EPB standards: Why choose hourly calculation procedures?

The set of Energy Performance of Buildings (EPB) standards has been published in summer 2017. For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval (hourly, monthly, seasonal, yearly and bin). This article provides some background information why an hourly time interval is recommended.

Keywords: energy performance of buildings, EPB standards, EN ISO 52000 family, hourly calculation procedures, EPB Center.

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Previous series of articles (REHVA 2015/1, REHVA 2016/3 and REHVA 2016/6) introduced the new set of international (CEN, CEN ISO) standards for the assessment of the overall energy performance of buildings (EPB).

The strongest interest is in those EPB standards that are 'collectively' needed to calculate the overall energy performance, either for existing buildings, for new buildings or for new building designs.

The core of the energy performance calculation can be found in:

- EN ISO 52000-1, *Energy performance of buildings – Overarching EPB assessment – Part 1: General framework and procedures* ([1], [2]); and
- EN ISO 52016-1, *Energy performance of buildings – Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads – Part 1: Calculation procedures* ([3], [4]),

supplemented by series of other EPB standards (see overview in [9]):

- providing input data on:
  - outdoor climatic conditions,
  - indoor environment conditions and conditions of use,
  - building components,
- assessment of the energy performance of the technical building systems for heating, cooling, ventilation, domestic hot water and lighting, as function of –and interacting with- the energy needs calculation and with building or system automation and control;
- 'post-processing' of the overall and partial energy performance into numerical indicators, energy requirements and ratings.

Overarching EPB procedures (EN ISO 52000-1)

EN ISO 52000-1 provides the modular and overarching framework for the assessment of the energy performance of buildings. It provides a common basis for calculated and measured energy performance, and also for energy performance inspection, at whole building, building units or building element level. The framework comprises:

- identification and classification of the building or building unit to be assessed ("assessed object") and zoning,
- determination of the assessment boundary and perimeters,
- assessment of the energy flows at the assessment boundary, and,
- weighting of the energy flows according to primary energy factors or other metrics, e.g., CO_2 emission and aggregation to the energy performance and the renewable energy contribution.

Calculation time intervals

For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval: hourly, monthly, seasonal, yearly and bin. This article provides some background information why an hourly time interval is recommended. The calculation interval is one of the key issues to obtain a transparent and coherent overall structure, with all of the interactions at different levels and with a coherent set of input data.

For use in the context of building regulations it is essential that the procedures to calculate the energy performance of a building are not only **accurate**, but also **robust** (applicable to a wide range of cases). It is also essential that they are **reproducible** (unambiguous) as well as **transparent** and **verifiable** (e.g. for municipalities, to check compliance with national or regional minimum energy performance requirements) and **applicable/affordable** (e.g. for inspectors, assessing the energy performance assessment of an existing building).

In other words, it is important to find a balance between transparency, robustness and reproducibility of the calculation method, an affordable and reliable set of input data, and sufficient appreciation of the wide variety of available energy saving technologies.

Therefore, the accuracy of the model should always be in proportion with the limits and uncertainty in input data and with the required robustness and reproducibility of the method: a balanced accuracy.

Consequently, the most accurate, complete and state of the art method is not necessarily the most appropriate method for a specific calculation.

Many technologies, in particular for low energy buildings, are strongly and dynamically interacting with the hourly and daily variations in weather and operation (solar blinds, thermostats, needs, occupation, accumulation, mechanical ventilation, night time -free cooling-ventilation, weekend operation, etc.). This has a strong effect on the heating and cooling calculation.

Therefore, it is no surprise that the choice between hourly or monthly calculation procedures is most prominently visible in the calculation of the energy needs for heating and cooling.

Energy needs for heating and cooling (EN ISO 52016-1)

EN ISO 52016-1 provides the procedures for the calculation of the energy needs for heating and cooling. It supersedes the well-known EN ISO 13790:2008 (*Energy performance of buildings -- Calculation of energy use for space heating and cooling*).

In line with the overarching EPB standard, it contains a monthly and an hourly calculation method, side by side. A "bin" method is not an option, as explained further on. A building simulation tool is not recommended either, as also explained further on.

As introduced in previous articles ([5], [6], [7]), one of the main new features of EN ISO 52016-1 is the new specific hourly method to calculate the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads, in parallel to the simple monthly method which remained in essence the same as the method in EN ISO 13790.

