existence of accepted M&V standards

1.1.2 Type of instrument(s) used

There is an ongoing awareness and information campaign to promote refurbishment of wall insulation, as well as subsidies of up to 22% of the investment.

1.2 General and specific user category (economic sector and subgroups)

This program is ideally suitable for houses of more than 20 years.

1.3 Technologie(s) involved

The measure for energy saving described in this paper involves the improvement in the insulation of existing levels. The methods and techniques for the improvement are:

- Augmentation of the thickness of the insulation layer.
- Substitution of windows.
- Improvements in the air tightness of doors and windows.
- Employment of passive solar radiation techniques.
- Employment of Phase Change Materials in walls.

Since the widespread load is heating and natural gas is the most common energy source, the **reduction** in this fuel will be the most noticeable goal archived. Nonetheless, a **reduction in electricity consumption** will be achieved for the heating loads, and, with some measures, a reduction in cooling loads is to be expected too, which may impact in electrical consumption assuming that a cooling system is present.

1.4 Status of the evaluation and energy savings calculations

This case application holds a way how to calculate the energy savings of retrofit of wall insulation.

1.5 Relevant as a Demand Response measure

This measure cannot be considered an active Demand Response measure, beyond its impact in levelling the load curve

2. Formula for calculation of Annual Net Energy Savings

2.1. Formula used for the calculation of annual energy savings

For most of the measures described above, the only accurate method to determine energy savings is by energy simulation.

There are a number of software programs available for the thermal simulation of buildings, and their simplicity and accuracy are ever growing. Furthermore, some of the most reputed programs (like EnergyPlus from DOE) are freely distributed.

While running an energy simulation is far easier than 10 years ago, in general terms, the energy consumption of house does not justify the cost carried with the modelling and post-processing of a thermal simulation. Nonetheless, in a nationwide program for energy savings, a statistical approach could be affordable to determine the whole program savings by sampling.

To show an example of the calculation process, we shall model an actual house and run the simulation with two different thickness of insulation material.

2.2. Specification of the parameters for the calculation

As architectural information of the building, layout, materials, etc. two parameters are used in the example:

- the m^2 of the building
- the type of buildings.

As the heating system a gas boiler with standard efficiency is assumed.

For climate data the Typical meteorological Year for Madrid is used.

Typical occupation rates are based on a database holding information on type and size of buildings.

2.3. Specification of the unit in the calculation

The (unitary) object of assessment is a domestic building.

In this case no (specific) action is taken into account.

2.4. Baseline issues

Not applicable

2.5. Normalization

Not applicable, as the model already uses climate data.

2.6. Energy saving corrections

2.6.1. Gross-net corrections

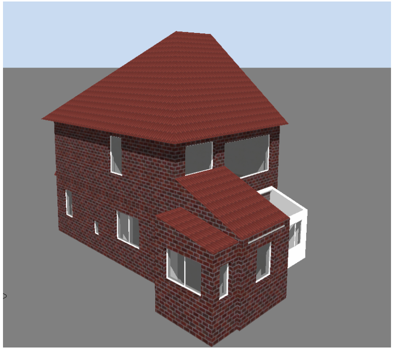
Not applicable

2.6.2. Corrections due to data collection problems

As this case holds an example of the calculation process, corrections due to data collection problems are not applicable.

3. Input data and calculations

3.1. Parameter operationalisation



The input data in order to model the system is:

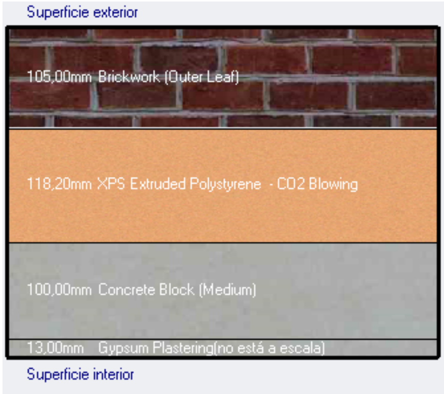
- Architectural information of the building, layout, materials, etc.
- Heating system.
- Climate Data.
- Typical occupation rates.

With this, it is possible to model the building performance and its energy consumption. The data under used is:

- Architectural and installations data. Standard construction, 100 sqm. built.
- Heating system: water boiler, natural gas feeding, standard efficiency.
- Climate data: TMY (Typical Meteorological Year for Madrid).
- Occupation rates from database.

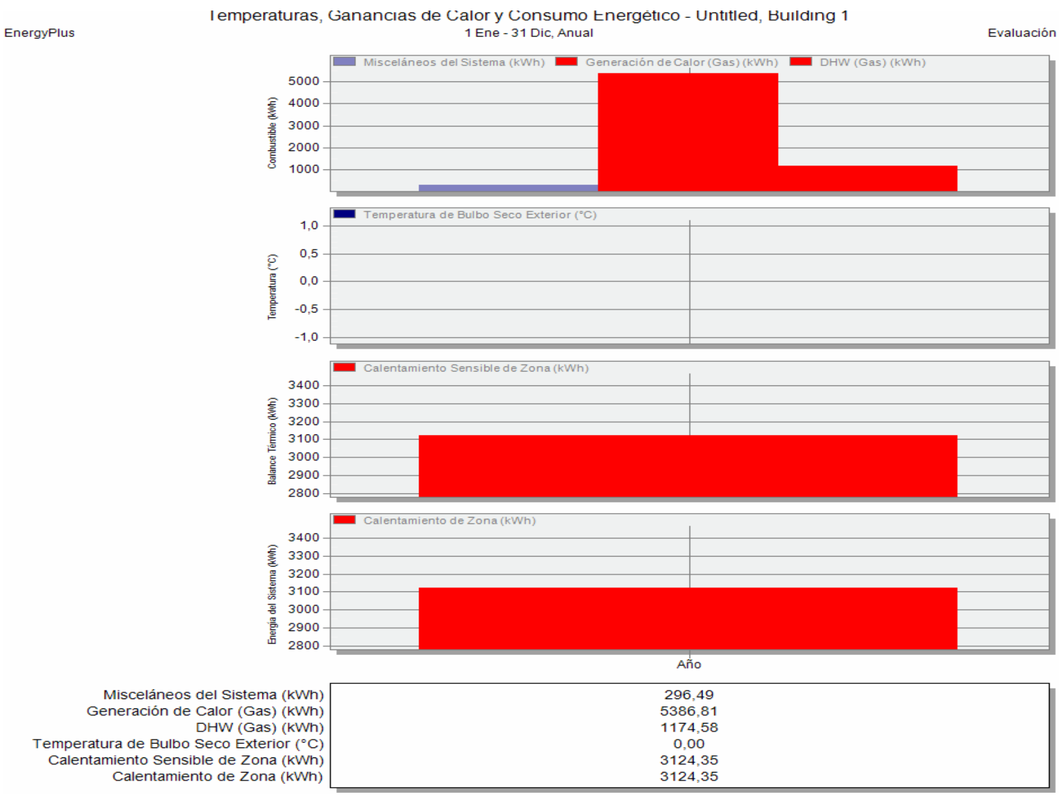
The two levels of insulation are:
1) Standard wall: medium weight; 79,50 mm of insulation; U=0,350 W/m2K.

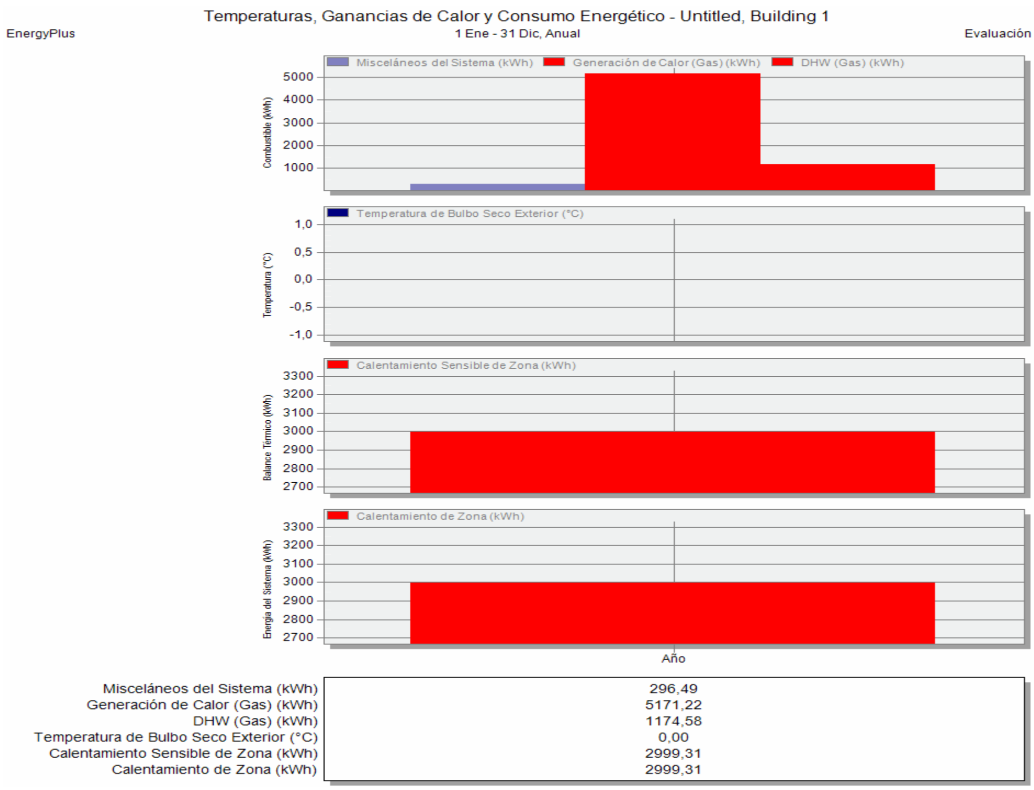
2) Evaluation wall: medium weight; 118,20 mm of insulation; U=0,350 W/m2K.



