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THE ENERGY PERFORMANCE OF BUILDINGS : HOW CAN THE RULE BE MODULATED TO BETTER REACH THE GOALS ?

Summary of the report drafted on behalf of the OPECST
by Messrs. Christian Bataille and Claude Birraux, deputies

By laying down the energy consumption norm in future buildings at 50 kWh of primary energy per square metre per year, Article 4 of the Act of 3 August 2009 implementing the Grenelle environmental roundtable talks entrusted the Parliamentary Office for Scientific and Technological Assessment (OPECST) with the mission of proposing a modulation of this norm, so as in particular to encourage the decrease in greenhouse gas emissions. A rapid response was required to guide the drafting of the implementing decrees. By making an early referral to the National Assembly Economic Affairs Committee in March 2009, Messrs. Christian Bataille and Claude Birraux, deputies appointed by the OPECST to carry out this study, were able to start their investigations early enough, before the final vote on the legislation, to transmit their conclusions on 2 December 2009, meaning they could be taken into account during the drafting of the implementing decrees

Aim of the study

Article 4 of the programme Act of 3 August 2009 on the implementation of the Grenelle talks plans to lower to 50 kWh/sq. m/year of primary energy, from 2011 for the tertiary sector, and from 2013 for the residential sector, the energy consumption ceiling for new buildings. The regulation in force (the so-called 'RT 2005') sets forth a primary energy ceiling of 110 kWh/sq. m/year for gas and 190 kWh/sq. m/year for electricity.

The need for such an effort is fully justified, in the energy savings context, because of the percentage buildings account for in the energy consumed by the French: for primary energy, they represent 45% of the total, as against 28% for industry and 26% for transport.

Primary energy merges with the energy consumed to produce fuels but, for electricity, it is equal to the energy serving to produce it. In accordance with the constraints of thermodynamics, two thirds of this energy dissipates in heat in thermal power plants. Final consumption of 1 kWh of electricity therefore requires nearly 3 kWh of energy at the production stage. By convention, the figure of 2.58, called the 'conversion factor[1]' is adopted.

However, a regulatory constraint based exclusively on primary energy could well bring about a disconnection between the reduction of energy consumption and the other major goal of the Grenelle talks, to combat the greenhouse effect.

In effect, with an unchanged technological configuration, the average consumption of an electric water heater (family of four persons living in accommodation measuring 100 sq. m) is 55 kWh of primary energy per sq. m per year (as against 22 kWh for a gas water heater), which means that strict application of the 50 kWh norm totally ousts conventional electrical equipment from new-build operations.

The mission entrusted to the OPECST consisted in defining the implementation conditions of the norm, thanks to a 'modulation', according to the terms of the bill, making it possible to avoid a massive switchover to the use of fossil energies by the elimination of electricity, which would have the opposite effect to the goal of a reduction of greenhouse gas emissions. In the process, it was of course necessary to promote the use of renewable energies which make an essential contribution to combating climate change.

The rapporteurs were also invited to express an opinion on two related questions: the need to adapt or not the electricity conversion coefficient, and the assessment of the economic impact of this new energy-framing legislation for buildings.

[1] *This figure was laid down by Article 35 of the decree of 24 May 2006.*

The method followed

Using OPECST's usual work methods, the rapporteurs, Messrs. Christian Bataille and Claude Birraux, set up a committee of ten experts – energy and building sector specialists – who provided them with supportive analysis and thought on the technological, economic and sociological aspects of the issue to be addressed.

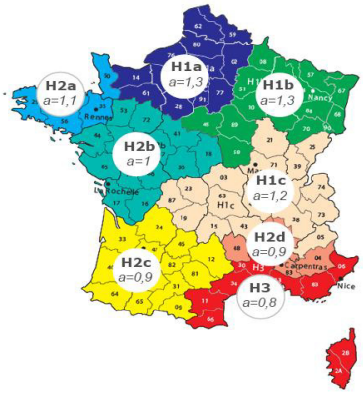
They also carried out a hearing of fifty or so players from the sectors concerned and made five trips in France: to Houilles, in the Yvelines department, to visit Mr Bruno Comby's 'ecological house'; to Lyon, to see 'Effinergie' buildings; to Grenoble, to meet 'Homes' project engineers at Schneider; and to Angers and Orléans, to visit Ademe's head office and Promotelec's 'Castor and Pollux' research centre. During three trips abroad, they also met managerial staff from Minergie in Switzerland, and visited the Vauban and Rieselfeld districts in Freiburg im Breisgau in Germany, followed by the BedZed district in London.

