1. Energy saving calculations in Spain

Commercial buildings heating systems

The goal of this program (included in the E4 Strategy) is to promote energy efficiency through the substitution of old boilers in commercial buildings with new, more efficient boilers. The program seeks to be implemented in the 20% of the existing buildings. The plan does not include how to measure and evaluate the impact and the savings in a standard way.

Technology:

As cooling loads are predominant in most offices buildings, **the heating 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:

- The building is used as **office.**
- 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. In this case, **we assume that the most convenient boiler is a low temperature one**.

Formula for calculation of Annual Net Energy Savings

To evaluate the savings prior to installation, **it is necessary to accurately know the efficiency of the existing boiler**. Apart from the mandatory combustion efficiency measurements, the consumption of gas in an hourly basis and the inlet and outlet temperatures in the boiler **during a month of operation** should be recorded. With this data it is possible to determine the efficiency at different loads. The power of the boiler will be:

$$Power\ (kW) = Cp * (Toutlet - Tinlet) * Flow$$

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:

$$Efficiency = \frac{\sum Power_i}{NHV * \sum Natural\ Gas\ Consumption}$$

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:**

$$Savings(kWh/year) = \sum Load * Hours * Nominal\ Power * (\frac{1}{\eta old} - \frac{1}{\eta new})$$

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.

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Input data and calculations

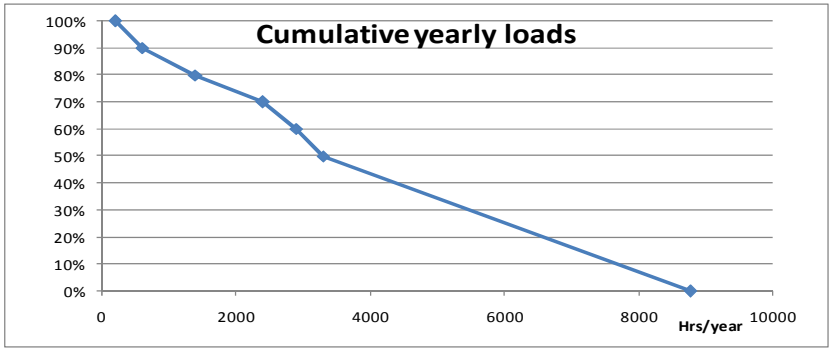
The **input data necessary** for the calculations is:

- 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. In the example, we assume a nominal power of 800 kW.

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.

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%	-



GHG Savings

The only GHG relevant is CO2, 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 CO2 per kWh.**

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

In this example, the annual savings would stand for 116.717 kg/year..

There is no standard methodology in Spain to measure savings in efficient lighting programs. The methodology followed in this document is based upon engineering calculations.