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QUALITATIVE VALIDATION OF AN ENERGY CONSUMPTION BEHAVIOUR-RELATED SURVEY FOR CERTIFIED TYPICAL WALLOON URBAN HOUSES

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Abstract *- Among other regulations, the European policy for energy consumption and greenhouse gases emission reductions has imposed, in its 2002/91/CE Directive, the certification of an existing building's energy performance, witnessing its energy consumption and efficiency, when it is sold or rented. In its objectives, the Energy Performance Certification (EPC) of a residential building is seen as a potential useful tool that could help create smart energy policies by introducing energy efficiency as a comparative criterion for real-estate purchase choices. It has been designed to influence real-estate market value, stimulate energy saving investments, move the housing market towards better energy efficiency and help create comprehensive databases.*

But EPCs in their actual form, calculated with a standardized approach which purposefully (and understandably) gets human factor out of the equations, do not allow appropriation of the results by potential buyers. Often distant from reality, overestimating consumption, they usually result in a general misunderstanding and misuse of the document. Though acknowledging the necessity to present the EPC as a basis of comparison between buildings, it is believed that complementary calculations and results could help future owners understand the performance of a coveted dwelling, and foresee a rough monthly energy bill.

Previous studies by the authors proposed a way to modify the existing (steady state) Walloon certification calculation method, in order to reduce the gap between real energy consumption records and the theoretical EPC consumption, by using behaviour-related additional data. This study shows the construction and qualitative validation of a questionnaire that aims at analysing the energy consumption related behaviours of Walloon households. It includes questions on socio-demographic variables (skills and knowledge, income, occupation, age of the head of the household, size of the family, rights on the dwelling (owner / tenant)...), attitudes and representations (motivation to save energy, attitudes towards energy saving, comfort representation, perceived behaviour efficiency, social standards, identification to others…) and behaviour variables (set temperatures, global temperature management, occupation patterns, ventilation habits…). During the qualitative validation phase, a series of personal interviews were led on the households' views on the certification scheme, the importance of energy performance in real-estate decisions and the renovation triggers and obstacles.

1. INTRODUCTION

European Union's strategy for a sustainable growth makes the building sector energy consumption reduction a central objective for meeting the commitments taken under the Kyoto protocol on climate change. At a worldwide scale, this sector is thus regarded as one of the most cost-effective options for saving CO_2 emissions (IPCC, 2007). To target the existing buildings potential, the European Union introduced (through the 2002/91/CE European Directive) Energy Performance Certificates (EPC), which should provide clear information about the energy performance of a building when it is sold or rented, including reference values, allowing performance comparisons between buildings. The EPC also includes "clear" recommendations for technically possible improvements, in order to increase investments in energy efficiency, move the housing market towards greater energy efficiency, influence real-estate market value and help built up comprehensive benchmarking databases, fundamental for shaping smart strategies on a local ('smart cities'), regional ('smart regions') and national level.

A general observation, however, is that the EPC potential remains underexploited in Wallonia, showing the same early dysfunction than UK's or German's EPCs (Laine, 2011; O'Sullivan, 2007, Amecke, 2012). Given necessary standardisation, calculation methods do not provide realistic results, and this is easily confirmed by energy bills; furthermore, the EPC is often overestimating the consumption and appears too long and technical, confusing, unhelpful… and is therefore mistrust. As stated by a respondent in the qualitative validation phase of this study: "*It is useless for old houses, it has been designed to promote new and efficient houses. It is not subtle enough to differentiate two old houses. They will both be at the bottom of the scale, and let us face it, the scale level is the only thing people understand.*"

Sociology of energy points the lack of appropriation of those results as a missed opportunity. This study is therefore based on the assumption that, though acknowledging the importance of a standardized approach to allow building comparisons, other (and more accurate) results could be obtained from EPC inputs, by closing the gap between theoretical and real consumptions.

This study focuses on a small number of old urban typologies, highly representative of single-family housing in Wallonia, often characterized by poor insulation and inefficient systems. It was also important to focus on dwelling occupied by their owners, as it appears that a household's rights on the building influences comfort representation, social standards, financial interpretation of the consumption but, foremost, investment strategies.