And the outcome of the simulation for the standard insulation is:

For the improved insulation:





3.2. Calculation of the annual savings as applied

Thus the energy savings are evaluated comparing "Generación de Calor", which is the natural gas consumption, the savings in this case are of 215 kWh/year. This value is true just for the specific kind of building, size and climate zone.

To obtain valid data for all of Spain, it is necessary to run simulations in matrix of experiments such as:

Table 1[3] - Typology of buildings

	Detached buildings									
Size of building (sqm)	<30	30-45	46-60	61-75	76-90	91-105	106-120	121-150	151-180	>180
Number of buildings	x	x	x	x	x	x	x	x	x	x
	Multistore building									
Size of building (levels)	1	2	3	4	5	6	7	8	9	10 and more
Number of buildings	x	x	x	x	x	x	x	x	x	x

[3] Source: Ministerio de Fomento (http://www.mviv.es/es/)

To determine global savings per year, the next formula shall be applied:

$$Savings\,(kWh) = \sum 0{,}033 * Ni * Si$$

Where:

- o Ni is the number of buildings per type
- o Si is the annual savings per type
- o Penetration factor 0.033 is a correction factor employed to reflect the penetration sought by this energy saving measure

Table 2[4] - Number of buildings per typology

	Detached buildings									
Size of building (sqm)	<30	30-45	46-60	61-75	76-90	91-105	106-120	121-150	151-180	>180
Number of buildings	2.365	11.510	31.217	58.528	190.295	128.880	119.254	120.725	62.509	98.535
	Multistore building									
Size of building (levels)	1	2	3	4	5	6	7	8	9	10 and more
Number of buildings	69.001	146.563	206.827	270.887	259.922	183.320	105.641	84.637	17.764	1.379.927

3.3. Total savings over lifetime

3.3.1. Savings lifetime of retrofit wall insulation

No savings lifetime is applied

3.3.2. Lifetime savings calculation of retrofit wall insulation

No savings lifetime is applied

4. GHG savings

4.1. Annual GHG-savings

4.1.1. Emission factor for energy source

The only GHG relevant is CO_2, as we are assuming complete combustion of the natural gas (this can be tested with the combustion efficiency measurements), the savings are determined by applying the emissions factor to the energy savings, in the case of natural gas, the emission factor is 0.204 kg of CO_2 per kWh.

4.1.2. Annual GHG-savings calculation as applied

[4] *Source: Ministerio de Fomento (http://www.mviv.es/es/)*

$$GHG\ Savings\ (kg\ CO2) = 0{,}204 * \sum Energy\ before - Energy\ after$$

In this example, the annual savings for a single building would be of 43.86 kg/year.

4.2. GHG lifetime savings

4.2.1. Emission factor

No emission factor for GHG lifetime savings.

4.2.2. GHG lifetime savings as applied

N/A

References

CTE: TECHNICAL BUILDING CODE -HE1-
http://161.111.13.202/apache2-default/cte/CTE_DB-HE.pdf

IDAE: Institute for Diversification and Saving of Energy
http://www.idae.es/index.php

REE: Spanish Electricity Network/Grid
http://www.ree.es/operacion/curvas_demanda.asp

MINISTRY OF INDUSTRY, TOURISM AND TRADE
http://www.mityc.es/energia/desarrollo/EficienciaEnergetica/Estrategia/Documentos/Documentos%20sectoriales/SectorEdificacion.pdf

MINISTRY OF HOUSING.
http://www.mviv.es

1.4 Centralized AC System in offices

1 Summary of the program.

1.1 Short description of the program

1.1.1 Purpose or goal of the program

The goal of this program (included in the E4 Strategy) is to promote energy efficiency nationwide through the **substitution of old HVAC systems**. The program seeks to be implemented in the 20% of the existing buildings. Thus, in this document, engineering calculations are the basis of the evaluation performed.

The energy efficiency calculations presented in this study represent regular methods in use in Spain due to the non-existence of accepted M&V standards

Other than energy savings, there are two additional factors to be considered regarding this program:

- Substitution of R22 machines with refrigerants of lower or zero GWP;
- Reduction in water consumption.

1.1.2 Type of instrument(s) used

The substitution of old machines is subsidized with up to 22% of the investment.

1.2 General and specific user category (economic sector and subgroups)

The aim of this program is commercial and more specifically, large office buildings.

1.3 Technologie(s) involved

This document describes the process to evaluate the energy savings in an office building by substituting a decentralized water cooled loop system with a two pipe **centralized chilled water system**.

A number of hypotheses are necessary to describe the problem, and evaluate the correct Energy Saving Measures. These hypotheses are:

- The building is used as offices
- The terminal units are fan coils with a two pipe distribution system. Ventilation air is supplied via a central AHU
- There are only cooling loads in the building
- The existing system is composed of water cooled chillers in each section of the office
- Condensation water is provided via centralized cooling towers

With this raw data, we can assume that **the best measure to be applied is to substitute the existing chillers with a new centralized one chiller or group of chillers**. The piping used for the condensation loop will be used for the distribution of chilled water and the cooling towers will be used for the new system too.

1.4 Status of the evaluation and energy savings calculations

This case application holds a way how to calculate the energy savings of retrofit of wall insulation.

1.5 Relevant as a Demand Response measure

This measure cannot be considered an active Demand Response measure, beyond its impact in levelling the load curve

2. Formula for calculation of Annual Net Energy Savings

2.1. Formula used for the calculation of annual energy savings

To evaluate the savings prior to installation, it is necessary to accurately know the efficiency of the existing cooling system. There are two possible approaches:

a) Using manufacturer supplied data of load vs. efficiency; or
b) Measuring the efficiency of the system at various loads.

Unless the manufacturer data is readily available and the machines have not suffered significant degradation, the second approach is desirable.

Since we are dealing with a water condensed chillier system, outdoor temperature is not a significant variable; it will only impact upon cooling tower fan consumption and water consumption, but will have no effect in the electricity consumption of the chillers. Thus, the data to be recorded are inlet and outlet temperature and input power in the chillers. It may be difficult to take measurements in all the chillers if the number is large; in this case, a statistical approach is suggested by taking a sample of the chillers.

With this data, it is possible to determine the efficiency at different loads. The useful power delivered by the chillier will be:

$$\text{Useful Power (kW)} = C_p * (T_{outlet} - T_{inlet}) * \text{Flow}$$

With Cp = the calorific capacity of water (4,18 kJ/kg-K) and
Flow = the mass flow of water in kg/s.

The load is determined as:

$$Load = \frac{Useful\ Power}{Nominal\ Power}$$

And the COP (Coefficient of Performance) for each load:

$$COP = \frac{\sum Power\imath}{Electricalinput}$$

The next step is to develop the annual heating load profile. To do so, it is necessary to have the electricity bills of at least a year and assume a yearly distribution which can be obtained from a variety of sources (ASHRAE, Atecyr, etc.).
This will give us a table with the number of working hours per heating load in a year. With this data and the efficiency vs. load of the new chiller, the savings are determined with the following equation per load fraction:

$$Yearly\ Savings\left(\frac{kWh}{year}\right) = Discount\ factor * \sum Load * Hours * Nominal\ Power * \left(\frac{1}{COPold} - \frac{1}{COPnew}\right)$$

There will also be savings in the pumping system and cooling tower fan. Nonetheless, these will be significantly smaller than the energy savings in the chiller system itself and can be ignored.

This method for calculation is based upon engineering calculations and rooted in simple relationships for performance. The only hypothesis of the model is that load will be constant before and after changing the HVAC system, this implies to accept a static baseline[5].

To calculate national savings, the sum of savings in all affected installations is used:

$$Total\ Savings\left(kWh/_{year}\right) = \sum S\ Installations\ Year\ 0 + \sum S\ Installations\ Year\ 1 + \cdots + \sum S\ Installations\ Year\ i$$

The number of installations affected per year is:

$$\sum S\ Installations\ Year\ 0 = N * Fp * Discount\ factor * \sum Load * Hours * Nominal\ Power * \left(\frac{1}{COPold} - \frac{1}{COPnew}\right)$$

Where

N is the total number of office buildings.

Fp is the capacity factor of yearly chiller change:

Fp = (N x mean number of chillers)/Chillers sold in year i

2.2. Specification of the parameters for the calculation

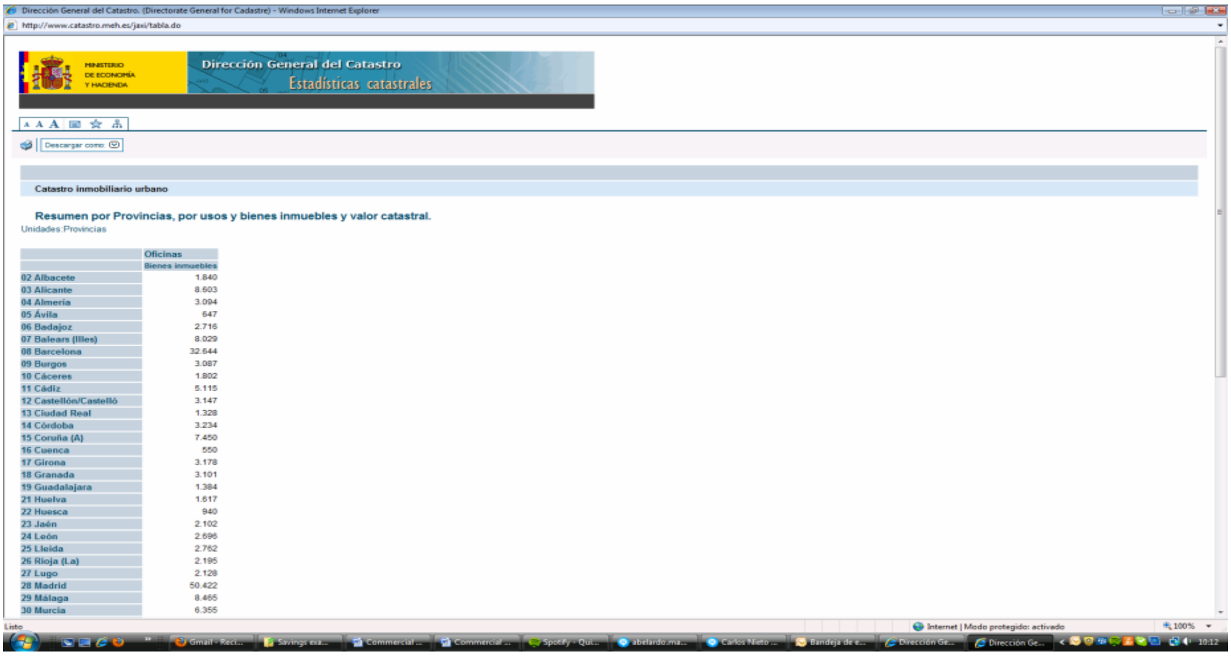
The parameters for the calculation of the useful power are:

Cp = the calorific capacity of water (4,18 kJ/kg-K) and

[5] *Source: hypothesis based on everis/exeleria calculations.*

Flow = the mass flow of water in kg/s.