With the **hourly calculation method** the thermal balance of the building or building zone is made up at an hourly time interval.

Additional applications covered in the hourly method of EN ISO 52016-1 are:

- calculation of **internal temperatures**, e.g. under summer conditions without cooling or winter conditions without heating;
- calculation of heating or cooling load under **system design** conditions.

The effect of specific system properties can also be taken into account, such as the maximum heating or cooling power and the impact of specific system control provisions. This leads to **system-specific** loads and needs, as introduced further on.

In the **monthly calculation method** of the energy needs for heating and cooling, correction or adjustment factors are required to account for the dynamic effects mentioned above, in a kind of statistical way. These factors are usually pre-calculated, based on a large series of building simulations with e.g. variations of daily weather and conditions of use.

What is "bin" and why is "bin" not an option here?

"Bin" refers to a statistical method, where the frequencies of occurrence of short time interval values for one or more boundary condition variables (e.g. hourly values for the outdoor air temperature) are allocated to defined intervals (the "bins"). The calculation is then done bin by bin, by using the value of the variable in the middle of the bin as a boundary condition and multiplied by the frequency of the respective bin.

This method is especially of value when calculations with longer time intervals for some parts (e.g. monthly or seasonal for the building) need to be combined with calculations of technologies where the influence of the variation of a driving force is essential and averaging is not acceptable (e.g. the outdoor temperature for air-to-water heat pumps).

The limitation of the bin method is that there is no 'memory' between the bins. In case of energy storage systems or in case of heat accumulation in building elements, a bin does not know how much heat was accumulated or released during the previous time interval, because the bins are not sequential in time as e.g. an hourly time interval.

This limitation is the reason why a bin method is not an option for the calculation of the energy needs for heating and cooling in a building: the heat accumulation in the building mas typically stretches over several days.

Why not recommend a full dynamic building simulation tool?

A standard reference method for the calculation of the energy performance of buildings should be realistic, sufficiently sensitive (=discriminating between technologies and their performance), fair and robust. But a standard calculation method should also be affordable, reliable, verifiable, transparent, reproducible and affordable.

Typically a detailed full dynamic simulation tool is regarded as a suitable alternative reference approach, provided that sufficient information is available on all the input data (including operating conditions) and their variations.

In practice, however, a detailed full dynamic simulation tool introduces a lot of choices, details and complexities that makes it quite a job to use it as a reference tool for a standard method to calculate the energy performance of buildings; in particular for use in the context of building regulations where reproducibility and transparency are key quality aspects of the standard method.

Conclusion: depending on the technologies and/or physical processes a suitable reference method is **a tailored choice** and not necessarily a detailed simulation tool.

Tailored hourly method: same input data needed from the user as for the monthly method

A direct hourly calculation does not need the correction factors that are needed in the monthly method to account for the dynamic effects. But the challenge for an hourly method is to avoid the need for too many input data from the user, which would introduce uncertainties that could easily lead to a loss of overall accuracy.

The hourly and the monthly method in EN ISO 52016-1 are closely linked: they use as much as possible the same input data and assumptions.

The main goal of the hourly calculation method compared to the monthly method is to be able to take into account the influence of hourly and daily variations in weather, operation (solar blinds, thermostats, heating and cooling needs, occupation, heat accumulation, etc.) and their dynamic interactions for heating and cooling.

This **tailoring to the goal** enables to avoid the need for extra input to be supplied by the user compared to the monthly calculation method.

And the hourly method yields as additional output monthly results which can be compared with the monthly method or be a basis for the derivation of the correlation factors for a monthly method for a specific location and building type. See flow chart in **Figure 1**.

In the hourly method, only the standard writers will have to introduce extra data: hourly operation schedules and weather data. On the other hand, the standard writers don't need to prepare and maintain tables with pre-calculated factors (on operation of blinds, effect of solar shading, etc.).

Moreover, these hourly data are available anyway, e.g. for applying the principle of equivalence for novel technologies. The hourly method brings these data to the visible foreground of the method.