Previous papers (Monfils, 2014; Monfils, 2016) proposed a method for the introduction of additional data (on the number of inhabitants, occupation patterns of the dwelling, levels and quality of electr(on)ic equipment and lighting) into a recalculation of internal gains, Domestic Hot Water (DHW) demand and Net Heat Demand (NHD), based on extra information related to the dwellers' heating habits. Based on these, this paper will first describe the uncertainties that are inherent to the Walloon EPC calculation method, the selection and qualitative validation of those that will be addressed, through additional data, in the modification of the calculation method. The next part will explain the construction of the questionnaire in light of the targeted uncertainties and modifications proposed in the calculation method. The third part will display NHD and final energy consumptions results for five houses analysed during the qualitative validation of the questionnaire. Both results have been evaluated with the regulatory method and the proposed modified method; in addition, real consumption data, given by the respondent in the questionnaire are presented for comparison. Discussion and conclusions will close the paper.

2. UNCERTAINTY PARAMETERS OF THE METHOD

First comparison of results from the qualitative validation phase (see Figure 1) proves that EPCs overestimate final energy consumptions of natural gas by a factor that spreads (in these cases) between 2.58 and 4.34. What could explain such important gaps in the calculation method? Any fixed parameter could be questioned and pointed out as uncertain, as it often reflects an average or a disadvantageous default value, resulting from a difficult balance between necessary parameters, precision possibilities and the time and cost required to make a full assessment. This paper will not focus on each and every one of those parameters, but it seems necessary to, at least, sort out the different types of uncertainties.

First reservations would be directed towards the certification process itself and the assessor's skills and professionalism. An elaborate protocol and a precise list of "accepted proofs" have been developed to impose a rigid assessment method and a short list of acceptable sources of accurate data in the dwelling description, leaving few liberties in the process. It is said by the Administration that the process has been developed so that different assessors should obtain the same results for the same dwelling. In 2012 however, a magazine that advices and defends the consumers (Vanparys, 2012), asked 5 assessors to certify the same houses in different parts of the country. For a single dwelling, the greatest range of estimated consumption spanned between 162 and 402 kWh/m².yr, witnessing divergences in the process. Should we be surprised? However tight the protocol, the human nature of the assessor taints the process by uncertainties on input precision, accuracy or even plain correctness, so that differences in data investigation and interpretation, or in profitability definitions, arise.

Secondly, we must acknowledge the high number of default values (when no accepted proof of more accurate value is available) and standardized parameters (which cannot be replaced by more accurate values, even if they are known) in the method. Some of these, like the average Belgian climatic data, are as good as any when it comes to predicting consumption. In assessing past consumption however, variations between local climates and the average climate used in the regulatory calculation method have to be considered.

Other default values are more questionable, for example when it comes to the always challenging characterization of an existing building's envelope or heating systems (emission, distribution, storage, production) and Domestic Hot Water (DHW) systems (distribution, storage and production). Resorting to default values saves precious time and money, but also questions the precision of the heat loss coefficient by transmission or the heating system efficiency, both obtained by default through multiple choice questions. The accuracy of the value increases with the number of questions, which also increases the time needed to assess the system and the cost of the process.

Last but not least, there are the shortcuts that have been imagined to get human factor out of the equations: the evaluation of internal gains or DHW demands, for example. In theory, two different families living in two identical homes would receive identical EPCs, but in reality, their real consumption would vary from one to three or four (Hens, 2010), depending on occupants' behaviour and household characteristics. So this paper focuses on the parameters of the calculation method that should be considered influenced by dwellers' behaviour and comfort standards in a realistic approach, and have been replaced by standardised parameters in the calculation method. This mainly concerns:

- The evaluation of NHD, specifically through the estimation of set temperatures, heating periods, heat losses by ventilation and internal gains.
- The evaluation of DHW demands.

A questionnaire has thus been constructed, in order to gain additional data on respondents' behaviour and energy consumption habits. Modifications have been proposed to the regulatory calculation method in order to close the gap between real and theoretical consumptions, based on their answers to that survey.