The parameter for the number of offices N might be taken from official data (see illustration below)[6].



Dirección General del Catastro. (Directorate General for Cadastre) - Windows Internet Explorer

http://www.catastro.meh.es/jaxi/tabla.do

MINISTERIO DE ECONOMÍA Y HACIENDA

Dirección General del Catastro

Estadísticas catastrales

Catastro inmobiliario urbano

Resumen por Provincias, por usos y bienes inmuebles y valor catastral.

Unidades:Provincias

	Oficinas
	Bienes inmuebles
02 Albacete	1.840
03 Alicante	8.603
04 Almería	3.094
05 Ávila	647
06 Badajoz	2.716
07 Balears (Illes)	8.029
08 Barcelona	32.644
09 Burgos	3.087
10 Cáceres	1.802
11 Cádiz	5.115
12 Castellón/Castelló	3.147
13 Ciudad Real	1.328
14 Córdoba	3.234
15 Coruña (A)	7.450
16 Cuenca	550
17 Girona	3.178
18 Granada	3.101
19 Guadalajara	1.384
21 Huelva	1.617
22 Huesca	940
23 Jaén	2.102
24 León	2.696
25 Lleida	2.762
26 Rioja (La)	2.195
27 Lugo	2.128
28 Madrid	50.422
29 Málaga	8.465
30 Murcia	6.355

2.3. Specification of the unit in the calculation

The unit in the calculation is a water condensed chiller system.

2.4. Baseline issues

The baseline is the energy consumed before the application of the measure and is considered to be static, as implied in the earlier point.

2.5. Normalization

There is no normalization

2.6. Energy saving corrections

2.6.1. Gross-net corrections

There are no significant interactions to be considered. There is no need for normalization as there are no influence variables.

2.6.2. Corrections due to data collection problems

[6] Source: Ministry of Economy. Dirección General del Catastro: http://www.catastro.meh.es/jaxi/tabla.do?path=/est2009/catastro/urbano/&file=03002.px&type=pcaxis&L=0

As this case holds an example of the calculation process, corrections due to data collection problems are not applicable.

3. Input data and calculations

3.1. Parameter operationalisation

The input data necessary for the calculations is:

- Nominal power.
- Mass flow of water in the chiller.
- Inlet and outlet temperatures.
- Electrical consumption.
- Yearly cooling load profile.
- New chiller efficiency vs. load curve.

This data is to be either measured, taken from references of accepted prestige or from the equipment manufacturer.

3.2. Calculation of the annual savings as applied

Thus, applying the equations showed in the earlier point and for a nominal power of 1.000 kW, we would obtain the following table:

Load %	Hours per year	Old System COP	New System COP	Savings (kWh)
100%	400	3,1	4,1	31.471
90%	400	3,2	4,3	28.779
80%	800	3,3	4,7	57.769
70%	1000	2,7	4,9	116.402
60%	1600	2,5	4,3	160.744
50%	2200	2,3	3,7	180.964
40%	800	2,1	3,1	49.155
30%	400	1,8	2,5	18.667
20%	300	1,5	1,9	8.421
10%	100	1,1	1,4	1.948
0%	760	0,0	0,0	-

The net annual savings are the sum of the savings for each of the load fractions. With these efficiencies and load curve, and with a nominal power of 1,000 kW, the net annual savings are 654,320 kWh.

3.3. Total savings over lifetime

3.3.1. Savings lifetime of a chiller

The expected lifetime of a chiller is around ten years.

3.3.2. Lifetime savings calculation of a chiller

Using the expected lifetime of a chiller of ten years, savings over the whole lifetime of the chiller are to be the annual savings multiplied by ten and discounting by a factor of performance reduction of 2,5% annually over the theoretical performance.

Year	Nominal savings	Discount factor	Actual savings
1	654.320	1	654.320
2	654.320	0,975	637.962
3	654.320	0,95	621.604
4	654.320	0,925	605.246
5	654.320	0,975	637.962
6	654.320	0,9	588.888
7	654.320	0,875	572.530
8	654.320	0,975	637.962
9	654.320	0,85	556.172
10	654.320	0,825	539.814

Thus, total lifetime savings amount to 6,052,463 kWh.

4. GHG savings

4.1. Annual GHG-savings

4.1.1. Emission factor for energy source

The GHG savings are determined using the medium emission factor for the national electrical system. For Spain the value is 0.360 (using as reference data from REE, and evaluated in accordance to the European Commission Directive 2007/589/CE) kg of CO_2 per kWh of electrical consumption.

4.1.2. Annual GHG-savings calculation as applied

Using the medium emission factor, the annual savings of CO_2 are:

$$GHG\ Savings\ (kg\ CO2) = 0{,}360 * \sum Energy\ before - Energy\ after$$

For this example, the CO_2 savings are 235.555 kg per year.

There are no other GHG affected significantly by this measure other than CO_2.

4.2. GHG lifetime savings

4.2.1. Emission factor

No emission factor for GHG lifetime savings.

4.2.2. GHG lifetime savings as applied

N/A

References

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
http://www.ashrae.org/

ATECYR: Spanish Technical Association of Air Conditioning and Refrigeration.
http://www.atecyr.org/eATECYR/index.php

IDAE: Institute for Diversification and Saving of Energy
http://www.idae.es/index.php

MINISTRY OF ECONOMY AND FINANCE.
http://www.catastro.meh.es/jaxi/tabla.do?path=/est2009/catastro/urbano/&file=03002.px&type=pcaxis&L=0

1.5 Efficient boilers in commercial building

1 Summary of the program.

1.1 Short description of the program

1.1.1 Purpose or goal of the program

The goal of this program (included in the E4 Strategy) is to promote energy efficiency through the **substitution** of old boilers in offices with new, **more efficient boilers**. The program seeks to be implemented in the **20%** of the existing buildings. The methodology followed in this document is based upon engineering calculations.

The energy efficiency calculations presented in this study represent regular methods in use in Spain due to the non-existence of accepted M&V standards

1.1.2 Type of instrument(s) used

The substitution of old machines is subsidized with up to 22% of the investment.

1.2 General and specific user category (economic sector and subgroups)

The aim of this program is commercial and more specifically, large office buildings.

1.4 Technologie(s) involved

This document describes the process to evaluate the energy savings in an office building by substituting its existing heating system. As cooling loads are predominant in most offices buildings, this system has frequently been overlooked, and, while it is true that a greater potential exists for savings exists in the cooling system, the age and state of disrepair of many installations allow for very profitable measures.

A number of hypotheses are necessary to describe the problem, and evaluate the correct Energy Saving Measures. These hypotheses are:

- The building is used as offices
- The existing system is composed by water boilers fed by natural gas and its performance is relatively low, around 80% at nominal load
- The terminal units are fan coils with a four pipe distribution system. Ventilation air is supplied via a central AHU
- Heating and cooling loads can be simultaneous in the building

With this raw data, we can assume that the best measure to be applied is to substitute the existing boilers with new, more efficient ones. Depending on the characteristics of the distribution system, terminal units and annual heating demand, it can be justified to invest in a condensation or low temperature boiler. In this case, we assume that the most convenient boiler is a low temperature one.

1.4 Status of the evaluation and energy savings calculations

This case application holds a way how to calculate the energy savings of boiler replacements.

1.5 Relevant as a Demand Response measure

The ultimate goal of this measure and of a hypothetical nationwide program to substitute boilers is to reduce global natural gas consumption. **It has a negligible impact on the electrical grid load.**

2. Formula for calculation of Annual Net Energy Savings

2.1. Formula used for the calculation of annual energy savings

In most office buildings, the only point of consumption of natural gas will be the heating boiler. Thus, it is irrelevant to consider the Energy Saving Measure in isolation or the whole building, since the system studied will be the same.

To evaluate the savings prior to installation, it is necessary to know accurately the efficiency of the existing boiler. To do so, apart from the mandatory combustion efficiency measurements, it will be recorded the consumption of gas in an hourly basis and the inlet and outlet temperatures in the boiler during a month of operation, at least.

With this data it is possible to determine the efficiency at different loads. The power of the boiler will be:

$$Power(kW) = C_p \cdot \bullet (T_{outlet} - T_{inlet}) \bullet Flow$$

With Cp the calorific capacity of water (4,18 kJ/kgK), and Flow, the mass flow of water in kg/s.

The load is determined as:

$$Load = \frac{Power}{Nominal\ Power}$$

And the efficiency for each load:

$$Efficiency = \frac{\sum Power_i}{NHV \bullet \sum NaturalGasConsumption}$$

NHV stands to Net Heating Value, which is the energy contained in natural gas per mass unit.