Modulation according to the climate

The thermal regulations have long taken into consideration the fact that France has at least three distinct climates: a Mediterranean climate, a cold climate in the North and East, and a moderate climate in the West.

The 'Effinergie' association which has set itself the aim of promoting low-consumption buildings in France since 2006, and which plays a precursory role with regard to the future thermal regulation, has drawn up a map of corrective coefficients around the pivotal 50 kWh value.

The hearings allowed it to be checked that this correction, which shifts for instance the ceiling to 65 kWh (coefficient 1.3) in the North of France, and to 40 kWh (coefficient 0.8) along the Mediterranean coast, is entirely relevant and should be adopted in the national regulation.



In addition to the techniques used to obtain cool internal temperatures in summer, the report recommends equipping buildings occupied during summer[2] with an active air-conditioning system (Canadian well, reversible heat pump, cold network) to cope with midsummer heat when night ventilation no longer suffices to moderate the internal day temperature. Climate change is indeed exposing European countries to more frequent scorching heat, which should be anticipated.

Modulation according to size

The converging remarks of the professionals they had heard convinced the rapporteurs of the need to compensate for the specific handicaps of small housing as regards energy consumption. These handicaps are related:

– first, to the fact that the hot water and ventilation consumption per square metre is greater there than in large housing;

– second, to a geometric factor: the heat losses of a small volume are relatively greater, as its external envelope is relatively bigger.[3]

Small housing therefore needs proportionally more energy to operate. This concerns in practice surfaces under 100 'useful' square metres.

Consequently, basing itself on the German model, the report proposes a form of modulation depending on the surface (variable S), it being up to the regulatory authorities to specify the coefficients. The pivotal value of 50 kWh, adjusted depending on geographic location (coefficient a) and altitude (coefficient b), and which must be applied 'as an average' according to the Act, is then respected by compensating for above-pivotal values authorised for small surfaces by obliging large surfaces to make a greater saving effort. For compensation taking place at 40% of the pivotal value, the following consumption ceiling (Cmax) is obtained:

$$C_{max} = 50\ (a + b)\ c\ (S) \quad \textit{with}\ c\ (S) = 0{,}6 + \frac{80}{100 + S}$$

This equation expresses a solidarity logic justified, on the one hand, by it being easier to reach demanding energy consumption goals in spacious accommodation and, on the other hand, by the greater financial resources generally held by the owners of such accommodation who can therefore invest more easily in high-performance equipment.

According to the Act, the thermal constraint does not apply to accommodation itself but to buildings. In the case of blocks of flats, the formula shall therefore apply to the average surface of the flats.

[2] *At the very least, buildings that continuously house fragile persons (hospitals, nursing homes) are more specifically concerned.*
[3] *If the building has the shape of a cube with an edge E, its volume is E3 and the surface of its external envelope is 6E2. Therefore the ratio between the external envelope surface and the volume is 6/E, and increases when the value of E decreases.*

Refusal of easy modulations

The rapporteurs explicitly dismissed three forms of modulation which would have presented a disadvantage from the viewpoint of the technological adaptation incentive.

- The first would have consisted in transitionally reducing the number of the five uses taken into account (heating, domestic hot water, air conditioning, lighting, ventilation) to the first three alone, therefore aligning the basis of the thermal regulation with that of the energy performance rating (DPE). The energy consumption constraint could therefore have been eased by approximately 10 kWh.

