A LIFE-CYCLE COST ANALYSIS FOR DELIMITING THE NEW FRENCH ENERGY CONSERVATION REQUIREMENTS IN THE NON RESIDENTIAL BUILDING SECTOR.

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ABSTRACT:

The current French energy conservation regulation for non-residential buildings was elaborated at the end of the 80 s. Since then, many parameters have changed (energy prices, emergence of new techniques, growing public concern for the environment, ...).

It is the reason why the public authorities have decided to reinforce the energy conservation regulation. The expected result is a global reduction in energy consumption of about 25% as regards the current situation.

The Centre Scientifique et Technique du Bâtiment (CSTB) has been commissioned to delimit the new energy requirements to be applied to the non residential building sector.

A present life-cycle cost analysis including investment, running and maintenance costs has been carried out. More than 15 000 simulations were performed for that purpose combining HVAC systems, building envelope techniques and economic parameters.

This paper will briefly describe the methodology and present the main results.

1 - INTRODUCTION.

Current energy conservation regulation applicable to non-residential buildings was developed ten or so years ago to come into force at the end of 1988. During these ten years, changes have occurred:

- the national and world energy situation has altered,
- energy-related environmental protection has come to the forefront of concerns,
- advances in performances, both in terms of building envelope component and equipment, have been made partly due to the actions undertaken in housing,
- nowadays, designers have more effective and higher performance tools available. The range of available techniques has been enlarged and improved (e.g. in the case of air conditioning equipment), and certain have been largely developed (such as building energy management systems).

All these changes form the background to modifications to the current regulation. On the request of the French Ministry of Housing and ADEME (French Agency for the Environment and Energy Conservation), the CSTB has been commissioned to propose an approach for simplifying and updating energy conservation regulation in the non-residential building sector.

2 - APPROACH ADOPTED

The general approach adopted to allow new requirements to be established in terms of heat loss through the building envelope has consisted in optimizing the levels of insulation of the different building surfaces (walls, roof, windows, floors) from a technical and economic standpoint. This optimum is obtained by seeking the minimum value of the present life-cycle cost (CGA) associated to the building heating process.

$$CGA = CI + \left(CF_{ct} + CE_{nt}\right) \cdot \sum_{t=1}^{N} \frac{(1+g)^t}{(1+a)^t}$$

where:

CGA = Present life-cycle cost; FFR.

CI = Cost of investment; FFR.

CF_{ct} = Annual running cost in current value; FFR.

CE_{nt} = Annual maintenance cost in current value; FFR.

a = Annual discount rate; %.

g = Escalation rate of energy prices; %.

N = Economic horizon; years

To consider this approach, we have used a well-defined project known as the base case. This corresponds to a standard shape and composition building. The envelope of this building is identified:

- either by a thickness of insulation in the case of opaque surfaces (walls, roof, floors),
- or by a thermal transmission coefficient K_{GV} in the case of glazed surfaces.

Table 1 groups together the different cases dealt with.

Type of surface	Optimization variable	Number of samples	Range of variation
Walls	Thickness of insulation	5	1 to 10 cm
Roof	Thickness of insulation	6	1 to 10 cm
Floors	Thickness of insulation	5	1 to 10 cm
Windows	Thermal transmission coefficient	5	2.30 to 3.55 ($W/m^2.K$)

- Table 1 - Base case : investigated configurations.

The combination of these four optimization variables covering just the building envelope generates 750 different configurations.

The building equipment (heating and ventilation systems) are identified by their energy performances. These performances are maintained at conventional values corresponding to the reference systems defined in agreement with professionals. To this end, building equipment are not considered as optimization variables. However, performances are parametered in relation to the type of energy and building occupancy (see figure 1).

For each configuration (for the base case there are 4 x 750 = 3000), we calculate, *inter alia*:

- the specific transmission heat loss of the building; G1,
- the specific heat loss of the building; G,
- the annual running cost associated to the building heating process,
- the initial investment cost associated to the building heating process,
- the present life-cycle cost associated to the building heating process.

From this base case, a parametric study was undertaken in order to test the sensitivity of the different requirements to certain parameters.

The parameters adopted are related to:

- the morphology of the building,
- the construction techniques,
- the type of building (school, office, hospital, ...),
- climatic conditions,
- economic scenarios.