3 CALCULATION METHOD AND QUESTIONNAIRE

Using a questionnaire's answers to feed a calculation method requires a back-and-forth movement between both tools. A qualitative validation campaign ensued, where 10 households were asked to fill the questionnaire, in the presence of the interviewer, in order to evaluate their understanding of the questions or their level of consciousness on some behaviours that have been pointed out to influence energy consumption. This allowed the interviewer to witness some important temperature management behaviours that contradicted the standardized approach. The result of this validation are presented in the next part.
The first two parts of the questionnaire, which will not be developed here, are dedicated to the household's socio-demographic variables (as a consumer entity: its size, its head's age and gender, level of education, professional situation and incomes...) and to a complementary investigation on the building (its age, typology, disposition in the street and the block, revealing the number of exterior facades…). The presence of a (frequent) extension to the original building and the use made of the "upper floor" (the highest floor of the building that *could* be inhabited, in terms of available area, volume, ceiling height…) are also important information, in order to explain some consumption differences in otherwise similar dwellings (for example, in Table 1 results, an "inhabited" upper floor is one that contains living (heated) spaces (bedrooms, bathroom), while the "inhabitable" floor is fit to live in but is used, for example, as storage and is therefore not heated).

The third part of the questionnaire, however, focuses on this paper topic by investigating on heat demands parameters. The method described in (Wallonie, 2013) has been developed for the energy performance assessment of new residential buildings, and has been adapted (in a different document, which is not yet officially published but accessible to all assessors) for the existing buildings. The official calculation method estimates the NHD thus:

$$Q_{heat,net,m} = Q_{T,heat,m} + Q_{V,heat,m} - \eta_{util,heat,m}\,(Q_{i,m} + Q_{s,m}) \quad (1)$$

With:

- $Q_{heat,net,m}$ = monthly Net Heat Demand [MJ];

- $Q_{T,heat,m}$, $Q_{V,heat,m}$ = monthly heat losses due to transmission or airtightness and ventilation [MJ];
- $\eta_{util,heat,seci,m}$ = monthly heat gains application rate, a factor that tames the internal and solar gains when they are less needed (depending on the losses/gains monthly ratio).
- $Q_{i,m}$ = monthly internal gains [MJ], see (Monfils, 2014) for proposed evaluation method; Some questions have been added in the questionnaire to describe behaviour and electr(on)ic equipment, in order to refine the quantification of the internal gains.
- $Q_{s,m}$ = monthly solar gains [MJ].

The heat losses by transmission are evaluated as follows:

$$Q_{T,heat,m} = H_{T,heat} * (18 - \theta_{e,m}) * t_m \quad (2)$$

With:

- $Q_{T,heat,m}$= monthly heat losses through the envelope [MJ];
- $H_{T,heat}$: transmission heat losses coefficient [W/K], sum of the heat losses through the different walls of the envelope;
- $\theta_{e,m}$= monthly average exterior temperature [°C];
- t_m= length of the month [Ms].

The evaluation of the heat losses by ventilation is very similar, but the heat losses coefficient by ventilation – $H_{V,heat}$ – is estimated by default with the protected volume as only parameter. It can be seen in these equations that, first, the set temperature in the official calculation method is fixed at 18°C (20°C during day-time, 16°C during night-time), which means that the whole protected volume is considered heated, all year round, at this set temperature. Secondly, the length of the month (t_m) can be subdivided thus in order to integrate differently heated periods (for example, all-day heating days or unheated periods):

$$Q_{T,heat,m} = \sum_{i=1}^{i=\infty} H_{T,heat,m} * (T_{set,i} - \theta_{e,m}) * t_{m,i} \quad (3)$$

$$t_m = \sum_{i=1}^{i=\infty} t_{m,i} \quad (4)$$

With:

- $T_{set,i}$ = average set temperature for the “i” period;
- $t_{m,i}$ = length of the “i” period [Ms];

If time can be subdivided to consider heated and unheated periods, so can the protected volume, between heated and unheated spaces. In what remains a steady-state monthly calculation, subdivision of time and space is believed to reduce the greater uncertainty on the too rigid, general or standardized regulatory approach, into a series of smaller uncertainties on each periodic term of the equation, during which the parameters of the energy performance can be considered constant. Keeping the global heat loss by transmission for the whole protected volume (heated and unheated spaces alike) means that:

- It is the resulting average temperature ($T_{set,i}$) that must be defined for a given period “i”, based on the volumetric proportions and set temperature of the different spaces.

- Aside from set temperature given for main spaces, a temperature has also to be assigned to unheated parts of the volume. No temperature monitoring allowed exact hypothesis during qualitative validation phase, so that the ΔT between spaces is defined empirically, setting an uncertainty on the result that must be acknowledged.