However, regulations are tending, on the contrary, to take a greater number of uses into account because greater insulation increases interdependence phenomena between uses. For instance, the energy used in cooking or the heating of electronic devices contribute to space heating. Above all, Directive 2002/91/EC of 16 December 2002 on the energy performance of buildings is very clear about the list of uses to be taken into account.

- The second modulation that was dismissed would have led to unduly encouraging 'positive energy buildings' by accepting that the 50 kWh norm applies by subtracting, from the total energy consumption, the electricity produced by photovoltaic panels and sold back to the network. At that rate, a thermal wreck covered with photovoltaic captors could comply with this regulation, and that is undesirable. The energy performance of a building is one thing, the promotion of photovoltaic energy another.

At this stage, only energies consumed on the spot should be taken into account, which does not exclude the share of photovoltaic energy directly supplying equipment in a building. As for 'positive energy buildings', they will first of all have to be well insulated to consume less than 50 kWh of primary energy, like the rest.

The Carnot cycle

The Carnot cycle, discovered by the French physician Sadi Carnot (1796-1832), describes an ideal machine producing mechanical energy by the compression and then the expansion of a gas. At the time, it was a matter of modelising the operation of a steam machine, but the reasoning applies to any heat engine. The maximum theoretical efficiency (E) is equal to the quotient of the mechanical energy produced by the heat energy received; it depends on the temperatures (in degrees Kelvin) of the hot reservoir (Th) which allows steam generation, and of the cold reservoir (Tc) which allows compression, according to the formula :

$$R = (T_c - T_f) / T_c$$

With a cold reservoir at atmospheric temperature (20°C), a production of electricity based on a conversion coefficient of 2.58 corresponds to a theoretical Carnot cycle using a hot reservoir at approximately 200°C. In practice, the hot reservoir of thermal power plants reaches more like 500°C, the gap giving an idea of the many losses taking place in reality.

- The third form of modulation envisaged would have led to playing on variations of the electricity conversion coefficient. This was legally possible but the rapporteurs preferred to insist on two medium-term economic arguments regarding, on the one hand, compliance with the realities of physics and, on the other hand, the incentive to make technological progress.

The first argument refers to the already mentioned link between the primary energy conversion coefficient, and the laws of thermodynamics, especially the Carnot cycle. The electricity of thermal power plants is produced by a steam generator that disperses two-thirds of the energy in the form of heat. France reached its figure of 2.58 by adopting the analysis of the real efficiency of thermal power plants at the beginning of the 1990s; but all European countries have adopted a conversion coefficient between 2 and 3.

GB	D	F	DK	NL	B	I	CH
2,65	2,6	2,58	2,5	2,5	2,5	2,4	2

The rapporteurs however recommend, as in Germany, a five-year re-examination[4] of the conversion coefficient depending on progress made in the production of electricity from renewable energy (wind, solar, hydraulic), which will modify its value downwards.

The second argument takes account of the disadvantages of manipulating this coefficient on technological innovation. The 50 kWh norm encourages the development of active research on heat pumps: their operation must be consolidated when the cold reservoir reaches low temperatures of under 10°C; water circulation problems must be settled for thermodynamic water heaters for use in blocks of flats; speed regulators must be developed allowing them to operate at different speeds; and the manner of combining heat pumps with other systems or other energies must be planned. All these technological avenues are chances to be seized in developing products with export market prospects.

Constraints must be left behind by constantly heading forwards, by carrying on research to overcome technical obstacles. The momentum must not slacken, otherwise manufacturers from elsewhere would seize the available markets and the resulting sources of employment.

A single goal: research, industrial development and the conquest of new markets thanks to the quality of products.

[4] *On the occasion of the publication of the 'Pluriannual investment programme' (PPI).*

A ceiling for CO2 emissions

To combat climate change a constraint must be set in place for carbon dioxide emissions that is symmetrical to that laid down for the consumption of primary energy. Of course this ceiling cannot concern renewable energies.

It would indeed be paradoxical for the thermal regulation resulting from the Grenelle talks to leave this concern aside, by simply postulating that energy savings equate to the equivalent avoidance of CO2. As for the impact of the 'carbon' tax, the difficulties of implementing it clearly demonstrate that it will be somewhat haphazard; both mechanisms, ceiling and tax, are necessarily complementary.