In this paper, we will only present the results for the base case.

3 - SYNTHESIS OF RESULTS

The essential base case data are as follows:

* Internal insulation on vertical walls,

* Characteristics of the building:

Effective volume: 1125 m^3.
Effective floor area: 450 m^2 on two levels.

* Degree-days =2490 °C.day (base 18°C)

* Economic data:

- Discount rate: 8 % p.a.
- Escalation rate of energy prices: 3 % p.a.
- Economic horizon: 15 years.

Figures 2 to 5 give the results obtained according to the type of occupation and the type of energy. We have chosen to identify on these figures the five types of window characterized by their coefficient K_{GV}:

- K_{GV}=2.30: PVC frame and 4-12-4 low emissivity double glazing.
- K_{GV}=2.75: PVC frame and 4-12-4 clear double glazing.
- K_{GV}=3.05: PVC frame and 4-6-4 clear double glazing.
- K_{GV}=3.25: Aluminium frame with thermal break profile, 4-12-4 clear double glazing.
- K_{GV}=3.55: Aluminium frame with thermal break profile, 4-6-4 clear double glazing.

On each figure, 750 points are plotted, using coefficient G1 as X axis and the CGA expressed in FFR per m2 of effective floor area as Y axis. Many points have a similar coefficient G1 (rounded up to 0.01) but their CGA is different (i.e. their investment cost is different).

A curve (thick line) is joining all minimum values of CGA. The broken lines on the right of the curve are linked to the method of representation used and to the insulation thickness variation which is 1 cm. The high values of coefficient G1 on this part of the figure correspond to the high values for the thermal transmission coefficient and therefore to low insulation thicknesses. At these low thicknesses, a difference of 1 cm of insulation leads to a large variation in coefficient K and therefore a high variation in coefficient G1.

The economic optimum corresponds to the absolute minimum of the curve linking the minimum values of CGA to coefficient G1.

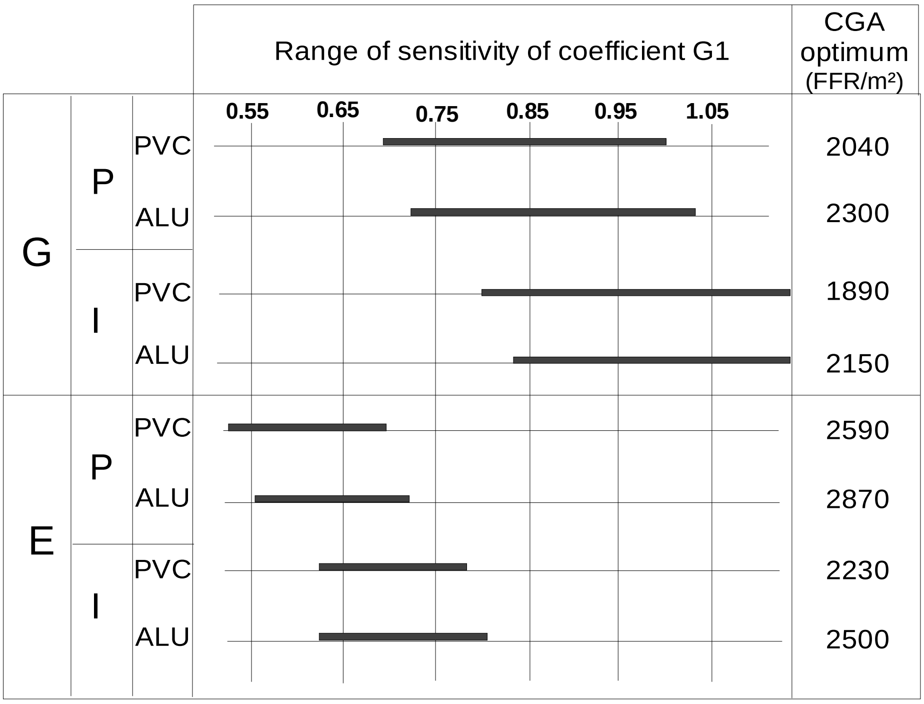
Insofar as the curve is generally flat, we feel it is necessary to complete the information given on the optimum by a sensitivity range. This range of sensitivity is calculated using a 1% deviation from the optimum value of CGA. In this way it defines an optimum G1 coefficient with an upper limit and a lower limit. Figure 6 illustrates the method of calculating this range.