System specific calculation of the energy needs for heating and cooling

The hourly calculation procedures in ISO 52016 1 are best suited to reveal the influence of the system on the energy loads and needs for heating and cooling:

- undersized heating or cooling power,
- recoverable heat losses,
- adjustment of the temperature set-points (value and time-schedule) due to imperfect system control, and
- limitation of the heating or cooling season for the calculation defined by the operation time of the respective technical systems.

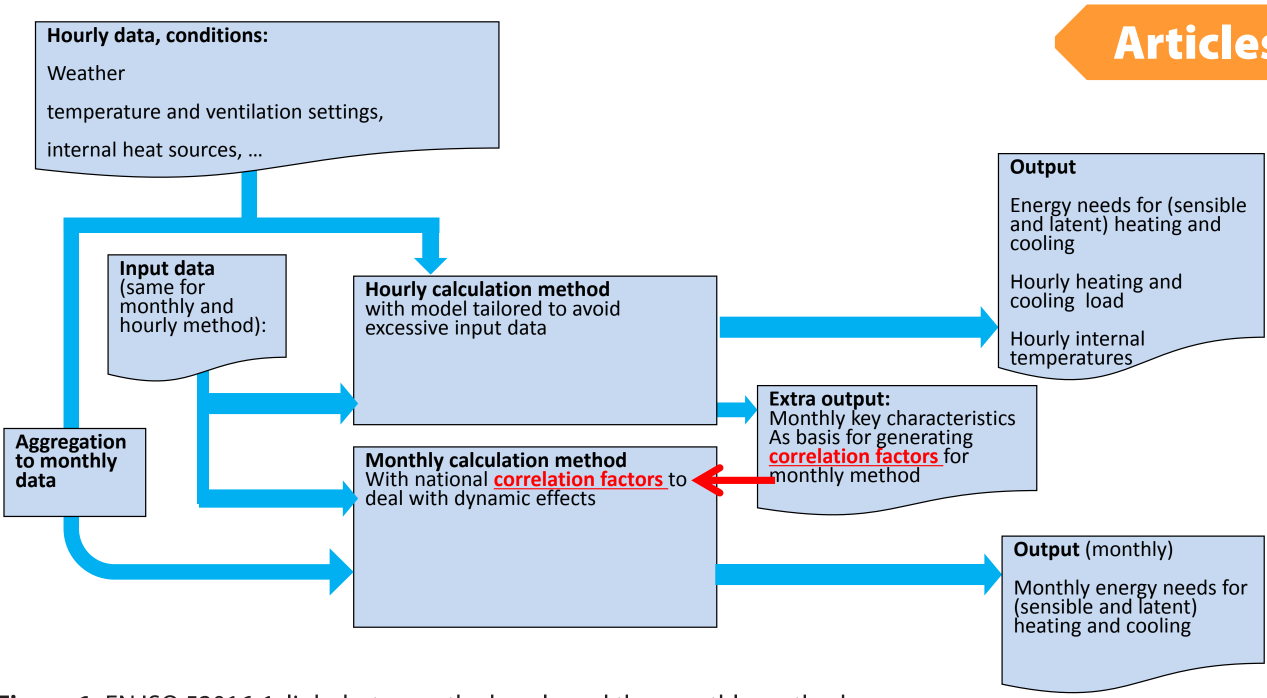

Figure 1. EN ISO 52016-1: links between the hourly and the monthly method.

But also for the interaction the other way around: to take into account the influence of the calculated hourly heating and cooling load and indoor temperature on the performance of the technical systems and their components (as described in the system related EPB standards).

Thermal balance

As illustrated in **Figure 2** versus **Figure 3**, the thermal balance in buildings changes dramatically compared to the past: nowadays the solar and internal gains have a relatively much larger influence on the energy needs for heating and cooling.

Due to relatively much larger solar and internal gains the (low) energy needs are much more dependent of the highly fluctuating heat gains, in combination with the heat accumulation in the thermal mass of the building. This makes it much more difficult to find proper and robust correction factors that are needed to take into account the dynamic effects.

