

Towards cost-optimal nearly zero-energy buildings

Lorenzo Pagliano, Salvatore Carlucci

End-use Efficiency Research Group, Energy Department, Politecnico di Milano

Introduction

The building sector is one of the key sectors to achieve the 20/20/20 targets of the European Union (EU). Beyond these targets, Europe also aims at bringing about drastic reductions of greenhouse gas emissions in the residential and service sectors of 88% to 91% compared to 1990 by 2050.

With the recast of the Energy Performance of Buildings Directive (r-EPBD) (European Parliament and Council 2010), the framework has been set to proceed along this track. Two mechanisms will be decisive for the development of the building sector: the principle of nearly zero-energy buildings and the principle of cost-optimality.

The principle of nearly zero-energy buildings

According to the article 2.2. of r-EPBD, “‘nearly zero-energy building’ means a building that has a very high energy performance, as determined in accordance with the Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby”; the article 1 of the Annex I stipulates that “the energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs”. Hence Annex I highlights the necessity of high quality of the envelope (high insulation levels, high performance windows, solar shading,...that reduce energy needs for heating and cooling) Then, the article 9.1 regulates that “Member States shall ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings”.

The principle of cost-optimality

This principle gives guidance for the energy performance requirements of new buildings, existing buildings undergoing major renovation and retrofitted or replaced elements that form part of the building envelope.

Brief summary of the content of cost-optimality framework methodology

Grid Interaction and its implications

Under the above framework, the share of buildings able to perform electricity generation on-site is assumed to rise and therefore the interaction of (nearly zero-energy) buildings with the grid will gain importance. Many energy experts agree that the primary energy balance over a year “does not show the complete interaction with the grid; assumes that the grid is an infinite storage; [and] allows for «lazy» design: no concern about timing of electricity generation and use” (Hogeling 2012).

In fact, even if using a one-year time step, the primary energy equivalent of on-site generated electricity equals the annual consumption, shorter sub-intervals yield different results. As an example,

without local storage on an hourly basis, only 25% of energy generated on-site might be used exactly at the time step of generation, while 75% is sent to the grid at a certain time step and taken from the grid at a different one. This implies the use of conventional energy sources with high primary energy content and emissions and/or the installation of large storage capacity on the grid side.

Cost-optimal nearly zero-energy buildings in practice

In compliance with r-EPBD, in five years all new public buildings and in seven years also the private buildings shall be nearly zero-energy buildings. In order to reach this objective the two aforementioned principles need to be coupled. However, identifying the optimal properties of the components of the building envelope and its energy systems is not an easy issue. Often a strategy that is optimal according to an aspect, results inappropriate with respect to another. There is, hence, a need for a structured design approach, which can drive a designer towards the most effective choices. The European project MaTrID aims at supporting the implementation of Nearly Zero Energy Buildings by 2020 with the adoption of an Integrated Design (ID) approach. ID is, in general, a valuable approach to manage the complexity of the design process and facilitates the interaction between the members of the design team. ID approach helps to search for the optimal solutions for the whole building and, in general, it is not limited to the sole energy performance and can go beyond this issue. However in order to be effective, ID approach requires to increase the effort in the earliest stages of the project when design changes are still easy to implement (figure 1).