The analysis of figures 2 to 5 leads to the following observations:

a) ***The curve linking the minimum values of CGA to coefficient G1 is very flat, more especially for gas.*** The ranges of G1 coefficient variation close to this economic optimum when the CGA varies from 1% are given in table 2 for the two types of energy: gas (G) and electricity (E), the two types of occupation: permanent (P) and intermittent (I), and the two types of window frame, PVC and ALUminium.

   A change of 1% in the optimum corresponds to a difference of between 20 and 30 FFR/m² depending on the configuration. As a comparison, it is to be noted that the difference between electricity and gas is between 350 FFR/m² and 550 FFR/m², between permanent and intermittent occupency 150 FFR/m² and 350 FFR/m² and between aluminium and PVC windows close to 250 FFR/m².

   With gas, doubling the thermal performance of the envelope (dividing coefficient G by 2 and therefore the heat transmission coefficients of surfaces) leads to an overall CGA variation of less than 100 FFR/m².



- Table 2 - Sensitivity ranges of coefficient G1

b) ***Within a same type of energy, there is no notable difference between permanent and intermittent occupancy.***

c) ***The optimum in gas is fairly clearly differentiated from that obtained with electricity.*** The very high difference between energy costs (in France, gas is 3 to 4 times cheaper than electricity) is however tempered by the fact that the overall efficiency of the gas heating system is lower, largely due to the heat generator losses occuring during operation and during stand by.

For that reason the present value of the running cost is half as much with gas as with electricity.

d) ***With electricity and in case of permanent occupancy, the optimum is obtained with PVC frame, low emissivity double glazing window.*** Otherwise, the optimum is obtained with PVC frame, clear double glazing window.

e) ***No significant difference is noted between the G1 range of variation corresponding to the economic optimum for PVC windows and for aluminium windows.*** Going from one type of window to an other one introduces similar translations in terms of investment costs and running costs, and therefore it does not affect the position of the economic optimum.

4 - CONCLUSIONS

A present life-cycle cost (CGA) analysis has been undertaken for delimiting the new french requirements in terms of heat loss through the building envelope in the non-residential sector.

It has been shown that the curve linking the minimum values of CGA to the specific transmission heat loss coefficient of the building (G1) is very flat and this is much clearer in the case of gas heating appliances than in the case of electricity heating appliances.

The range of variation of the optimum has been determined for a very low fixed variation of CGA of 1 %. As showed the aforesaid results, this range of variations is very wide.

A discrepancy of 1 % only represents 20 to 30 FFR per m^2 effective area, 10 to 15 FFR per m^2 envelope area.

This difference is to be compared with the 10 to 20 times higher figure obtained by certain technological choices such as type of windows, type of insulation or energy used for heating.

If this range of variation is examined, we note that the right end and left end correspond to the same present life-cycle cost, but with different investment costs and running costs: the left hand part corresponds to the highest investment (therefore to the highest level of insulation) and to the lowest running costs.

This is where the level of requirement has to be determined for at least two reasons:

- Life time of the envelope insulation is very long and changes to the energy context may require this to be upgraded, a very expensive operation, and impractical in certain cases. However, the lower life time and the ease of replacing heating equipment enables them to be more easily adapted to technological evolutions and to new regulations.

- A high running cost is synonymous with high heating consumption and therefore affects the environment. Although we have not considered it as part of the study, the possibility of taxing polluant emissions (notably CO_2) must not be excluded within the context of the draft European Directive. This tax, if it were to be set up, would strengthen requirements in terms of insulation.