The qualitative validation of the questionnaire enlightens different heating schemes for four main spaces (living room, kitchen, bathroom and bedrooms). It became apparent, for example, that the day-time and night-time zones of the dwellings are often managed differently in terms of set temperatures and heating schedules, depending on occupation patterns (which depend on the professional and/or scholar situation of the occupants). Kitchen's heating scheme generally follows the living room pattern, except when both spaces are separated by doors, walls or hallways. Bathrooms are often heated only when needed, and at a higher temperature (often, even, boosted with an electrical device in addition to the central heating system); children's bedrooms are more often heated than parental bedrooms. As a consequence, we considered 6 spaces in these equations: living room, kitchen, unheated bedrooms, heated bedrooms, bathroom and "others".

$$Tset,i = \frac{\sum_{j=1}^{j=6} T_{i,j} \times V_{p,j}}{V_p} \tag{5}$$

$$V_p = \sum_{j=1}^{j=6} V_{p,j} \tag{6}$$

With:

- $T_{i,j}$ = temperature of the "j" space, during the "i" period [K];
- $V_{p,j}$ = protected volume of the "j" space [m³];
- V_p = protected volume of the whole dwelling [m³].

Consequently, the third part of the questionnaire displays 15 to 22 questions that can describe the household's heating pattern and temperature management profile for those main spaces. A "normal" winter week (work or school week) have to be described, in terms of:

- Number of "all-day heating" days a week, during which the whole volume / the day-time zone only are fully heated (14 hours a day by hypothesis).
- Number of "partial heating" hours (average number of hours during which the main spaces are heated on "other days" (not "all-day" heating days)).
- Set temperatures (when known; default values will have to be used otherwise).
- Heating devices (for the repartition of real consumption data).

Due to their influence on energy consumption, ventilation habits are also to be investigated for those spaces, despite their often unconscious, irregular and inconstant nature in old buildings where no complete system exists. The questionnaire displays a series of possible ventilation schemes for those four main spaces, from very little ventilation rates ("we do not (or rarely) ventilate") to standard rates when a normalized system exists.

Another consumption evaluation which depends on the number of inhabitants is the domestic hot water (DHW) demand. In the official method, it is calculated with the building's protected volume as only parameter:

$$Q_{water,bathi,net,m} = f_{bath,i} \times max(64,64 + 0{,}22 \times (V_{PER} - 192)) \times t_m \quad (5)$$

$$Q_{water,sinki,net,m} = f_{sink,i} \times max(16,16 + 0{,}055 \times (V_{PER} - 192)) \times t_m \quad (6)$$

With:

- $Q_{water,bathi,net,m}$, $Q_{water,sinki,net,m}$: net DHW energy demand for a bath or a kitchen sink [MJ];
- f_{bathi}, f_{sinki}: the part of the bath or kitchen sink in the total DHW net energy demand [-];
- V_{PER}: the protected (heated) volume of the EPB unit [m³];
- t_m: the length of the month [Ms].

In this study, we adopted as first approach the hypothesis of 40l of water to be heated, every day, for each occupant, to a minimal temperature of 50°C. The water supplied comes out of the network at an average temperature of 10°C, so that the net energy demand for DHW becomes:

$$Q_{water,net,m} = \frac{\left(N_{lt} \times N_{d,m} \times 4{,}1855 \times \left(\theta_{water,out} - \theta_{water,in}\right)\right)}{1000} \quad (7)$$

With:

- $Q_{water,net,m}$: the net energy demand for domestic hot water production [MJ];
- N_{lt}: the number of litres to be heated [l];
- $N_{d,m}$: the number of days in the month [-];
- 4,1855: the energy needed to raise of 1°C the temperature of 1 cm³ of water [J];
- $\theta_{water,out}$: the temperature of the heated water = 50°C;
- $\theta_{water,in}$: the temperature of the supplied water = 10°C.