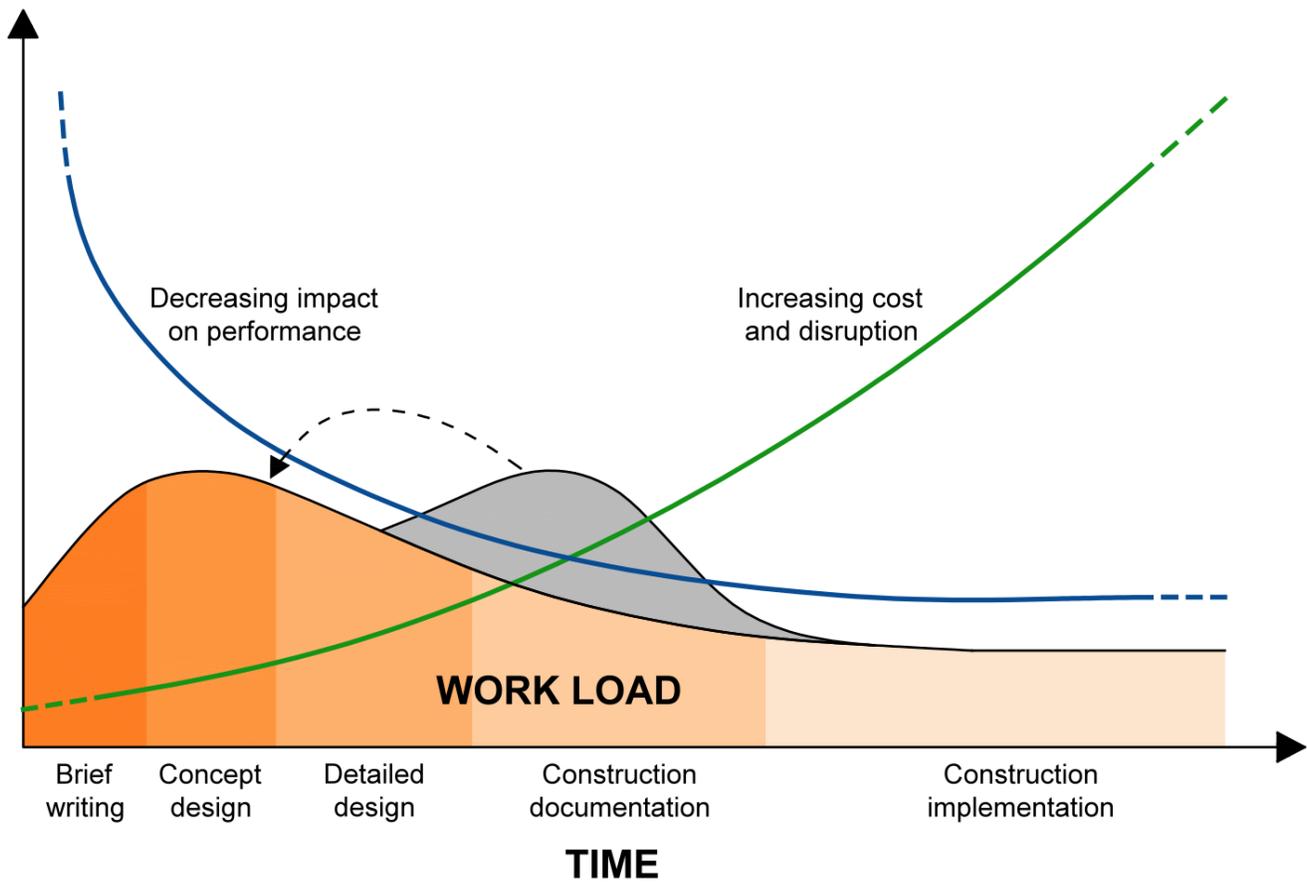


Figure 1: Adoption of the Integrated Design approach.

In such condition, ID approach provides the greatest benefits and leads to a better performance with respect to a conventional design process.

A feasible way for the future

A way to reduce the absolute value of the potential mismatch between demand and local generation (also non-electricity) is to design or renovate buildings in order to reduce their energy needs, while satisfying thermal and visual comfort objectives.

For a scenario with 2010 prices, even under relatively conservative assumptions about the performance and availability of energy efficiency technologies, buildings constructed with very low-energy needs for heating, cooling and domestic hot water have global costs (evaluated over 30 years) lower or comparable to buildings with high energy needs, all those results being relatively robust towards changes in various economic parameters, e.g., the assumed interest rates.

This result is reinforced should energy prices rise more significantly than assumed in the main part of the study. Buildings with low-energy needs are thus significantly less prone to risks connected to volatility of costs/prices of conventional and renewable energy during their lifetime.