Lavoisier's law

Antoine de Lavoisier (1743-1794) laid down the basics of modern chemistry by expressing the law of the conservation of mass which is usually summarised by the sentence: 'Nothing is lost, nothing is created, everything is transformed'. This law, when applied to 'natural gas', i.e. methane (CH_4), means that combustion, which is a chemical recomposition reaction with oxygen in the air, produces a molecule of carbon dioxide for each molecule of methane burnt. The carbon atom (C), which forms the heart of the molecule, is indeed kept, the bonds with four hydrogen (H) atoms being replaced by bonds with two oxygen (O) atoms taken from the surrounding air:

$$CH_4 + 2\,O_2 \Rightarrow CO_2 + 2\,H_2O$$

***The carbon dioxide molecule is far heavier than that of methane, in a** ratio of 44 to 16, as the oxygen atom is 16 times heavier than a hydrogen atom.*

The setting of a CO2 emission ceiling complies with European legislation, as it is mentioned as a possibility by Directive 2002/91/EC, in which the last paragraph of Article 3 states that: 'The energy performance of a building shall be expressed in a transparent manner and may include a CO2 emission indicator.'

Also, the proposal under discussion for a new directive on the energy performance of buildings goes even further in this direction, since an agreement reached on 17 November 2009 between the European Parliament and the Council of Ministers led to introducing into it a 'zero emission'[5] goal by the year 2021, following the example of the choice made by England to apply by 2016.

In addition, the setting of a carbon dioxide emission ceiling contributes to a genuine energy efficiency improvement, insofar as it bans the already mentioned misleading arithmetics consisting in subtracting from the total energy consumption the energy produced by a building. The obligation to comply with a CO2 emission ceiling will therefore be another way of ensuring that so-called 'positive-energy houses' really comply with the thermal regulation.

Last, a carbon dioxide emission ceiling encourages the development of renewable energies by countering 'all gas' solutions. Similarly, the setting of a single primary energy ceiling for all energy consumptions puts paid to 'all electric' solutions. The use of solar hot water is in particular encouraged by this move. In the medium term, this ceiling encourages the development of new technological solutions (gas heat pumps, for instance) and also of biogas, a field where France has clearly fallen behind Germany.

A dual ceiling on CO2 emission and on primary energy consumption would therefore operate as an obligation to use renewable energies on the spot.

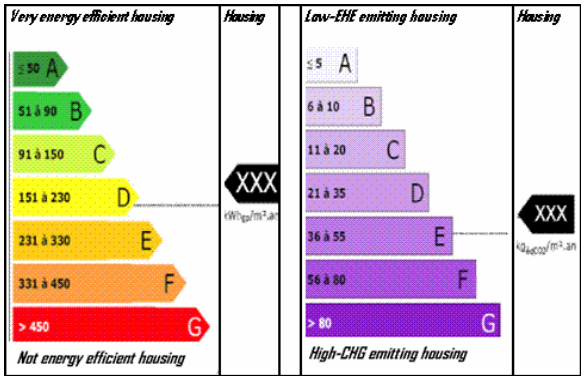
It should be observed that the combined follow-up of these two magnitudes is already recommended as part of the 'energy performance rating': the decree of 15 September 2006, which organizes it, establishes a dual performance scale - one for primary energy and the other for greenhouse gas emissions. For the three uses concerned (heating, hot water, refrigeration), the 'A classes' of these two scales are respectively set at 50 kWh and 5 kg per square meter per year.

The level set for the CO2 emission ceiling must in no case prevent the inhabitants of France from continuing to enjoy the two major assets of 'natural gas' (methane):

- First, its very broad transport and distribution network is a victory of the national community, since one of the goals of the 1946 nationalization was to allow the greatest number of the French to benefit from it. Today that represents 11 million households, in other words 75% of the population.