4 RESULTS: QUALITATIVE VALIDATION

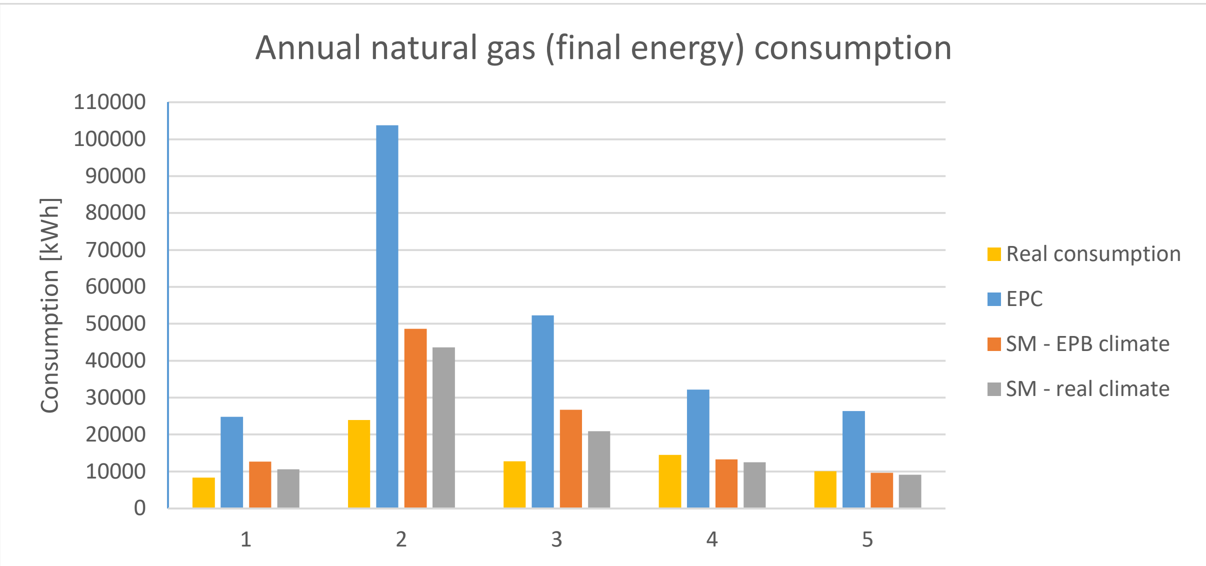

Figure 1. Comparison of final natural gas consumption data for 5 case studies: real data given by respondents (yellow), EPC regulatory results (in blue) and revaluation of theoretical final energy consumption using the EPB average climate (in orange) or the climate corresponding to the period of time to which real consumption data refers (in grey). Numerical values can be found in Table 3.

Five examples of the qualitative validation phase are displayed hereunder, chosen for the completion of their answers to the questionnaire and their common energy vectors that are electricity and natural gas.

Table 1 – Data from the questionnaire for 5 validation examples.

Case study	**1**	**2**	**3**	**4**	**5**
Photo					
Number of inhabitants [-]	4	5	4	4	3
Protected Volume [m³]	487	841.8	443.2	505.5	323.1
Heated Floor Area [m²]	160.7	254.9	138.1	162.6	101.3
AT - Total heat loss area [m²]	228.2	598.9	225.5	257.2	179.4
$H_{T,heat}$ [W/K]	180.6	951.2	397.1	297.6	217.4
Average U-value [W/m².K]	0.79	1.59	1.76	1.16	1.21
Number of exterior facades [-]	2	3	2	2	2
Presence of an extension ?	No	Yes	Yes	No	Yes
Inhabited(-able) upper floor ?	Inhabited	No	Inhabited	Inhabitable	Inhabitable
Kitchen open on living room ?	Yes	Yes	No	Yes	Yes
Temperature regulation device ?	Yes	Yes	Yes	Yes	No
Normal winter week : number of all-day heating for the whole Vp / the day-time zone only [days/week] ?	0/7 and 5/7	2/7 and 0/7	2/7 and 5/7	2/7 and 0/7	0/7 and 5/7
Number of "partial heating" hours (average number of heating hours on “other days" (not “all-day” heating days)) for					
The living room (LR)	4	8	0	8	4
The kitchen (K)	4	8	10	8	4
The main bedroom (MBDR)	0	0	0	0	0
The other bedrooms (OBDR)	0	6	6	6	0
The bathroom (BTR)	2	2.5	2	6	1.25
Heated spaces at night ?	LR, K, OBDR	LR, K	LR	OBDR	LR, K
Set temperatures - day-time					
LR	21	21	22	21	22
K	21	21	22	21	22
BDR	21	21	20	21	-
BTR	21	21	22	21	22
Set temperature - night time	18	16	18	16	16
Ventilation of…					
the living-room	occasional	occasional	occasional	-	daily
the kitchen	hood	occas. + hood	daily	daily + hood	-
the bedrooms	daily	daily	daily	occasional	daily
the bathroom	timed	occasional	occasional	daily	timed

The first part of the Table 1 shows some important performance parameters for each example, extracted from the EPC files. The second part presents answers the respondents have given to the questionnaire, identified as some of the most important influential behavioural parameters (see Figure 1). In this table, “occasional” ventilation indicates that respondents do not ventilate daily, only when discomfort occurs; “hood” is the extractor hood used when cooking; “timed” refers to the use of a temporised extractor, during bathroom use.