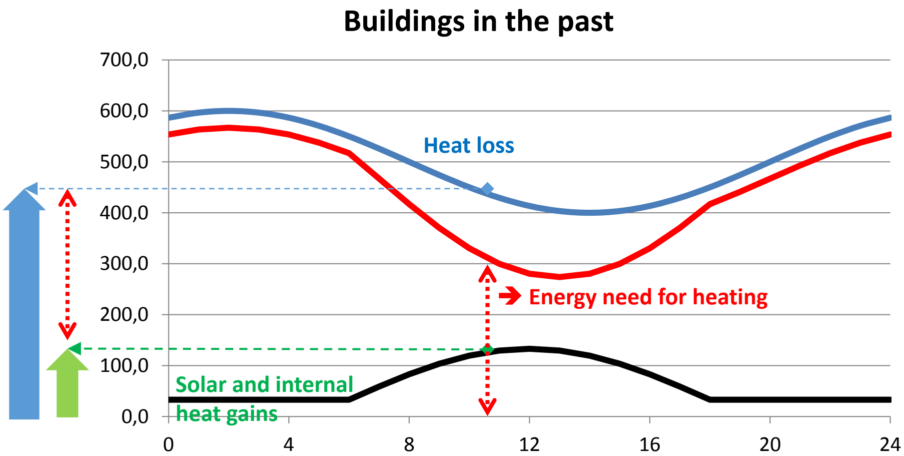

Figure 2. Illustration of the thermal balance in case of buildings in the past: the difference between the heat losses and the heat gains (➔ the energy need for heating) is large and much less fluctuating as in low energy buildings (compare **Figure 3**).

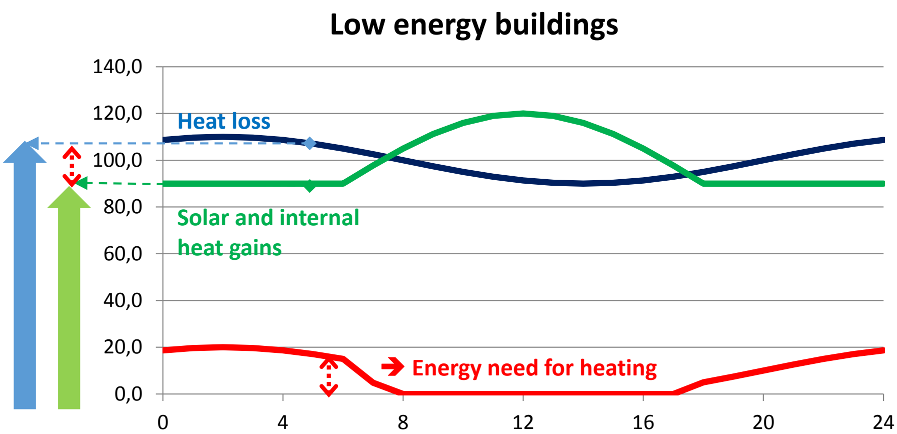

Figure 3. Illustration of the thermal balance in case of low energy buildings: the difference between the heat losses and the heat gains (➔ the energy need for heating) is small and more fluctuating.

Heating and cooling needs in the same month?

Another major drawback of the monthly method is the following.

Because there are possibly months with both heating and cooling needs, and because this cannot be predicted without doing the actual calculation, two *independent* calculations are performed:

1) for each month a calculation of the *heating needs*, with assumptions for the heating mode (e.g. on the use of solar blinds, ventilation, etc.)
2) for each month a calculation of the *cooling needs*, with assumptions for the cooling mode (e.g. on the use of solar blinds, ventilation, etc.)

Evidently this can lead to strange assumptions and to incomprehensible results.

In the hourly method it is simply determined at hourly basis whether there is a heating or a cooling need and the inertial effect of heating or cooling or over-heating during previous hours is taken into account automatically.

More dynamic effects

A number of other dynamic effects add to the problems for a monthly method in addition to the influence of hourly and daily variations in weather:

The hourly and daily variation in operation and/or in energy performance of dynamic technologies or processes (see **Figure 4**).

Examples of relevant dynamic technologies or processes (related to building and building elements or technical building systems and their interactions):

- nocturnal temperature set back, occupation (internal gains) and operation (ventilation system, shutters/blinds, …);
- weekend temperature set back, occupation (internal gains) and operation (ventilation system, shutters/blinds, …)
- solar shading by e.g. overhangs (passive heating, cooling needs, lighting needs);
- movable solar shading provisions (cooling and lighting needs);
- adaptive facades;
- nocturnal ventilation (free cooling);
- heat recovery unit (ventilation): frost protection in winter; use of by-pass in summer;
- variable ventilation air flow rates;
- heat pump, with performance strongly depending on the source temperature and with auxiliary back up heater;
- other system components with load dependent system efficiencies;
- cooling system with limited cooling capacity (comfort cooling).