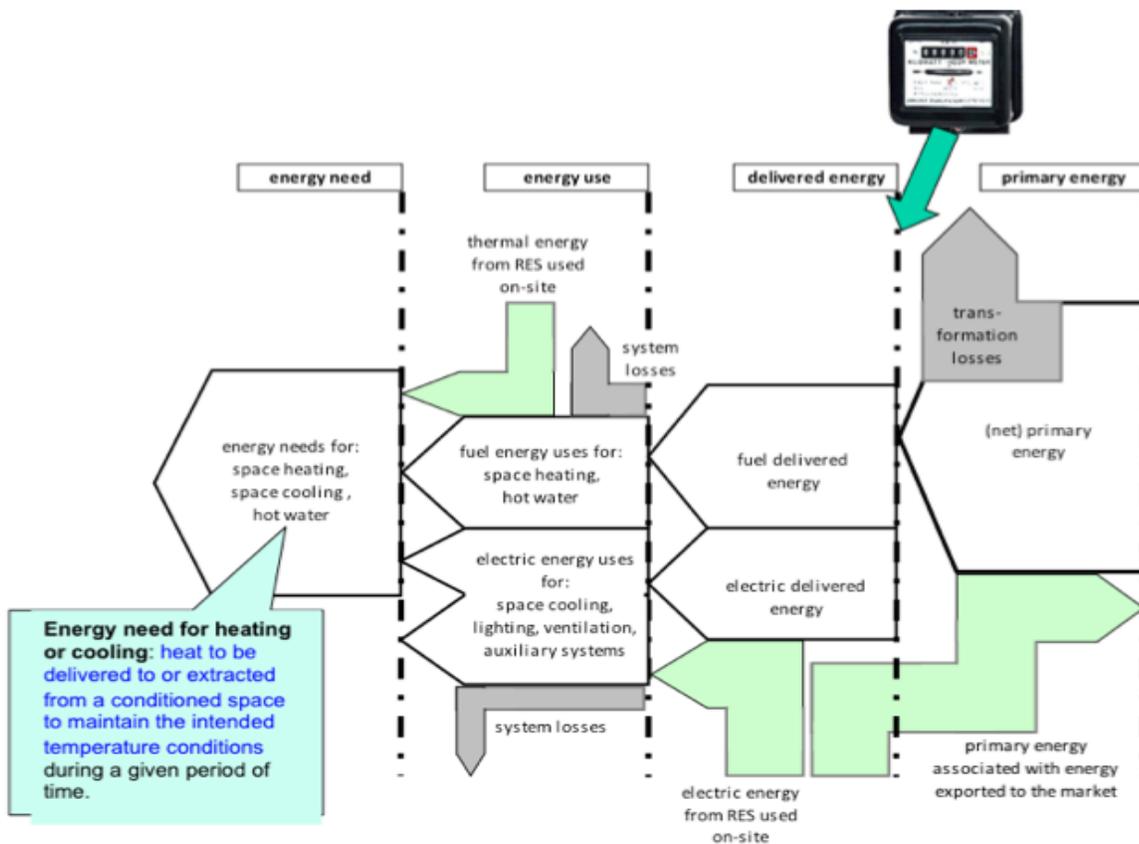
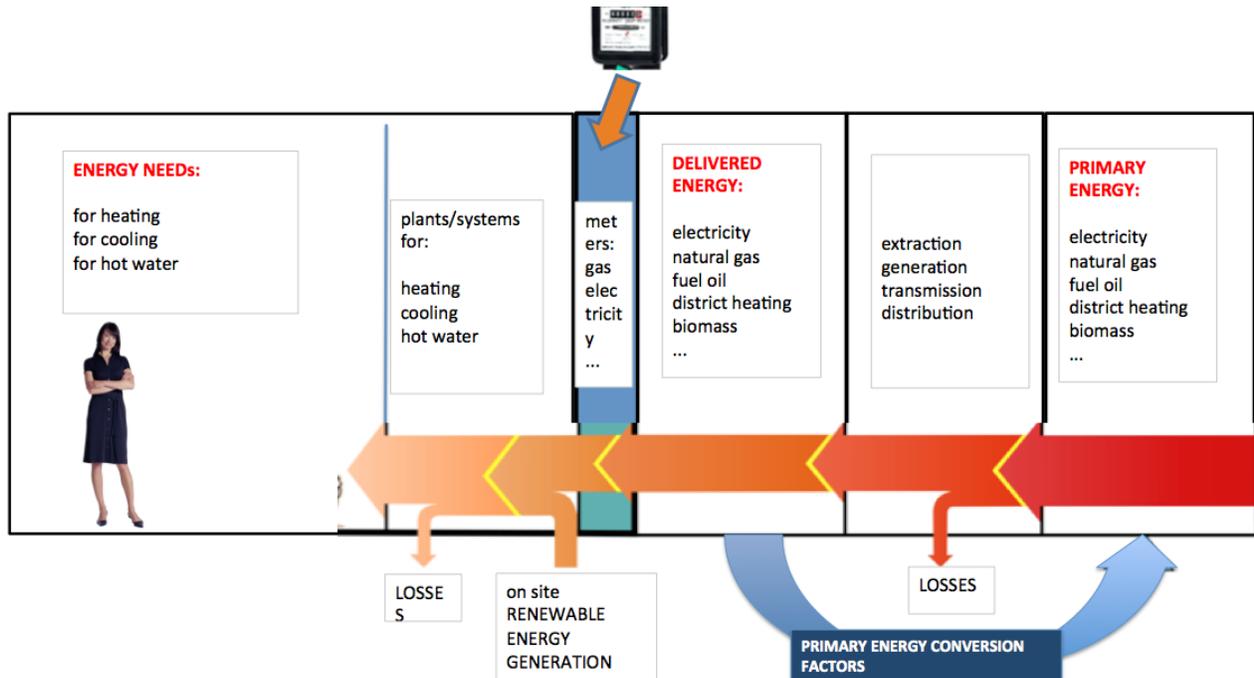


Figure 2: Energy levels according to the European standard EN 15603.