Table 2 – Intermediate results for the 5 validation examples

Case study		1	2	3	4	5
$H_{V,heat}$ [W/K]						
	EPC	133.8	140.5	128.6	223.5	105.4
	Revaluation	45.6	45.6	34.9	92.9	29.5
	Revaluation / EPC [%]	34.1%	32.5%	27.1%	41.6%	28.0%
Internal gains [kWh/yr]						
	EPC	4785.5	6869.1	4527.3	4897	3823
	Revaluation	6625	8213	5975	6424	5077
	Revaluation / EPC [%]	138.4%	119.6%	132.0%	131.2%	132.8%
Net Heat Demand [kWh/yr]						
	EPC	14817.2	67652.4	28843.4	22574.2	17600.8
	Revaluation	5142.5	29346	11140.3	6128.5	7031.7
	Revaluation / EPC [%]	34.7%	43.4%	38.6%	27.1%	40.0%
DHW net demand [kWh/yr]						
	EPC	1411.5	2266.7	1305.5	1457.2	1016.4
	Revaluation	2715.6	3395.6	2715.6	2715.6	2037.8
	Revaluation / EPC [%]	192.4%	149.8%	208.0%	186.4%	200.5%

Table 3 – Final results for the 5 validation examples

Case study		1	2	3	4	5
Annual electricity consumption [kWh/yr]						
(1)	Real data (respondent's)	3989	9436	3774	4691	4609
(2)	EPC regulatory calculation(*)	613.9	841.1	376.6	430.1	1599
(3)	SM(**) - EPB climate	5060	9093	4210	4730	6372
(4)	SM(**) - real climate [kWh/yr]	4997	8736	4210	4712	6366
	(2)/(1) [%]	15.4%	8.9%	10.0%	9.2%	34.7%
	(3)/(1) [%]	126.8%	96.4%	111.6%	100.8%	138.3%
	(4)/(1) [%]	125.3%	92.6%	111.6%	100.4%	138.1%
Annual natural gas (final energy) consumption [kWh/yr]						
(5)	Real data (respondent's)	8300	23897	12743	14493	10091
(6)	EPC regulatory calculation(*)	24805.8	103780	52303.7	32163.1	26390
(7)	SM(**) - EPB climate	12644	48653.6	26690.3	13260	9590.9
(8)	SM(**) - real climate [kWh/yr]	10578.8	43634.7	20927.6	12478.9	9082.4
	(6)/(5) [%]	298.9%	434.3%	410.5%	221.9%	261.5%
	(7)/(5) [%]	152.3%	203.6%	209.5%	91.5%	95.0%
	(8)/(5) [%]	127.5%	182.6%	164.2%	86.1%	90.0%

Table 2 displays some important intermediate results of both regulatory and modified calculations, as discussed above. Table 3 shows final energy consumption results for electricity and natural gas. Electrical consumptions results are not comparable between both methods, however: regulatory results (*) only include consumptions from ventilation and heating systems auxiliaries (when there is no electrical heating or cooling in the assessments, which is the case here; only case 5 also includes electric DHW production). Results from this study (indicated

"SM(**)") include electrical consumption for electr(on)ic equipment, lighting, auxiliaries, and, when indicated thus by the respondents, local heating (mostly bathrooms, but also "other" bedrooms in case 2), DHW production (case 5) and cooking. Comparison of final energy (natural gas) consumptions are graphically presented in Figure 1.

5. DISCUSSION

It is undeniable that the methodology proposed here allows to partially close the gap between theoretical and real consumption: margins decrease from [221.9%; 434.3%] to [86.1%; 182.6%] by the only introduction of behavioural parameters in the EPC steady-state calculation method. Intermediate results are visible proof that the high number of default values in the calculation method often leads to sanctions on the accuracy of final results. Losses by ventilation are exaggerated, internal gains are underestimated; as a result, this realistic approach revaluated net heat demands in a [27.1%; 43.4%] range, as percentage of the regulatory method NHDs.
These results are encouraging, without entirely closing the gap, and main reasons for this are:

- The adaptation of a steady-state method, with a defined set of input data. Multi-zone dynamic calculations would obviously render more precise (and probably closer) results.
- The remaining pool of unknown parameters, which influence grows in the balance when other inputs are refined.