ACKNOWLEDGMENT

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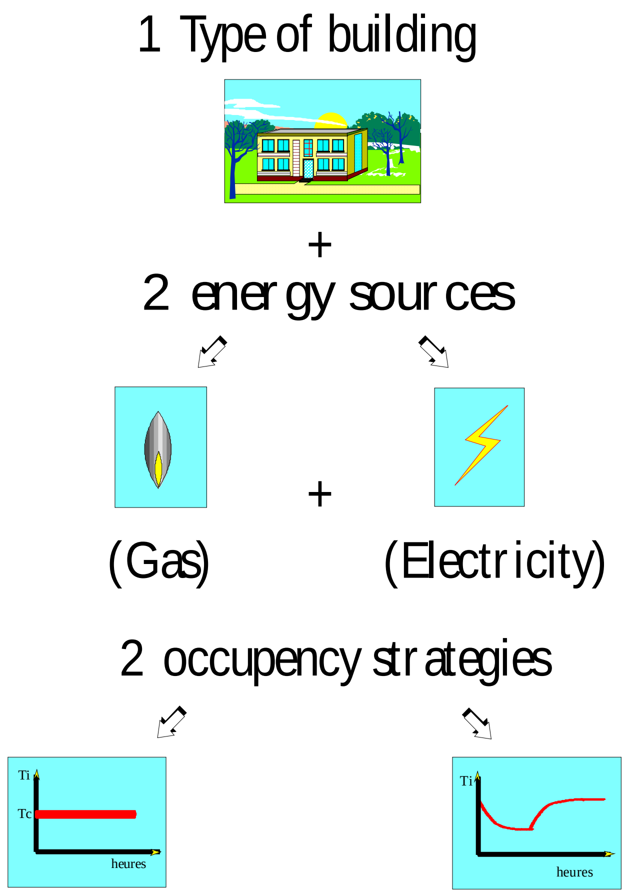
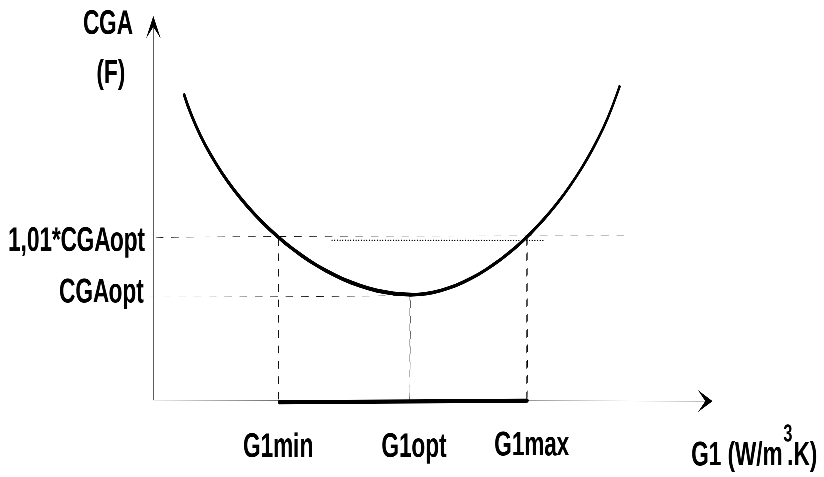
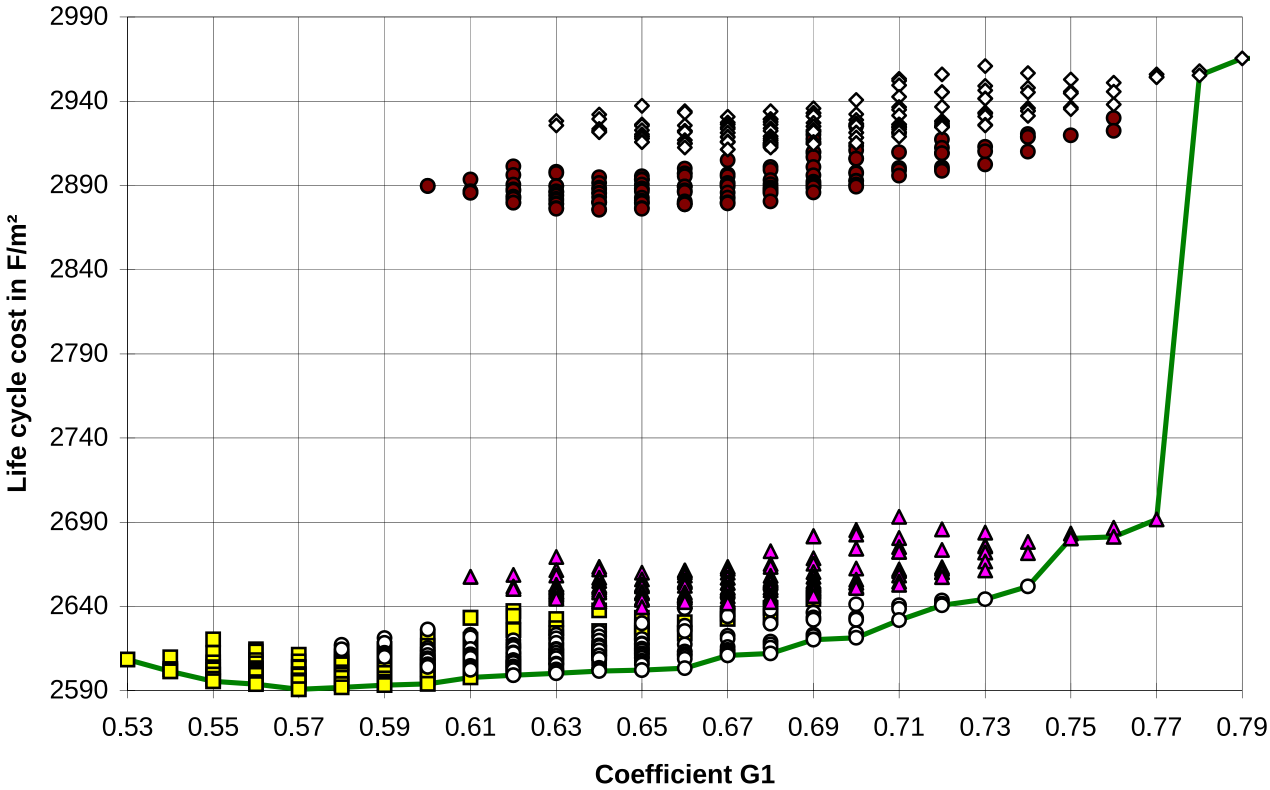