In the monthly method these influences are taken into account by monthly **correlation factors**, such as the utilization factors for heating and for cooling needs, supplemented by **additional correction factors** (e.g. for night and weekend temperature set back) and **detailed pre-calculated tables** that are based on agreed reference cases which cannot always be representative for all building types and ages.

Some of these tables can be very voluminous, e.g.:

- Solar shading factors (for overhangs or other shading objects): shading reduction factors per location, orientation and tilt, per month (provided in

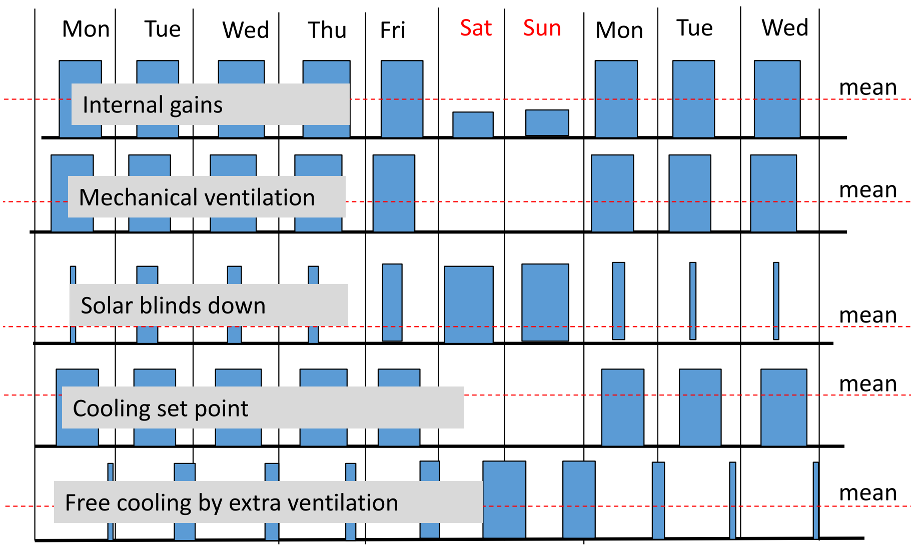

Figure 4. Illustration of hourly patterns that have a dominant influence on the thermal balance, with as a consequence that the use of monthly mean values can be problematic, even more so in case of buildings with deviating weekend operation.

EN ISO 52016-1 for only a few selected cases). In the hourly calculation method it takes only a few equations (provided in EN ISO 52016-1).

- Movable solar shading provisions: for each set of criteria for open/closed: pre-calculated tables with time-average (weighted) reduction factor for the solar energy transmittance of windows per location, orientation and tilt, per month (provided in EN ISO 52016-1 for only a few selected cases). In the hourly calculation method the choice between properties for "open" and properties for "closed" are simply determined hourly, on the basis of the criteria for open/closed (provided in EN ISO 52016-1).

In the monthly method, the interaction between the calculation of the energy needs and the system energy use can lead to the need for several additional correction factors. And it is often difficult to predict to what extent these might be neglected, because that will depend on the specific situation.

For example: preheating and precooling in an air handling unit to a constant supply air temperature (output): see **Figure 5**: the fluctuating outdoor temperature leads to momentary preheating followed by momentary precooling. In the hourly method this is correctly calculated; in the monthly method, when the preheating and precooling is simply based on the average outdoor temperature the energy needs may be significantly underestimated.

Transparency

As shown in the examples above, for low energy buildings and buildings with dynamically (inter-)acting technologies, the monthly method is no longer the simple transparent method that it used to be. Due to the necessity to introduce several correction or adjustment factors, the original transparency and robustness of the monthly method has been lost: the more of the above mentioned dynamic technologies and processes are included in the monthly calculation method, the less transparent the monthly calculation method becomes, and the more an hourly method becomes transparent.