The next step is to develop the annual heating load profile. To do so, it is necessary to have the natural gas bills of at least a year and assume a yearly distribution which can be obtained from a variety of sources (ASHRAE, Atecyr, etc.). This will give us a table with the number of working hours per heating load in a year. With this data and the efficiency vs. load of the new boiler, the savings are determined with the following equation per load fraction:

$$YearlySavings\left(\frac{kWh}{year}\right) = DiscountFactor \bullet \sum Load \bullet Hours \bullet No\min alPower \bullet \left(\frac{1}{\eta_{old}} \bullet \frac{1}{\eta_{new}}\right)$$

For the whole heating facilities installed in Spain, in office buildings:

$$\sum InstalationsYear_t = N \bullet F_p \bullet DiscountFactor \bullet \sum Load \bullet Hours \bullet No\min alPower \bullet \left(\frac{1}{\eta_{old}} \bullet \frac{1}{\eta_{new}}\right)$$

$$TotalSavings\left(\frac{kWh}{year}\right) = N \bullet F_p \sum_{atoi} [\ \sum Load \bullet Hours \bullet No\min alPower \bullet \left(\frac{1}{\eta_{old}} \bullet \frac{1}{\eta_{new}}\right)\ ]$$

Where

N = the total number of office buildings
Fp = the capacity factor of yearly heater change:

Fp = (N x mean number of chillers)/Chillers sold in year i)

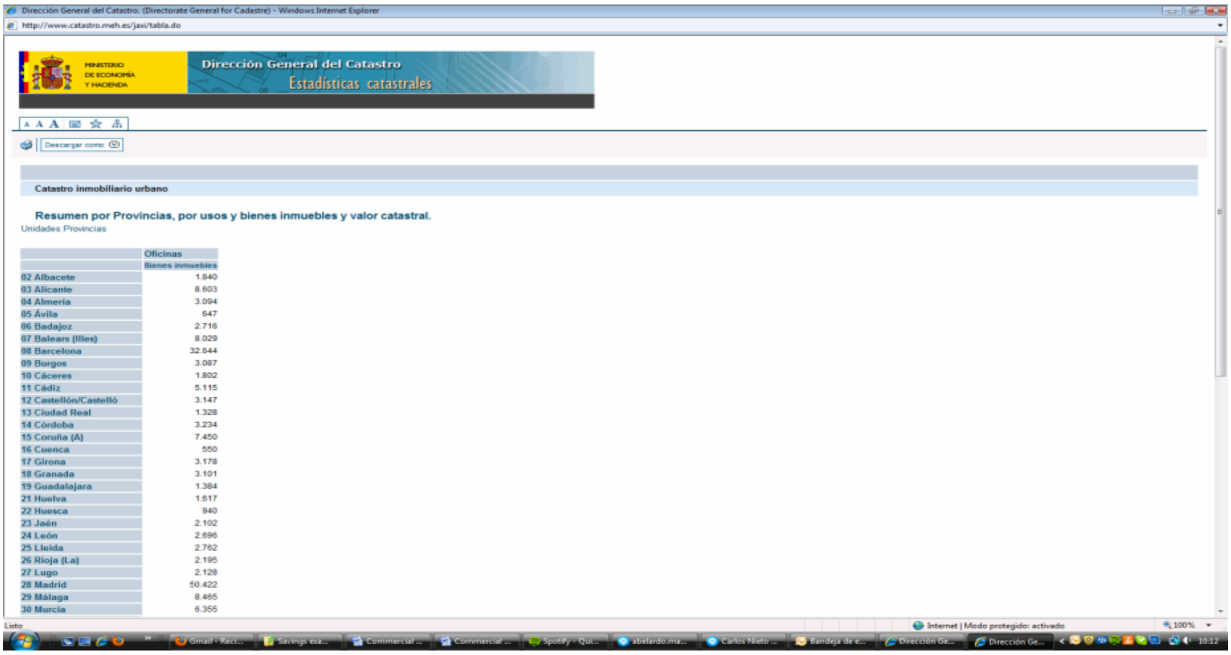
This method for calculation is based upon engineering calculations and rooted in simple relationships for performance. The only hypothesis of the model is that load will be constant before and after changing boilers.

2.2. Specification of the parameters for the calculation

The parameters for the calculation of the useful power are:
Cp = the calorific capacity of water (4,18 kJ/kg-K) and
Flow = the mass flow of water in kg/s.

The parameter for the number of offices N might be taken from official data (see illustration below) [7].

[7] Source: Ministry of Economy. Dirección General del Catastro: http://www.catastro.meh.es/jaxi/tabla.do?path=/est2009/catastro/urbano/&file=03002.px&type=pcaxis&L=0



Catastro inmobiliario urbano

Resumen por Provincias, por usos y bienes inmuebles y valor catastral.
Unidades:Provincias

	Oficinas
	Bienes inmuebles
02 Albacete	1.840
03 Alicante	8.603
04 Almería	3.094
05 Ávila	647
06 Badajoz	2.716
07 Balears (Illes)	8.029
08 Barcelona	32.644
09 Burgos	3.087
10 Cáceres	1.802
11 Cádiz	5.115
12 Castellón/Castelló	3.147
13 Ciudad Real	1.328
14 Córdoba	3.234
15 Coruña (A)	7.450
16 Cuenca	550
17 Girona	3.178
18 Granada	3.101
19 Guadalajara	1.384
21 Huelva	1.617
22 Huesca	940
23 Jaén	2.102
24 León	2.696
25 Lleida	2.762
26 Rioja (La)	2.195
27 Lugo	2.128
28 Madrid	50.422
29 Málaga	8.465
30 Murcia	6.355

2.3. Specification of the unit in the calculation

The unit in the calculation is a water condensed chiller system.

2.4. Baseline issues

The baseline is the energy consumed before the application of the measure and it is considered to be static, as it has been implied in the earlier point.

2.5. Normalization

There is no normalization

2.6. Energy saving corrections

2.6.1. Gross-net corrections

There are no significant interactions to be considered. There is no need for normalization as there are no influence variables.

2.6.2. Corrections due to data collection problems

As this case holds an example of the calculation process, corrections due to data collection problems are not applicable.

3. Input data and calculations

3.1. Parameter operationalisation

The input data necessary for the calculations is:

- Nominal power.
- Mass flow of water in the boiler.
- Inlet and outlet temperatures.
- Natural gas consumption.
- Yearly heating load profile.
- New boiler efficiency vs. load curve.

This data is to be either measured, taken from references of accepted prestige or from the equipment manufacturer.

3.2. Calculation of the annual savings as applied

Thus, applying the equations showed in the earlier point and for a nominal power of 800 kW, we would obtain the following table:

Load %	Hours per year	Old Boiler eff. %	New Boiler eff. %	Savings (kWh)
100%	200	85%	95%	19.814
90%	400	80%	90%	40.000
80%	800	75%	85%	80.314
70%	1000	65%	80%	161.538
60%	500	50%	70%	137.143
50%	400	40%	60%	133.333
0%	5460	0%	0%	-

The net annual savings are the sum of the savings for each of the load fractions. We have assumed that the minimum load for the boiler is 50%, and that the new boiler will have the same nominal power than the existing one. In this example the annual savings are 572,143 kWh/year.

3.3. Total savings over lifetime

3.3.1. Savings lifetime of a efficient boilers

The expected lifetime of a heater is of twenty years or more

3.3.2. Lifetime savings calculation of efficient boilers

During its lifetime - of twenty years or more- there should not be an appreciable reduction in performance. Thus total savings are the expected lifetime for the annual savings, 11,442,860 kWh.

4. GHG savings

4.1. Annual GHG-savings

4.1.1. Emission factor for energy source

The only GHG relevant is CO_2, as we are assuming complete combustion of the natural gas (this can be tested with the combustion efficiency measurements), the savings are determined by applying the emissions factor to the energy savings, in the case of natural gas, the emission factor is 0.204 kg of CO_2 per kWh.

4.1.2. Annual GHG-savings calculation as applied

Using the emission factor of 0,204 kg of CO_2 per kWh in the formula would result in this example of annual savings of 116,717 kg CO_2.

$$GHG\ Savings\ (kg\ CO2) = N * Fp * 0{,}204 * \sum Energy\ before - Energy\ after$$

There are no other GHG affected significantly by this measure other than CO_2.

4.2. GHG lifetime savings

4.2.1. Emission factor

No emission factor for GHG lifetime savings.

4.2.2. GHG lifetime savings as applied

N/A

References

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
http://www.ashrae.org/

ATECYR: Spanish Technical Association of Air Conditioning and Refrigeration.
http://www.atecyr.org/eATECYR/index.php

IDAE: Institute for Diversification and Saving of Energy
http://www.idae.es/index.php

MINISTRY OF ECONOMY AND FINANCE.
http://www.catastro.meh.es/jaxi/tabla.do?path=/est2009/catastro/urbano/&file=03002.px&type=pcaxis&L=0

1.6 Installation of VSDs in electric motors

1 Summary of the program.

1.1 Short description of the program

1.1.1 Purpose or goal of the program

The aim of the program is to obtain a significant **reduction in electrical consumption in industrial pumping, ventilation and air compressed systems** in an economical way. This document is based upon common engineering calculations.

The energy efficiency calculations presented in this study represent regular methods in use in Spain due to the non-existence of accepted M&V standards

1.1.2 Type of instrument(s) used

The installation of VSD systems is subsidized with up to 22% of the investment.

1.2 General and specific user category (economic sector and subgroups)

The aim of this program is the industrial sector, specially the chemical/process industry.
.
1.3 Technologie(s) involved

This program is based upon **the installation of Variable Speed Drives** in Industrial pumping, ventilation and air compressed systems.