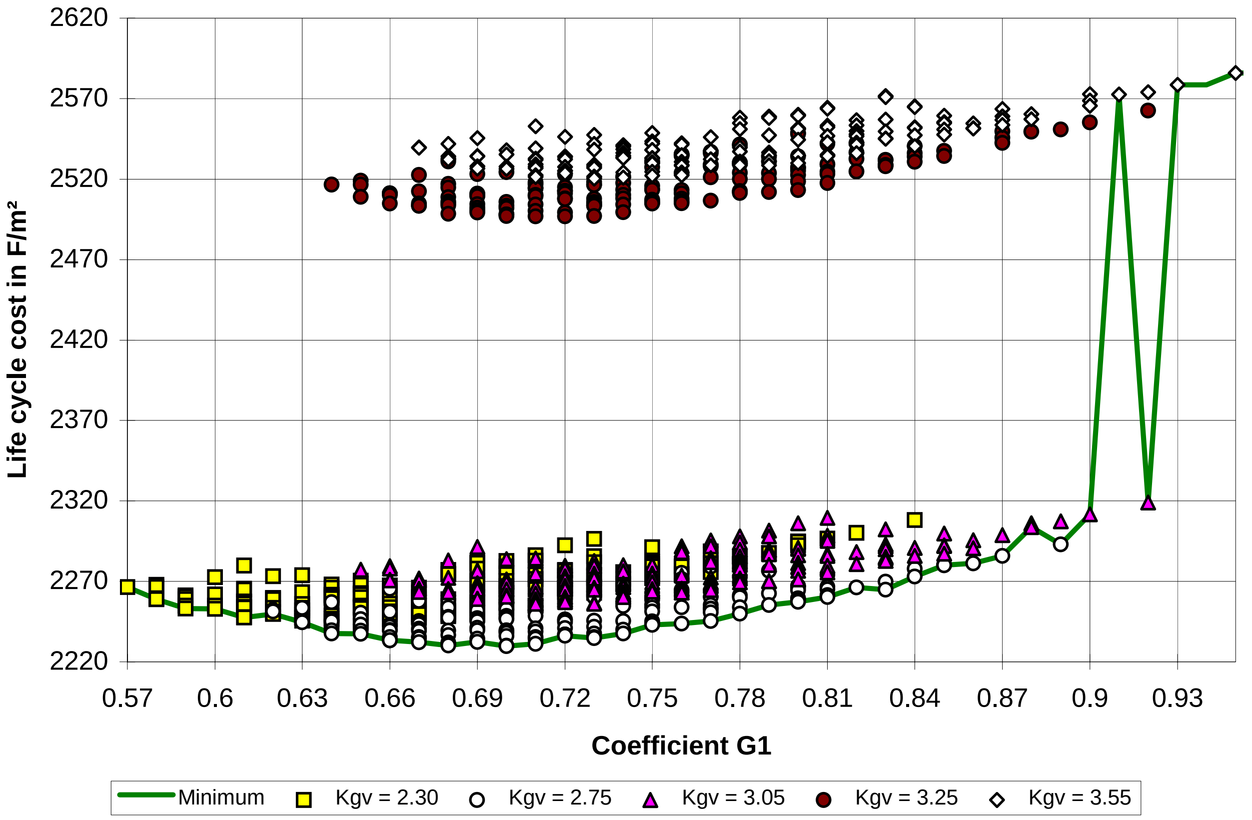
- Figure 1 - Selected parameters for the reference case.