- Second, it is an energy that can be stocked, thereby providing a safe supply, above all in winter. France therefore has an underground storage capacity equivalent to 28% of its annual consumption, whereas that of Germany represents only 22%. Access to natural liquefied gas (NLG) also contributes to a safe supply, and GDF-Suez is the first importer of NLG in Europe with a fleet of fifteen or so methane tankers.

The two scales of the energy performance rating



[5] *The exact terms of the agreement are: 'zero energy with a very significant share of renewable sources'.*

By taking basic data into account, including the average carbon content of methane (234 g/kWh6 as against 75 g/kWh for electricity, on average), the rapporteurs recommended a level, for this ceiling, of 5 kg per square metre per year: this is the possible lower limit for a measure which sets out to be binding without being crippling. The higher limit providing an effective constraint is probably located around 8 kg per square metre per year. The value between these two limits remains to be adjusted before the regulation for residential buildings enters into force at the end of 2012.

The adjustment must take account of the fact that the CO2 emission norm will be modulated exactly like the primary energy norm, with the same corrective coefficients for climate, altitude and surface area.

A procedure for the tertiary sector

The sector of private and public tertiary buildings will be the first concerned by the new regulation, which will apply to it as of 1 January 2011.

The 50 kWh norm has been imposed on it in a somewhat forced manner, since the 'Effinergie' label itself adopts a less demanding criterion.7 In fact a somewhat excessive simplifying determination has led to extending the scope of the ceiling from the residential sector to the tertiary sector.

A very harsh norm in a very short timeframe: the hearings brought to the fore that these conditions would be difficult to respect, except in the case of offices, close to that of housing.

The hearing of La Poste, which builds sorting platforms with sides open to lorries delivering mail or taking it away, underscored that the 'regulatory calculation' was out of touch with reality as it establishes compliance with the regulation at the stage when the sole 'intrinsic' performances of the building are checked. The effective energy consumption does not always coincide with the result of the calculations.

Also, the meeting at Schneider, in Grenoble, with the engineers in charge of the pan-European 'Homes' project launched in 2006 by the former Agency for Industrial Innovation (AII), brought about awareness of the potential complementary savings, with respect to the systematic insulation of the frame of buildings, obtained by active energy management based on the effective occupation of premises.

Therefore the rapporteurs preferred to recommend for the tertiary sector, instead of a specific modulation, a procedure to reach the target performance of 50 kWh: spread the effort as best as possible between insulation and active energy management; install consumption follow-up systems; appoint an energy manager; and exchange good practices within a network of contacts between energy managers.

It would be a matter of abandoning the exclusive a priori reference to the 'regulatory calculation' in favour of an approach where it would be striven to really reach an a posteriori performance, by prolonging the construction effort thanks to active energy management and exchanges of experience, if the goal were not reached the first time round: in the race to performance, the best must serve as a model for the rest.

The 'regulatory calculation' would then give way to a 'design calculation', an essential intermediary instrument and no longer sole goal in itself.

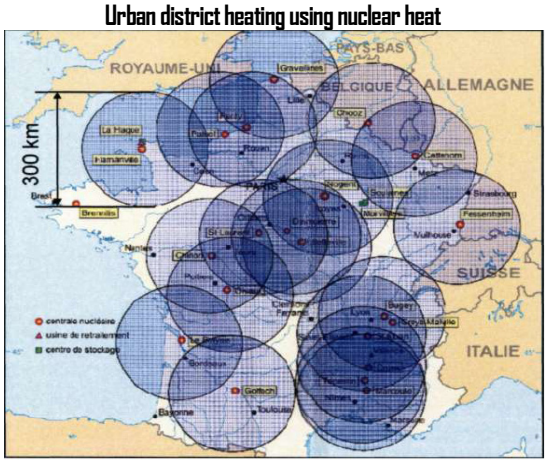
In this set-up, a key coordination, follow-up and monitoring role would be assigned to the Department of Public Works.

Assessing the economic impact

Referring to the economic impact of the new heat regulation, the report makes three remarks.