The Variable Speed Drive adjusts the power output of these devices and thus, the flow, depending of the actual demand in the installation.

1.4 Status of the evaluation and energy savings calculations

This case application holds a way how to calculate the energy savings of installing VSD.

1.5 Relevant as a Demand Response measure

This is a proven and mature technology and can result in significant savings in system with variable loads.

Its effect as DRM is lowering the load curve, but it cannot be considered as a controllable measure, since it depends of factors beyond control of the grid operator.

2. Formula for calculation of Annual Net Energy Savings

2.1. Formula used for the calculation of annual energy savings
Energy savings to be determined will consider the percentage of energy saving in industrial pumping, ventilation and air compressed processes using VSD, the average power of the

electric motors to be changed and the number of operating hours. This value will be corrected with the market penetration of the VSD in industrial sectors and the energy savings value in the UE calculated will be also adjusted and corrected with a coefficient in order to narrow it only for Spain.

The main formula for the calculation of energy savings achieved is the next one:

$$(AnnualSavings)_j = k_{Spain} \sum K_{ij} \bullet N_j \bullet \%ES_i \bullet \sum P_{average} \bullet H_{ij}$$

2.2. Specification of the parameters for the calculation

For the annual energy savings, parameters are follows:

j = Industrial Sector
- Food, beverage and tobacco
- Paper and cardboard
- Basic chemistry,
- Iron and steel

i = Type of application
- Pumps
- Fans
- Air compressors

$K_{(Spain)}$: = Correction factor
K = Percentage of motors in which the application of VSDs is cost-effective
N = Total number of motors
%ES = percentage of energy saving achieved using VSD for each application
$P_{average}$ = Average power (kW) of electric motors
H = Operating hours

2.3. Specification of the unit in the calculation

The unit is a VSD system.

2.4. Baseline issues

The baseline is the energy consumed before the application of the measure and is considered to be static.

2.5. Normalization

There is no normalization

2.6. Energy saving corrections

2.6.1. Gross-net corrections

There are no significant interactions to be considered. There is no need for normalization as there are no influence variables.

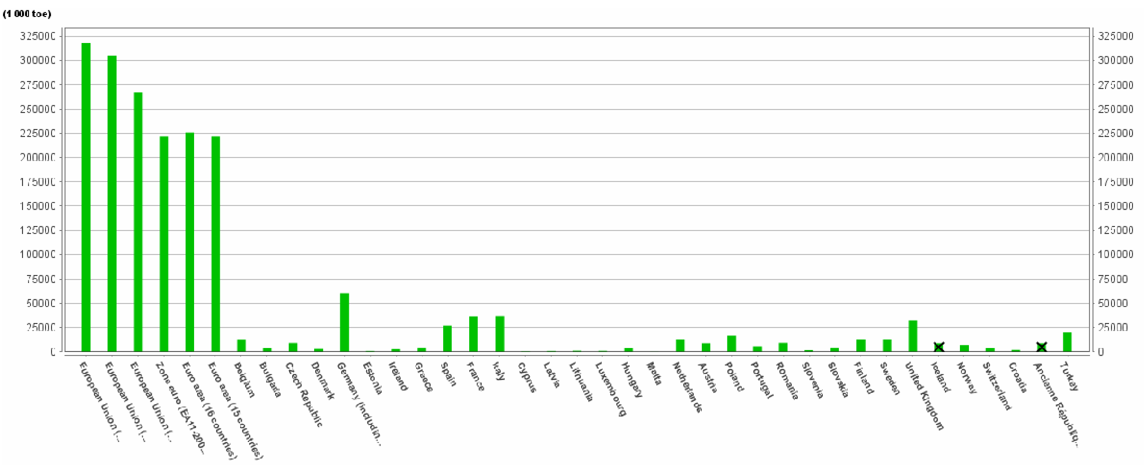
2.6.2. Corrections due to data collection problems

For the correction of the total energy savings obtained with the total number of electric motors, the percentage of the existing motors that are susceptible of the application of the VSD has been used, just because its application in the industry sector is cost-effective.

The energy savings calculated above show the total energy saving achieved applying VSD in pumps, fans and air compressors in the 4 industrial sectors determined before, for all the European Union. In order to correct this value and establish the energy savings for these industrial sectors only in Spain, it has been used the following coefficient[8]:

Ki Spain = (Final electricity consumption in the Spanish industrial sector/ Final electricity consumption in the EU industrial sector)

The energy consumption could be consulted in Eurostats:



3. Input data and calculations

3.1. Parameter operationalisation

See paragraph 3.2.

3.2. Calculation of the annual savings as applied

For the calculation of the energy savings it has been considered different industrial sectors, specially the chemical/process industry and also different uses of the electrical motors:

$$(Annual\ Savings)_j = k_{Spain} \sum (K_{ij} * N_j * \%ES_i * \sum ((P_{average}) * h_{ij}))$$

[8] 2008 has been considered as the last reference of electricity consumption in the industrial sector in Eurostats. Link: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=ten00099&plugin=1

Table 1. Percentage of motors in which the application of VSDs is cost-effective in each surveyed industrial sector (Kij)

Percentage of motors in which the application of VSDs is cost-effective in each surveyed industrial sector				
	Food	**Paper**	**Basic chemistry**	**Iron Steel**
Pumps	26%	38%	37%	32%
Fans	34%	35%	40%	38%
Air compressors	15%	18%	19%	18%

Table 2. Number of electric motors per industrial sector, application and power ranges (Nj)

	Number of Electric Motors. Pumps			
Power range	**Food**	**Paper**	**Basic chemistry**	**Iron Steel**
0,75-4	277.727	93.388	197.769	57.733
4-10	85.517	66.393	172.426	34.421
10-30	15.290	100.306	59.331	17.692
30-70	10.943	62.454	38.606	11.646
70-130	931	25.896	15.395	1.808
130-500	1.701	23.466	10.895	537
	Number of Electric Motors. Fans			
Power range	**Food**	**Paper**	**Basic chemistry**	**Iron Steel**
0,75-4	167.128	178.414	39.554	52.173
4-10	75.494	40.978	25.698	27.695
10-30	13.247	58.768	3.434	13.229
30-70	12.788	33.989	13.974	5.123
70-130	1.092	12.415	8.171	2.131
130-500	1.990	4.820	4.974	1.238
	Number of Electric Motors. Air compressors			
Power range	**Food**	**Paper**	**Basic quemistry**	**Iron Steel**
0,75-4	442.828	25.976	6.040	27.402
4-10	34.772	15.323	9.829	10.871
10-30	9.459	11.597	6.158	4.090
30-70	5.821	10.575	10.895	2.497
70-130	828	4.138	5.566	1.052
130-500	1.846	4.891	6.513	3.927

Table 3. Percentage of energy savings as an average by type of application (% ES)

Average energy savings (% ES)	
Pumps	35%
Fans	35%
Air compressors	15%

The number and average power have been also obtained from the study "Improving the Penetration of Energy- Efficient Motors and Drives". This report studies the operating hours of each kind of electric motor per power range, for each one of the industrial sectors considered, as it shown in the table below:

Table 4. Number of operating hours per industrial sector, application and power ranges (hij)

	Operating Hours. Pumps			
Power range	**Food**	**Paper**	**Basic quemistry**	**Iron Steel**
0,75-4	3.887	4.341	3.700	3.300
4-10	2.470	5.733	5.200	3.800
10-30	3.269	6.107	5.200	4.000
30-70	5.063	6.650	5.700	5.100
70-130	5.063	5.332	4.700	5.000
130-500	5.063	5.398	5.700	7.200
	Operating Hours. Fans			
Power range	**Food**	**Paper**	**Basic chemistry**	**Iron Steel**
0,75-4	8.390	4.045	5.100	4.500
4-10	3.583	5.996	6.100	3.700
10-30	5.063	5.687	6.500	3.700
30-70	5.063	5.467	6.600	4.100
70-130	5.063	5.248	7.600	7.100
130-500	5.063	6.264	7.100	7.200
	Operating Hours. Air compressors			
Power range	**Food**	**Paper**	**Basic quemistry**	**Iron Steel**
0,75-4	1.878	4.302	3.700	700
4-10	5.063	5.869	2.700	2.200
10-30	5.063	8.471	4.600	2.400
30-70	8.453	5.362	4.700	2.400
70-130	5.063	3.335	5.300	7.000
130-500	4.147	5.238	6.100	5.200

The average power for each power range is shown in the following table:

Table 5. Average power (kW) by power range (kW) – (P average)

Power Range (kW)	**Average power (kW)**
0,75-4	1,3
4-10	5,1
10-30	14,1
30-70	39,2
70-130	82,4
130-500	230,7

3.4. Total savings over lifetime

3.4.1. Savings lifetime of VSD

The expected lifetime of a VSD is infinite, but depending on the lifetime of the motor it is installed.

3.4.2. Lifetime savings calculation of efficient boilers

During its lifetime there should not be an appreciable reduction in performance.
No calculation conducted

4. GHG savings

4.1. Annual GHG-savings

4.1.1. Emission factor for energy source

The only GHG relevant is CO_2, the savings are determined by applying the emissions factor to the energy savings.

Each kWh consumed in Spain (using as reference data from REE, and evaluated in accordance to the European Commission Directive 2007/589/CE) amounts to 0.360 kg of CO_2:

4.1.2. Annual GHG-savings calculation as applied

Using the factor 0.360 kg CO_2/kWh the global annual savings are:

$$GHG\ Savings\ (kg\ CO2) = 0{,}360 * \sum Energy\ before - Energy\ after$$

4.2. GHG lifetime savings

4.2.1. Emission factor

No emission factor for GHG lifetime savings.