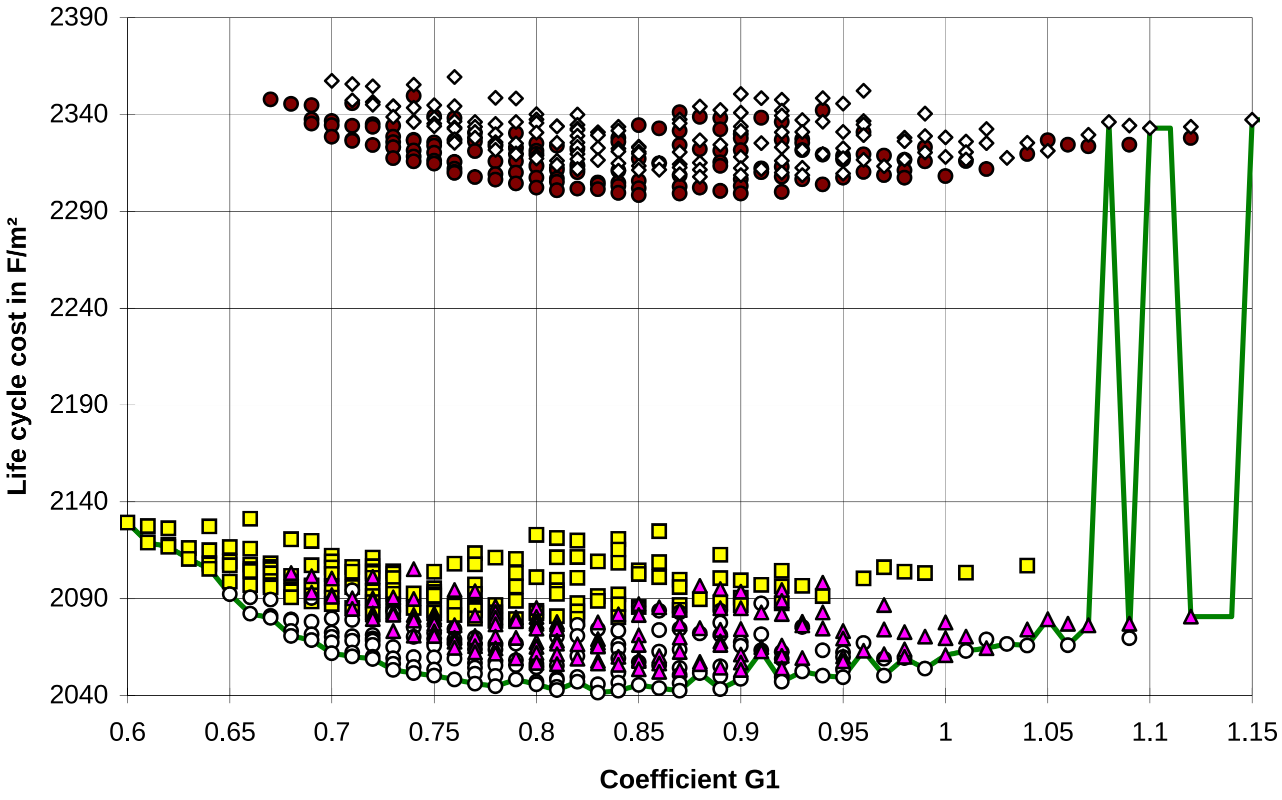
- Figure 6 - Sensitivity range.



