New evaluation metrics: the H2020 Mobistyle project contribution

GIULIA VERGERIO
TEBE-IEEM Group, Energy Department, Politecnico di Torino, Turin and Energy Center-Lab, Politecnico di Torino, Turin, Italy
giulia.vergerio@polito.it

CRISTINA BECCHIO
TEBE-IEEM Group, Energy Department, Politecnico di Torino, Turin, and Energy Center-Lab, Politecnico di Torino, Turin, Italy
cristina.becchio@polito.it

ANA TISOV
Huygen Engineers & Consultants, Maastricht, Netherlands
a.tisov@huygen.net

In energy planning for the building sector, it is possible to identify two needs: i) considering the multiple benefits of renovation strategies in evaluation procedures; ii) educate occupants about their impacts on buildings energy consumptions to control the performance gap. In this paper the H2020 Mobistyle project contribution is underlined.

Keywords: key performance indicators, KPIs, building performance, indoor environmental quality, IEQ, productivity, Mobistyle.

Most of the energy consumptions in buildings is related to space conditioning. In particular, the energy demand for cooling is expected to increase in the next years, and mechanical ventilation systems are more and more needed in high performing building to guarantee comfort to the occupants without compromising the energy performance of the building itself. As a consequence, the HVAC sector has a key role in bolstering the improvement of the energy efficiency of the building sector and the subsequent reduction of energy-related greenhouse gases (GHG) emissions. In particular, the European Roadmap to 2050 has identified the need of the building sector to achieve by 2050 a 90% reduction of GHG emissions with respect to 1990 level [1]. In this regard, the need to prepare a national plan addressing the existing building stock is stressed in the new Energy Performance of Building Directive 2018/844/UE [2]. In particular, the Directive underlines that building renovation strategies have to be fostered taking into account the multiple benefits coming from retrofit as the increase in comfort, air quality, health, etc.

Figure 1. The multiple benefits of energy efficiency according to the new EPBD [3].

The new EPBD also introduces the concept of the building readiness to smartness, defined as the capability to respond to both the occupants and the grid needs. This concept is measured as a percentage score, obtained as a weighted sum of the building readiness over the maximum score possible in regarding to different criteria. Within these criteria, also comfort, health and information to the occupants are mentioned as areas of interest. The methodology is based on a check-list approach, where the analyst has to identify the set of technologies inside the building and define their level of functionality that, according to a predefined scoring system, correspond to a specific level of readiness to smartness per each impact area. In this framework, a challenge in the planning of renovation strategies is the definition of proper metrics and tools able to take into account the multiple benefits related to the renovation itself. Technologies that can be deployed in the renovation process, as innovative HVAC technologies, should be evaluated taking into account their impacts not only in terms of energy efficiency, but also on the matters mentioned in the updated regulation panorama (i.e. indoor air quality, comfort, health, etc.).

Another challenge to tackle while planning renovation for buildings is the broadly recognized issue of the energy performance gap. It is defined as the difference between the real energy consumption of a building and the one assessed during its design phase. This discrepancy is mainly due to the influence of occupants. Consequently, education of occupants to increase their awareness about how their actions impact on energy consumptions of buildings cannot be disregarded in pursuing the European goals for the building sector.

In this paper, the H2020 Mobistyle project contribution is underlined, with a particular attention on the need of the implementation of new Key Performance Indicators (KPIs).

The H2020 Mobistyle project contribution

Mobistyle is a Horizon2020 European project aiming to drive behavioural changes in buildings occupants, leveraging on the three issues of energy, indoor environmental quality (IEQ) and health [4]. To reach this objective, personalized ICT solutions (Mobile App, Game and Dashboard) are deployed at different demo cases level. The Mobistyle approach is based on the provision of personalized feedback and on the deployment of a tailored awareness campaign to increase people perception about how their habits can influence energy consumptions and IEQ in buildings, but also their health and well-being. The set of tools and methodologies deployed within Mobistyle project and the experience obtained in the pilots represent a contribution with regards to the need to educate occupants about their impacts on energy consumptions of buildings to control the performance gap.