4.2.2. GHG lifetime savings as applied

N/A

References

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
http://www.ashrae.org/

IDAE: Institute for Diversification and Saving of Energy
http://www.idae.es/index.php

REE: Red Eléctrica de España, Electrical System Operator
http://www.ree.es/operacion/curvas_demanda.asp

EUROSTAT: European Commission Statistic Programme
http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables

STUDY: IMPROVING THE PENETRATION OF ENERGY- EFFICIENT MOTORS AND DRIVES - EU project coordinated by ISR-University of Coimbra. 1999.

2. EVALUATION PRACTISE

2.1 Introduction

The IEA-DSM Task XXI responds to the lack of common standards on Energy Efficiency Savings Calculations. The Operating Agent, in this case The Netherlands, is the responsible for the task planning and for the integration of its vision in cooperation with the other partners.

The Energy Savings Directive 2006/32/EC can be defined as the first European Directive concerning energy efficiency providing the possibility of using energy efficiency and demand-side management as alternatives to new supply and for environmental protection. To achieve its objectives, member states have launched action plans in energy efficiency. These action plans are designed to mobilize the general public, the policy makers and the market players, and transform the internal market of energy to provide for the citizens of the European Union the infrastructures, the products, the processes and the most efficient energy systems in the world.

The final aim of the action plans is to control and reduce energy demand and act selectively in relation to consumption and energy supply in order to achieve savings on annual primary energy consumption.

2.2 National Evaluation guidelines, guidance and selected reports on evaluations and energy savings calculations

2.2.1 List of guidelines

There is none.

2.2.2 List of guidance

The non-existence of a broadly accepted M&V standards in Spain restrains the future development of this market for the next years. M&V standards are fundamental to the development of an energy efficiency market because their application in a project is guarantee of its success

Situation of the ESCO market

- Limited development in comparison with another countries
- Lack of awareness and confidence in energy services provided by companies, mainly due to deficiency in information
- Resistance to outsource energy management
- Difficulties to access to necessary funds and financial methods
- Market development promoted mainly by The National Action Plan For Energy Efficiency 2008-2011

Limitation of M&V international guides in Spain

- Limited technical knowledge of the guides and lack of formative processes
- Lack of endorsement and guidance by the public sector

- Lack of a real background in the Spanish ESCO industry, which means that many projects are developed without a clear methodology
- Non-adequate funding in the early phases of a project, which is when the M&V Plan is at its most critical phase
- Language barrier to the spread of the existent guides, even though the IPMVP has been translated, only one of its volumes it is available in Spanish

Possible solutions

- Training and formation for the ESCO professionals
- Development of a local standard, of compulsory application in the public sector contracts
- Endorsement of this standard by the key players of the market
- Financing entities becoming aware of this business model and how the appliance of standardization can reduce the risk involved in it

2.2.3 Selected reports

Selected reports

Country:	Spain
Report number	1
Report title	Technical guide for consumption calculation
Year	2007
link	IDAE
Highlights/summary	The guide provides tips and practical solution aimed to calculate ratios related with energy consumption. It does not contained detailed information on the actual energy savings calculation.
Sector	Industry, services and commercial buildings
Technologies (max 15)	Various technologies for commercial buildings and industrial processes. Ventilation, Hot water, Heating, Cooling, lighting
Baseline approach	Before situation
Default energy or savings values	Default values per measure
GHG emissions	Not evaluated
Comment	None

Country:	Spain
Report number	2
Report title	Practical Guide about facilities centralized heating and hot water (DHW) in buildings
Year	2008
link	IDAE
Highlights/summary	The guide is aimed to promote the efficiency on final energy use at centralized hot water and heating household installations, also providing tips but not mechanisms to measure energy savings.
Sector	Household, services and commercial buildings
Technologies (max 15)	Hot water heating equipment (boiler, solar thermal, hot water storage tanks) and domestic heating (boiler, heat pump, district heating, timing devices, thermostats)
Baseline approach	Before situation
Default energy or savings values	Default values per measure
GHG emissions	Not evaluated
Comment	Technical guide

Country:	Spain
Report number	3
Report title	Practical Guidelines for Energy. Efficient and Responsible Consumption
Year	2007
link	IDAE
Highlights/summary	The guide provides general information about the importance of energy consumption, by sector and final use. It provides tips and advices to save energy, but it does not contained detailed information on the actual energy savings calculation.
Sector	Household, industry, services and commercial buildings
Technologies (max 15)	Insulation and building envelope, hot water, heating equipment, cooling, electrical appliances and lighting for several sectors
Baseline approach	Before situation
Default energy or savings values	Default values per measure
GHG emissions	Not evaluated
Comment	Easy guide, aimed to be understand by all audiences

Country:	Spain
Report number	4
Report title	National Action Plan for Energy Savings and Energy Efficiency PAE4+ 2008-2011
Year	2008
link	MITyC
Highlights/summary	The document contains the national strategies and objectives on energy efficiency and climate change, through the application of concrete measures for several sectors. It does not provide mechanisms to measure energy savings.
Sector	All sectors
Technologies (max 15)	Several techniques
Baseline approach	Before the application of the plan
Default energy or savings values	Current energy consumption
GHG emissions	Estimation of CO_2 tones avoided
Comment	National Regulation and road map

Country:	Spain
Report number	5
Report title	Energy efficiency indicators
Year	2008
link	Unión Fenosa
Highlights/summary	The document contains basic information about the application of energy initiatives in different sectors in Spain, and its savings potential. It does not provide mechanisms to measure energy savings.
Sector	All sectors
Technologies (max 15)	Several techniques for household, commercial and industrial sectors: Electric appliances, lighting, consumption management, cogeneration, pipes insulation, etc.
Baseline approach	Current energy consumption
Default energy or savings values	N/A
GHG emissions	Estimation of CO_2 tones avoided
Comment	Current situation analysis

Country:	Spain
Report number	6
Report title	Energy efficiency in the Iberian Peninsula
Year	2007
link	everis – Spanish Energy Club
Highlights/summary	The document contains a detailed analysis about the situation of energy efficiency and the perspective by household and industrial sectors, including the examples with the application of experimental economy. It does not provide mechanisms to measure energy savings.
Sector	All sectors
Technologies (max 15)	Several techniques for household, commercial and industrial sectors.
Baseline approach	Current energy consumption
Default energy or savings values	
GHG emissions	Estimation of CO_2 tones avoided
Comment	Current situation analysis

2.3 Use of international guidelines and guidance

Currently, there are four international measuring and verification (M&V) protocols that are the most deployed and applied worldwide in energy savings projects:

- IPMVP: International Performance Measurement and Verification Protocol, developed by the Efficiency Valuation Organization (EVO), a worldwide organization exclusively dedicated to the development of measurement and verification standards and the evaluation of projects allowing energy efficiency as a resource. IPMVP defines four measurement options based on the parameter measured and installation conditions
- ASHRAE guidelines 14-2002: standard developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). This guide defines three measurement schemes closed to those defined in IPMVP
- FEMP: M&V guide elaborated by the US Department of Energy (DOE) establishes the necessary methodology to implement energy efficiency projects under the Federal Energy Management Program (FEMP). It applies the same four IPMVP measurement options
- Energy Savings Measurement Guide (ESMG): elaborated by Australian Government for the application in energy efficiency projects, applies four measurement schemes similar to the four of IPMVP

Additionally to these international protocols, there are other M&V guides and methodologies, most of them with similar features as all they are based on IPMVP

3. STANDARDS RELATED TO ENERGY SAVINGS CALCULATIONS

3.1 Introduction

Although the Spanish standardisation organisation is a member of CEN and ISO, Spanish experts are not involved in the ongoing preparation of European and global standards on energy savings.

3.2 National standards

The non-existence of accepted M&V standards in Spain restrains the future development of this market for the next years. M&V standards are fundamental to develop an energy efficiency market since their application in a project is guarantee of its success

AENOR has recently published a standard procedure on energy management systems UNE-EN 16001:201031, as a transposition of the European standard EN 16001:2009.

This standard is aimed to help organizations to save energy costs and reduce greenhouse gases emissions caused by energy consumption, establishing the necessary systems and processes for improve energy efficiency in their operations. This standard procedure focuses only on energy management; future standards related with energy efficiency, energy savings and its mechanisms to be measured will be probably end up in the publication of AENOR standardized procedures.

3.3 Developments on standards

The European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC)

3.3.1 Ongoing and expected developments

Since 2007 CEN is elaborating standards for common methods of calculation of energy consumption, energy efficiencies and energy savings and for a common measurement and verification of protocol and methodology for energy use indicators. It is expected that by December 2012 the standard “Introductory element, Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods Complementary element” will be officially available at CEN as a standard **EN16212:2012**.

In 2011 the International Organisation for Standardisation (ISO) installed a Task Committee, **ISO/TC 257** dealing with “General technical rules for determination of energy savings in renovation projects, industrial enterprises and regions”. Workgroups are preparing draft documents to be discussed in meetings in the coming years.

3.3.2 Comments on (draft) international standards

As Spain is not active in the preparation of international standards, no comments are known.

3.4 Relevant organisations

AENOR, the Spanish standardization organization, plays a key role as the public entity responsible for the definition and maintenance of standards for different industry sectors.

Annexes

Annex A: Template energy savings calculation, with instructions, for case examples in IEA-DSM Task XXI

Annex B: Not included. There are no annexes to the Spanish case applications

Annex C: Case application of Demand Response: Interruptible service

Annex A: Template energy savings calculation, with instructions, for case examples in IEA-DSM Task XXI

<u>Frontpage:</u>
Case application: [Name, including technology and user category]
Country: [Name]
Author(s): [Name]
Date and version: [day month year] [only full numbers of version]

<u>Page 1</u>

1 Summary of the program

1.1 Short description of the program

1.1.1 Purpose or goal of the program

[Also include the period the program was running or when it started.]