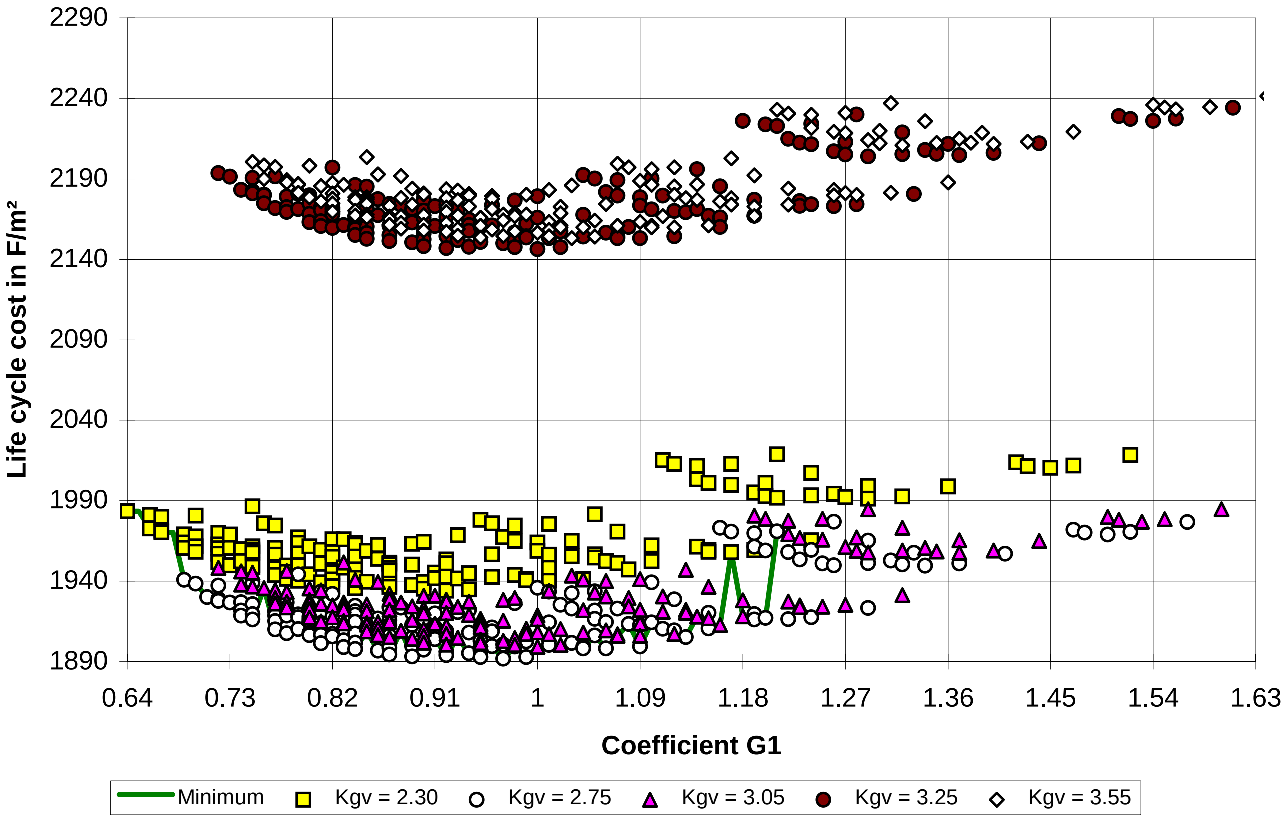
- Figure 2 - Electricity - Permanent occupancy.



- Figure 3 - Electricity - Intermittent occupancy.



- Figure 4 - Gas - Permanent occupancy.



- Figure 5 - Gas - Intermittent occupancy.