Therefore, it would be enlightening to consider an independent parameter in the analysis of these results, in order to consider the level of certainty that surrounds the unchanged hypotheses for example:

- The ratio of the total envelope heat loss area and/or the total heat loss coefficient that is described by accurate hypothesis regarding its (non-)insulation. There exists several levels of precision in the certification protocol, however, as the very existence of this layer can be unknown (and that is the lowest level of accuracy, where the thermal resistance of this layer is given a default value based on the age of the wall's construction or renovation). When the existence of this layer is acceptably proven, its thermal resistance can still present different values, when its thickness and/or type of insulation material is described correctly.
- The number of default efficiency values (for heating or DHW systems) that have been replaced or refined by added data. Globally, those default values are refined by a certain number of multiple choice questions. The only values that can be entered directly (when acceptably proven, of course) are normalised heat production efficiency (for boilers only).

DHW results seem to follow another conclusion, with the new demands evaluation always exceeding the official one (determined with the protected volume as only parameter). Therefore, and by decreasing the heating energy consumption in the total balance, detrimental DHW system efficiencies default values exercise higher influence on the final energy consumption. It could be argued that the "realistic" approach suggested here is still a bit too vague. This part of the study has to be refined, but there is a major obstacle: respondents could only give global water consumption, unable to distinguish cold and hot water. When asked about the number of baths and showers per week in their household, few conclusions could be drawn from the diversity of answers ("*It depends when [my daughter] is here or at her mother's*"; "*I do not bathe every day, sometimes I just rinse myself, sometimes I draw long and bubbly baths…*" or "*we used to shower, but the kid arrived mid-year, and now baths are more common*").

For the scientist, it is interesting to wonder where to stop in this process of detailing/questioning the behavioural habits of a household's energy consumption. As every parameter of the method could be questioned, every parameter of a household representations, attitudes and behaviours could be studied. There are, however, limitations to this exercise:

- The prediction of energy bills is, by essence, uncertain. If it is crucial to understand occupant-related parameters that could give more realistic calculation of residential energy consumption, it would be quite lucky to predict the exact energy consumption of a household in next year's climate.
- The questionnaire media in itself is a limitation: the attention and interest of the respondent is important for the reliability of his answers, so that the number of questions should be controlled. Therefore, the number of added parameters will be restrained.
- It is almost impossible to get exact correspondence between theoretical and real consumption data, because there are too many uncertainty parameters in the method to control, too many local particularities or special occasions, too many conscious and unconscious ways to influence the result. Furthermore, the respondent to the survey cannot or will not always give the needed information, as some are considered private (to those who have a more emotional link to energy), and some are unconscious.
- Lastly, one must acknowledge that this questionnaire somehow replaces default values by others. New ones could be considered more accurate, because they refer to a household's habits or a dwelling's typological characteristics, rather than to a standardised approach that treats all houses and households equally. They remain default values, nevertheless, and their accuracy should be controlled too.

6. CONCLUSIONS

In order to reach energy efficiency at any level, human factor is crucial: on one hand, efficient solutions (regarding, for example, building energy consumptions) have to be implemented by an intelligent decision-making authority who understands the complexity of the urban context and its impacts on environment. On the other hand, smart cities authorities need smart citizens, who are aware of their environmental impact, to use smart solutions to their full potential. In the field of residential use of energy, people are therefore a crucial parameter of both the problem and its solution.

In order for the EPC to improve the housing stock by reducing its energy consumption, and be used to penetrate the decision-making process of potential buyers, it is essential to find a way (and scientific popularization seems to be the smallest step) to make it understandable, trusted and used by anybody. We acknowledge the necessity of presenting a "legal" result as a comparison base, following the approved standardized calculation method. But it is the goal of this study to question the uncertainty parameters, and propose a complementary calculation, based on the existing inputs and outputs of the EPC, to allow better decision-making strategies for households, as far as their real-estate ambitions are concerned. It is believed that other results could be displayed, closing of the gap between real and theoretical consumptions, allowing future owners to better understand and appreciate the EPC results and foresee a rough monthly energy bill.

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