1.1.2 Type of instrument(s) used

[Please indicate the type of instrument used. E.g. financial support, subsidize, label and standard, agreements, tax reduction]

1.2 General and specific user category

[Please by a specific as possible. Make a clear distinction between households, industry, services (commercial and non-commercial. If more users are targeted, please give some specification, especially if formulas would be different for different user categories.]

1.3 Technologie(s) involved

[Present the technology or technologies; please clarify in case a not well-known technology is used]

1.4 Status of the evaluation and energy savings calculations

[Provide information whether the energy savings calculations are used in an evaluation report. Include references and source in the Annex]

[Provide information whether the energy savings calculations itself have been evaluated. Include references and source in the Annex]

[Use one of the following options to qualify the status: 1. Legal; 2. Official stamped; 3. Semi official; 4. Use in practice; 5. Under development; 6. Under research)

1.5 Relevant as a Demand Response measure

[Indicate when the case is relevant for DR; if so refer to the separate DR case application description]

2 Formula for calculation of Annual Energy Savings

2.1 Formula used for the calculation of annual energy savings

[Short introduction and provide information on the origin of the formula; please use one of the three options:

- an existing formula (give reference; also in reference list in Annex the traceable source), or
- an adapted version of an existing formula; please describe adaptations in short and give reference for the original formula (also in reference list in Annex the traceable source), or
- self developed (short description; present additional documentation in Annex)]

[Present the formula]

2.2 Specification of the parameters in the calculation

[Provide information on the parameters and the reasoning of selecting those parameters]

2.3 Specification of the unit for the calculation

[The most common units are: an object of assessment; an action or an energy end-user]

2.4 Baseline issues

[Brief description which type of baseline is used in the energy savings calculations. The most commonly used types are:

a. before situation; evaluate the measure against the technique used before
b. stock average; evaluate the measure against the average stock technique
c. market average; evaluate the measure against the average technique on the market
d. common practice; evaluate the measure against the most commonly used technique]

[Describe whether a static or a dynamic baseline is used.
The before situation is always a static baseline. The other methods can be either static (using the values of a base-year or base period) or dynamic (changing over time, for example reflecting the change in most commonly used techniques)]
[Specify if a combination of approaches is used]

[Describe the important assumptions and the reasoning of the choice]

2.5 Normalization

[Normalization is a way to adjust the data in line with a normal situation; most common this is normalization for degree heating or cooling days.]
[Please describe briefly and give sources / references for the normal situation].

2.6 Energy savings corrections

[Specify which (gross to net) corrections have been applied and how these are calculated. Please be clear in the corrections taken into consideration and used to correct.
[The most common categories are: a) double counting; b) free riders; c) technical interactions; d) spill over effects and e) rebound effect]

3 Input data and calculations

3.1 Parameter operationalisation

[Describe how the calculation parameters are obtained; both for actual and reference situation.]

[Please also clearly indicate what type of values is used:

a) deemed (rough approximations, expert opinions, etc.)
b) calculated (for example using survey data)
c) measured (for example real measurements taken, billing information, etc.)
d) combination]

3.2 Calculation of the annual savings as applied

[Present the calculation with the values used. Please provide the data is several steps as this improves transparency and understanding]

3.3 Total savings over lifetime

3.3.1 Savings lifetime of the measure or technique selected

[Present information on the lifetime used. Also indicated whether this is an economical lifetime or not.]
[Present the number of years and the source for this value; include the reference in the Annex]

3.3.2 Lifetime savings calculation of the measure or technique

[Present the formula and the conducted calculation. In most cases this will be the outcome of 3.3.1 multiplied with the lifetime years. Please clarify if the energy savings calculated are not the same in all years. Explain if this is the case.]

4 GHG savings

4.1 Annual GHG-savings

4.1.1 Emission factor for energy source

[Present the emission factor used and give reference; included the source in the appendix.]
[Please specify what GHG emissions are included in the calculation: CO2; CH4 or N2O]

4.1.2 Annual GHG-savings calculation as applied

[Present the formula as well as the calculation]

4.2 GHG lifetime savings

4.2.1 Emission factor

[Present the emission factors used when not the same factor is used for the lifetime, and give reference; included the source in the appendix. Otherwise include: The same GHG emission factor(s) are used for the lifetime.]

4.2.2 GHG lifetime savings as applied

[Present the formula as well as the calculation]
[The lifetime should be the same as for the energy savings; if not please clarify]

References

[Please use: Report title, Author, year and if applicable the website]

Annex

[Present in the Annex additional information on methods, data sources etc. to elaborate the data, formulas etc]
[If no or no clear energy savings calculations is used in the case application, but a method could be used, please describe this in an Annex]

Definitions

[Provide definitions used for the target group, unit of saving etc.]

Annex C: Case application of Demand Response: Interruptible service

Introduction

Demand response (DR) refers to the reduction of customer energy usage at times of peak usage in order to help address system reliability, reflect market conditions and pricing, and support infrastructure optimization or deferral. Demand response programs may include dynamic pricing/tariffs, price-responsive demand bidding, contractually obligated and voluntary curtailment, and direct load control/cycling.

The information on Demand Response products is collected to relating impacts of DR projects to those for energy savings. For this reason the information is organised as following. We start with general information on the DR project and relations with other DR initiatives (section 1 and 2). Then we present information to be related to energy savings calculations: input data, baseline definition and key parameters considered, and savings calculations (section 3-5). Next is information on changes in the load shape and benefits in sections 6-8. We end with sources and documentation.

1. Description of the DR initiative

This Demand Response programme carried out in Spain describes the Interruptible service, a Demand Response initiative available in Spain since 2008 which key element is the possibility of cut electricity consumption by grid operator for some big industrial consumers who previously have sign a contract.
This initiative is based on previous similar interruption contracts applicable since 1983. The service is managed by Red Eléctrica de España (REE), the Electricity transmission operator.
This project seeks to achieve three main objectives:

- Minimising outages
- Increasing operating reserve
- Reducing peak loads

The project target is the whole electricity network, and the market segment addressed is large industrial electricity end users.
In 2010, more than 160 clients were subscribed to interruptible service, with a total interruptible power[9] of 2 163 MW, which corresponds to around 10% of total electricity demand in Spain.
By 1 June 2012, there are 151 interpretability contracts in force, of which 137 correspond to the mainland system, 13 to the Canary Island system and 1 to the Balearic Island system. The total interruptible power manageable by the system operator in periods of maximum demand reaches approximately 2 122 MW, of which 2 069 MW correspond to the mainland system, 50 MW to the Canary Island system and 3.3 MW to the Balearic Island system.

Under the Load Interruption Contract, the maximum numbers of interruptions that can be requested by the System Operator are as follows:

- 1 per day (12 hours maximum per day)
- 5 per week (60 hours per week)
- 120 hours per month

[9]This power corresponds to the maximum interruptible power with Type 3, which can be considered as the average interruptible power in the system

- 240 hours per year

Clients are connected to a control centre in REE, when the event is launched the client has the option to participate or decline the event. In case a declination, consumer will receive an economic penalty.

2. Related DR initiatives

The IEA DSM website holds information on three other Demand Response programs:

- Hourly Demand Tariff; is applicable to five different kinds of customers and is mandatory for low voltage customers. The Hourly Demand Tariff has four components: (1) a demand component calculated as the customer's maximum demand in each time of use period multiplied by the rate for that period;(2) an energy component calculated as the energy consumed in a time of use period multiplied by the rate for that period;(3) an interpretability discount; and (4) if applicable, a reactive power discount.
- Load Interruption Contract; an agreement through which large customers receive a discount on their electricity bills in return for being available to reduce their consumption on request from the System Operator.
- Flexible Load Interruption Contract; an extension (Since 2002) of the (basic) Load Interruption Contract and allows customers to reduce their consumption following a specific profile, more appropriate to the real profile of the system load.

3. Input data

The input data is the schedules of energy demand submitted by clients participating in the Load Interruption Contract:

- At the beginning of the year, participant customers must submit a forecast for estimated energy consumption;
- Bimonthly, customers must submit to REE monthly schedules for hourly energy demand and maintenance planning

4. Baseline definition and key parameters considered

Baseline energy is estimated with the schedules submitted by these clients; the key parameters considered for load interruption are the type of interruption depending on the duration and the warning time:
Based on these two parameters, there are five types of interruptions possible:
- Type 1. Maximum interruption time: 12 hours Minimum warning time: 2 hours
- Type 2. Maximum interruption time: 8 hours Minimum warning time: 2 hours
- Type 3. Maximum interruption time: 3 hours Minimum warning time: 1 hour
- Type 4. Maximum interruption time: 2 hours Minimum warning time: 5 minutes
- Type 5. Maximum interruption time: 1 hour Minimum warning time: 0 minutes

Where type is the nomination for the modality of power reduction offered to customers, maximum interruption time is the sum of maximum duration of all periods that constitutes the load reduction order and minimum warning time is the minimum space between reduction order and the beginning of the first period of application.

The load reduction order can include one or more periods of at least one hour and no necessary consecutives.
Each type of power reduction is characterized by the maximum number of periods per order, maximum duration of each period and maximum value of residual power available to consume in each one of them. For each them, the parameters will take the following values:

Type	Max number of periods per order	Max duration per period	Max residual power value to consume in each period
1	3	4 hours	P_{max1} in two periods, $P_{50\%}$ in one period
2	2	4 hours	P_{max2}
3	1	3 hours	P_{max3}
4	1	2 hours	P_{max4}
5	1	1 hour	P_{max5}

Where

- $P_{max.i}$ is the maximum residual power, that is, the value of maximum power to consume by service provider for power reduction type *i* in periods where maximum power reduction is requested
- P_f is the consumption power, that is, the verifiable value of power ready to use continuously by service provider
- $P_{50\%}$ is the residual power at 50%, calculated as: $P_{50\%}=P_{max.i} + 0,5*(P_f-P_{max.i})$

Additionally, the Load Interruption Contract includes the following provisions:

- Access tariff: Hourly Power Tariff or High Voltage General Power Tariff
- Billing mode: there is a single process, based on yearly payment
- Interruption modalities chosen:
  - Modality "a": only types 3, 4 and 5
  - Modality "b": all 5 types
- Energy consumption pattern: evolution from 2 years before and forecast for the next 2 years

Payment: there is a formula for payments, according to average energy price, yearly energy consumption, load modulation coefficient, annual discount and equivalent hours of yearly usage.