Level playing field

In case of a simple monthly method the designer's choice for, e.g., applying external movable solar shading, or the quality of the heat recovery unit, or the choice for a bypass in the heat recovery unit, or for comfort cooling, will be based on a highly simplified, very average situation, disregarding the specific impact which is a function of the specific design or given building. There is no level playing field for these techniques.

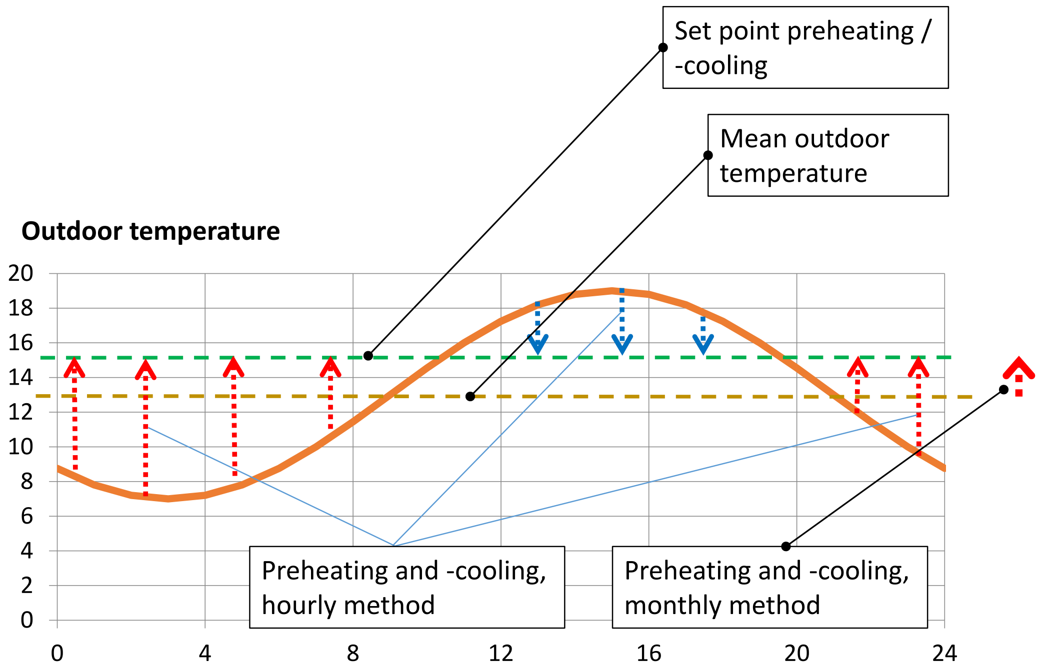

Figure 5. Illustration of the need for additional correction factors in the monthly method: the calculation based on the monthly calculation method may strongly underestimate the, preheating and precooling needs in an air handling unit.

As a consequence, having a monthly method, the pressure will increase to come up with tabulated correction factors to differentiate between specific low and high quality technologies. These tabulated values are derived by hourly calculation methods, but will make the monthly method more complicated and less transparent than intended.

By the way, an hourly calculation method does not require that all input quantities and all parts of the calculation are hourly based: if a component has a small impact on the overall result, or if it's functioning is only a very weak function of the actual conditions, it may assumed to be constant. This applies for instance for the *U*-value of building elements, but also for several components in the technical building systems.

EPB Center

More information on the set of EPB standards, with extensive background information and explanation, is provided at the website of the EPB Center [9].

One of the recently added features of the website is a complete overview of all EPB standards and their accompanying technical reports (http://epb.center/support), with information how the documents can be obtained. At each document a link is provided to the page in the ISO catalogue or CEN database where a summary and other information on the document can be found.

Conclusion

The set of Energy Performance of Buildings (EPB) standards has been published in summer 2017. For the calculation of the energy performance the overarching EPB standard (EN ISO 52000-1) lists different options for the time interval: hourly, monthly, seasonal, yearly and bin. This article provides some background information why an hourly calculation time interval is recommended.

In case of low energy buildings and in case of modern high performance technologies that are sensitive for the dynamic conditions and dynamic user requirements a well-chosen hourly calculation method is more transparent, more accurate and not necessarily more complex than a simple monthly method.

The claim that the monthly method can be useful for simple cases, like for existing residential buildings, may be true if no mayor energy efficiency improvements are going to be considered. However, this is in strong contrast with the energy saving policy we are committed to. ■

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