Many of the energy efficiency technologies, which contribute to buildings with low-energy needs are applicable both in rural and urban dense areas, while renewable energy sources (solar, soil, imported biomass, etc.) may have limitations as regards to production or related pollution in dense urban areas (e.g., the burning of biomass causes the emission of particulate matter). Finally, the calculation of energy needs does not require any additional assumption on weighting factors to take into account time of use, interaction with the grid (hourly or long-term fluctuating), conversion factors to primary energy, etc. All of those reasons support the usefulness of using energy needs for heating, cooling and domestic hot water and energy use for lighting (and optionally -and possibly- energy use for ventilation, auxiliaries and plug loads) as one important metric in defining nearly zero-energy buildings and setting corresponding benchmarks.

Conclusions

From this analysis it appears that a useful way to establish a definition might include all of the following four elements:

A) **A performance part on energy needs and energy use.** Energy needs for heating, cooling and hot water and energy use for lighting (and optionally energy use for ventilation, auxiliaries and plug loads) are based only on physical variables and the choice of thermal and visual comfort set points and hence do not require any weighting factors (performance part). Additionally, a prescriptive approach might indicate minimum requirements for components (e.g., U-values for windows and walls, g-values for solar protections, air tightness, (built-in) lighting installations) etc. Domestic hot water use is highly dependent on occupant density in a building unit. Therefore specific values are more difficult to establish than for heating and cooling, and should be derived from typical national occupant densities

and on typical national per capita water use. Today, specific domestic hot water use equals (single family home) or even exceeds (multi family home) space heating or space cooling needs of, e.g., passive houses. With a view to 2020 and beyond, the reduction of domestic hot water needs has to be seriously addressed, e.g., by applying low flow shower heads or faucets and/or heat recovery. As for lighting in non residential buildings, careful design of the envelope can maximize daylight availability; reduction of distance of light sources from task areas, use of efficient sources and luminaires, daylight and occupancy controls with low stand-by power may enable very good visual comfort with relatively low annual energy use. In the medium term, targets for lighting in residential buildings as well as appliances and plug-loads could be added, including e.g., refrigerators, washing machines, dishwashers, etc.

B) A yearly weighted primary energy balance defined as in EN 15603 (CEN 2008); preferably calculated based on monthly or shorter time intervals. Transparency of the calculation methodology and how primary energy factors are derived is fundamental. If relevant, especially in the case of electricity, the weighting may take into account the sources' actual input to the grid, or even additional factors such as related pollution, impact on the grid, etc. In case a load match index is not used, a proxy way to take this into account may be to choose a different (lower) primary energy conversion factor for energy exported to the grid in case of on-site generation, although being considerably less precise and thus less preferable than a load match index. In the long term, with a view to longer-term climate targets, primary energy might be supplemented with a comprehensive "total emissions" measure including greenhouse gas emissions, acidification, ozone depletion, particulate matter, nuclear waste, etc.

C) A value that illustrates the real share of energy from renewable sources. Although being partially integrated in the previous two elements implicitly, in the light of the EPBD definition for nearly zero-energy buildings this value should be made explicit. The main issues to be solved are clear definitions of temporal and spatial boundaries and avoidance of double counting especially for electricity from renewable sources. Here **the interaction of the building and on-site generation with the grid should be quantified by means of, for example, a "load-matching index" or other similar indices** – in the end showing the share of self-consumed locally generated renewable electricity – calculated with time steps of a month, day or (preferably) hour. In the presence of smart meters and smart grids, and the on-going quick reduction of costs of meters and data transfer, metering of generated and exported energy in little time steps and calculation of the load match index seem to cause small investments.

D) One or more **long-term comfort indices** calculated according to EN 15251 or other relevant literature, because "an energy declaration without a comfort declaration makes no sense" (CEN 2007). The joint IEA Project SHC Task 40/ECBCS Annex 52 titled "Towards Net Zero Energy Solar Buildings" has analyzed and proposed methodologies for incorporating long-term thermal discomfort indexes (Carlucci and Pagliano 2012) in the characterization of zero-energy buildings. In any case, energy-related benchmarks for nearly zero-energy buildings must include the underlying (thermal and visual) comfort level explicitly and quantified.

Acknowledgements

The authors would like to thank all participants of Subtask B of the joint IEA SHC Task 40/ECBCS Annex 52 project titled "Towards Net Zero Energy Solar Buildings" for the useful discussions.

The study was partially developed within the framework of the MaTrID Project focusing on integrated design and supported by the Intelligent Energy for Europe Programme.

References

- Carlucci, S. and L. Pagliano (2012). "A review of indices for the long-term evaluation of the general thermal comfort conditions in buildings." Energy and Buildings **53**: 194-205.
- CEN (2007). Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics. Brussels, Belgium, European Committee for Standardization. **EN 15251**.
- CEN (2008). Overall energy use and definition of energy ratings. Energy performance of buildings. Brussels, European Committee for Standardization. **EN 15603**: 62.
- European Parliament and Council (2010). Energy performance of buildings. Luxembourg, Official Journal of the European Union.
- Hogeling, J. (2012). Presentation on CEN EU Mandate M480.