As an example, in figure 1, a baseline load curve is given for a typical weekly distribution[10] for industrial customers participating in interruptible service. This load curve does not include energy units as it reflects the average weekly distribution. In figure 2 a daily distribution is presented.

[10] The load curve does not include energy units as is an example of energy consumption is distributed along the week

Figure 1: A typical weekly load curve for industrial customers in the programme

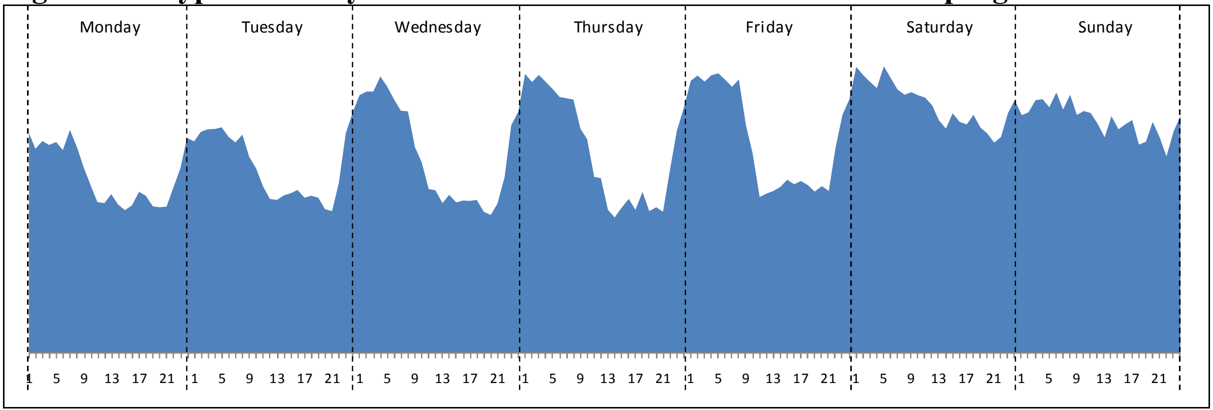
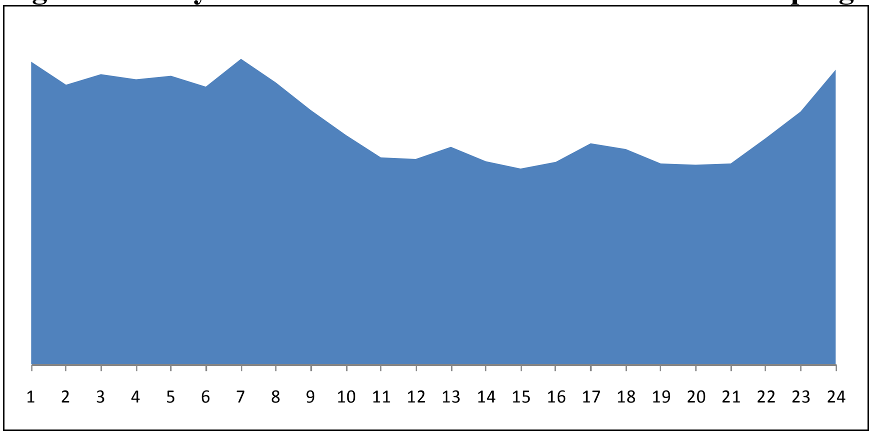


Figure 2: Daily load curve for industrial customers in the programme



5. Savings calculation

Energy savings from this initiative are measured as a whole from the energy not consumed by the clients participating in each interruption.

Responses from contracted customers are enough accurate as the probability of accepting the load reduction is very high.
Another factor which might impact in the confidence level is the possibility of failure of the communication system (probability for customer of not being aware of the possibility of interruption). However, high volume industrial consumers are highly reliable when they are requested to interrupt load by the System Operator.
Energy savings are highly related with load shape impact, the detail of energy savings can be found in the next section.

6. Load shape impact

The impact on load shape of energy savings can be considerable, as the grid operator decides when to launch the DR event (in periods of peak loads).

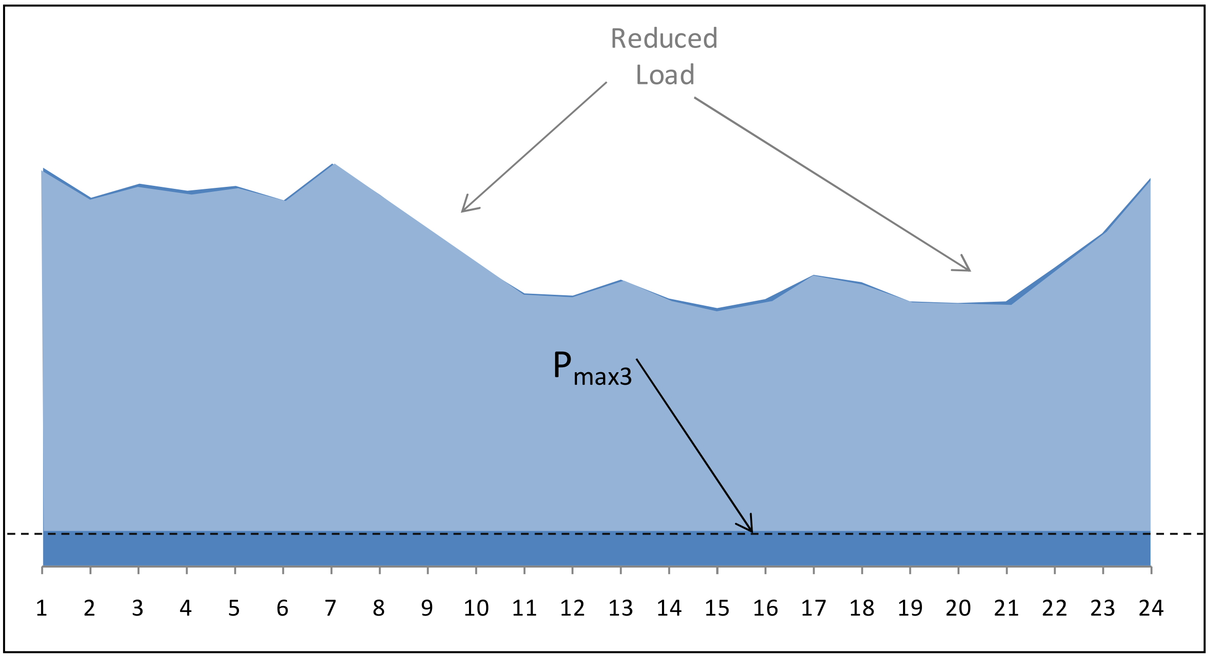
As an example[11], in an event with 164 participants that lasted for 3 hours, the load reduction was around 5%. This load in the system was measured with interval meters each 5 minutes:

- Large Industrial Customers Participating (number): 164
- Peak Load (MW): 45,000 MW
- Peak Load Reduction (MW and % of total demand): 2,300 MW (5,11%)
- Duration of Peak Load Reduction (hours): 3 hours
- Greenhouse Emissions Reduction (tCO_2-eq): Maximum 6.300 tCO_2 per year[12]
- How Load Reduction was Measured: Interval meter with 5 minutes

The load shape impact was measured over the global load curve at country level, since consumers with Load Interruption Contract represent a big share of energy consumed and their impact over the load shape is considerable.

Figure 3 holds an example for a load reduction. Taken the illustrative load shape given as baseline, in a demand response event maximum load can be reduced to P_{max3} (approximately 1.100 MW), which graphically can be represented on the load curve for interruptible customers:

Figure 3: Example for a load reduction



7. Benefits to participants

Participants sign a yearly contract with REE specifying the conditions and benefits they receive by the participation on the program, in the form of payments.
In 2011, the budget for payments to costumers joining the interruptible service is 522 Million €.

[11] This example was published in IEA-DSM Task XVIII, the data given considers the old interruption service available before 2008
[12]GHG calculated considering the coefficient for the mix generation when this example was measured

8. Other benefits

For TSO, the main benefits are grid stability and the reduction of peak loads in the global system.
Additionally to energy savings and load peak reduction, greenhouse emissions reduction can also be calculated. In this case, GHG savings are considering the current factor for electricity generation. For better GHG estimation, GHG calculation should consider a dynamic factor based on the generation mix when the interruption is produced.

9. Sources and documentation

Sources
Ministerial Decree January 12th 1995
Ministerial ITC/2370/2007
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IEA DSM Task XVIII, *Project description DSM-ES04 Load Interruption Contract*, November 2010, http://www.ieadsm.org/TaskXVIIIDSMProjectsDatabase.aspx

IEA DSM Task XVIII, *Project description DSM-ES03 Hourly Demand Tariff* November 2010, http://www.ieadsm.org/TaskXVIIIDSMProjectsDatabase.aspx

IEA-DSM Task XV, *IL02 Flexible Load Interruption Contract,* REE, October 2008 http://www.ieadsm.org/TaskXVNetworkDrivenDSMCaseStudiesDatabase.aspx

REE, Interruptible service, information on the internet http://www.ree.es/ingles/operacion/servicio_interrumpibilidad.asp and http://www.ree.es/operacion/sistema_gestion_interrumpibilidad.asp

Torriti J, et al., Demand response experience in Europe: Policies, programmes and implementation, Energy (2009), doi:10.1016/j.energy.2009.05.021 http://www.supergen-networks.org.uk/filebyid/48/file.pdf