1) The initial additional cost of low-consumption buildings, which entails the risk of slowing down construction, will probably remain limited, between 5 and 15%, so long as the players concerned accept to really take up a new design logic for buildings, in other words provided they do not content themselves with building like before, by simply increasing the thickness of layers of insulation. After a few years, if we refer to the German example, this additional cost will no longer appear as a brake, as the users of buildings will no longer see anything but the subsequent advantage in terms of lower energy bills resulting from the initial investment effort. Further, construction costs will really fall once building teams become acquainted with these techniques.

Urban district heating using nuclear heat



6 *Cf. the decree of 15 September 2006 on the energy performance rating.*

7 *For tertiary buildings, the 'Effinergie' label imposes a performance defined in relation to the thermal regulation in force (RT 2005): energy consumption must be half less (-50%).*

2) All sellers of energy are going to have to cope with a fall in their turnover owing to the development of low-consumption buildings. This fall will be around 60% on average, as it accepted that present-day buildings consume around 120 kWh per square metre per year. In this respect, the carbon dioxide emission ceiling is tending to balance the effort imposed on natural gas and electricity. New-build operations represent only 1% of the building market, which remains structurally oriented towards renovation. However, after a few years, this fall in consumption will nevertheless be felt. The major energy operators will have to find alternative markets.

3) The rollout of low-consumption buildings will have a technological stimulation effect, which should open export markets and create jobs. The rapporteurs mentioned major technological avenues, such as heat pumps, insulation materials, and the conditioning of indoor air. But they also mention the interest of heat networks connected to the heat rejected by thermal power plants. There is a 140 GW potential here, whereas the installed power capacity of district boiler houses is today 18.5 GW. The capacity of urban district heating could thus be multiplied by eight.

Remarks on implementation

The rapporteurs raised the question of the risk that the new thermal regulation may not be respected, which would deprive any modulation effort of its meaning.

The success of low-consumption building depends on the mobilisation of all the professionals of the sector, from architects to material manufacturers, but two factors in the chain appear especially weak: the training of craftsmen and the negotiating power of private individuals.

Craftsmen will have to become acquainted with different work methods. Vocational training is already gearing up to this change. However, the national education department is perhaps not taking enough action, despite a few agreements with Effinergie for training modules in technical grammar schools. Also, to guarantee the level of quality imposed by the new construction methods, the rapporteurs feel that a double certification would ultimately be the necessary goal – certification of companies and of people, as is the rule for service providers in the nuclear field.

As for private individuals, they risk finding themselves trapped if they need an energy efficiency certificate for their building because they may depend on a prime contractor who is stubborn to make the necessary corrections, if the delivered building is not sufficiently air-tight. The report suggests three avenues to strengthen their position:

- First, lower the threshold for dispensing with the need to use an architect, so that they more systematically benefit from an advisory and technical control capacity.

- Second, improve the legal means so that they can submit a case to a judge in an indisputable manner, by making the permeability control mandatory on handover of a building.

- Third, get the Department of Public Works, and especially the departmental directorates, to appear far more often on the spot to provide support to building owners.

The Department of Public Works has the authority to become a driving force in low-consumption building and must therefore also undertake a genuine cultural revolution within itself. The State must indeed provide its entire support, in an advisory and control capacity, for the very great adaptation effort required of building players as a whole.

In conclusion, the OPECST recommends organising the rollout of the new thermal regulation in line with two principles:

- First, there should be an opening to technological progress, so that the most effective solutions in energy-saving and greenhouse-gas-limitation terms can be marketed as soon as possible.

- Second, the sought energy performance should indeed be reached. It must therefore be ensured that it is always the best technical solution which is preferred, without any preconceptions, because it is the best guarantee to combat climate change.

The report's ambition is to remain a reference for these two principles.

The National Assembly on the Internet :
http://www.assemblee-nationale.fr
The National Assembly boutique
7, rue Aristide Briand
75007 Paris
Tel: 01 40 63 00 33

The Senate on the Internet :
http://www.senat.fr
The Senate bookshop corner
20, rue de Vaugirard
75006 Paris
Tel: 01 42 34 21 21

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