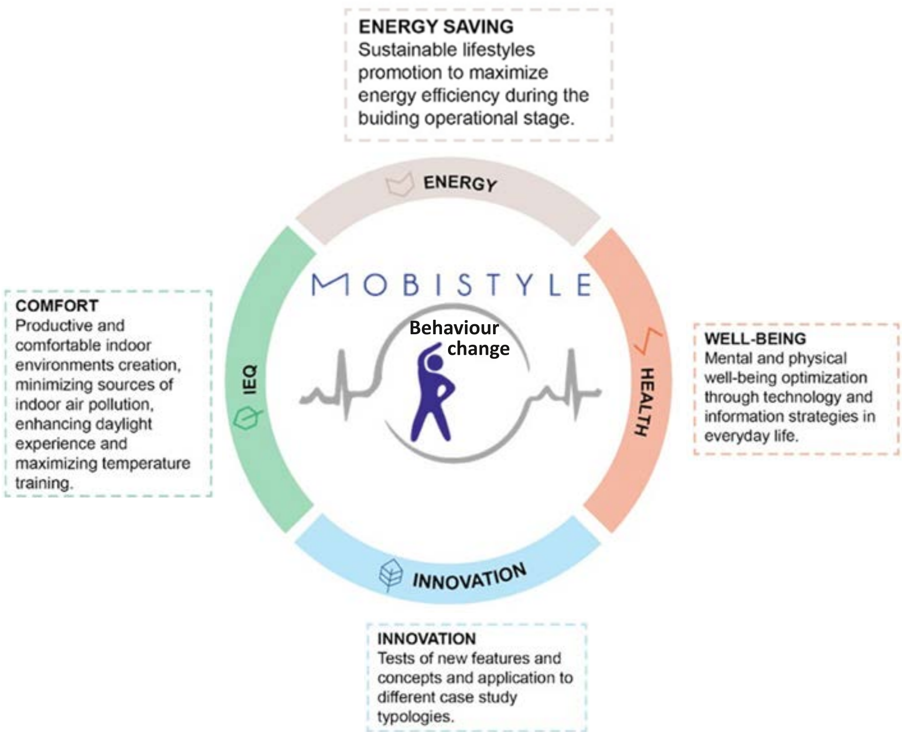

Figure 2. The Mobistyle concept.

However, this set of tools need a validation process according to a well-defined evaluation procedure. Accordingly, the objective of Working Package 3 is to formulate a methodology to (i) define, gather, elaborate and address energy, IEQ and health data to users aimed at providing a behavioral change [5], [6], and to (ii) evaluate the effectiveness of the proposed Mobistyle strategies [7]. Within Mobistyle, some single-domain KPIs are identified as part of the evaluation methodology to measure the outcomes of the project in terms of energy consumptions, IEQ and occupant behavior patterns in the different demo cases before and after the Mobistyle solutions deployment [7]. More interestingly, the KPIs to be displayed to the users through the ICT tools are defined according to the specific behavioral action plans, and translated into meaningful information and actionable tasks for building occupants [6]. The core of this paper is in the further implementation of the traditional single-domain KPIs towards new KPIs able to give a contribution with regards to the need to define new metrics able to take into account multiple benefits in the evaluation procedures.

Development of new KPIs

To define new KPIs, the starting point is thinking about the traditional domain KPIs and the expected correlations, keeping in mind value and relevance of the proposal:

- Value: Which is the derived knowledge from the new KPI?
- Relevance: Who would be interested in the new KPI and for which purpose?

In the followings, different examples of KPIs developed within Mobistyle project, with some insights about possible stakeholders which would be possibly interested in them, are reported.

Environmental performance

A fist indicator proposed is the carbon intensity of the stock, defined as the sum of all the final consumptions of the stock weighted on the GHG emission factors characteristic of each energy carrier. This KPI can be used to know the specific environmental performance of the stock and to identify possible improvements brought by the exploitation of different fuels. It can be a relevant index for the policy makers, whose need, between others, is to identify how far the building stock is from a targeted performance. Accordingly, within Mobistyle, a benchmark value on a set of residential building located in Aalborg, Denmark, will be computed based on the **Equation (1)**.

IEQ performance

In interventions aiming at improving the energy performance of a building, it's fundamental to improve also the IEQ. The Mobistyle project focuses on thermal comfort and indoor air quality, monitoring the indoor air temperature, the indoor air relative humidity and the indoor concentration of both CO_2 and Volatile Organic Compounds (VOC). There are several studies which try to assess to which extent the overall comfort perception of the occupants is influenced by each of these parameters [8]. Thus, another new KPI is represented by the sum of weighted percentage of hours in class II of comfort (as defined according to the EN 15251 [9]) according to the four measured parameters over the total hours of the monitoring period.

Each parameter has the same weight ($\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$), but by changing them it is possible to assess which parameter is influencing the most the overall percentage of hours in comfort and thus to disclose to the occupants where the criticalities in terms of IEQ are. The KPI is validated by its application to different demo cases of the Mobistyle project. Similarly, the nominator of **Equation (2)** can be replaced with a measure of severity of discomfort.

$$\frac{\sum_{d=1}^{365}(district\ heating\ consumptions)_d \cdot coeff.emiss_{DH} + \sum_{d=1}^{365}(electicity\ consumptions)_d \cdot coeff.emiss_{el}}{\sum_{d=1}^{365}(district\ heating\ consumptions)_d + \sum_{d=1}^{365}(electicity\ consumptions)_d} \quad (1)$$

$$[\frac{\mathrm{kg_{CO_{2eq}}}}{\mathrm{kWh}}]$$

where "*d*" is for day of the monitoring period and "*coeff. emissx*" are the emission factors characteristic of each energy carrier *x*.

$$\alpha_1 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR}(T))_d}{n \cdot Oh} + \alpha_2 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(RH)})_d}{n \cdot Oh} + \alpha_3 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(CO_2)})_d}{n \cdot Oh} + \alpha_4 \frac{\sum_{d=1}^{n}(Oh - \mathrm{hOR(VOC)})_d}{n \cdot Oh} \quad (2)$$

$$[\%]$$

where "*d*" is for day of the monitoring period; "*n*": total number of days; "*Oh*" are the total daily hours and "hOR(*x*)" the daily hours where the parameter *x* is out from the comfort range; "*T*": hourly mean indoor air temperature, "RH": hourly mean indoor relative humidity; "CO_2": hourly mean CO_2 concentration; "VOC": hourly mean Volatile Organic Compounds concentration.

Human performance: productivity economic value

When there is not correspondence between the energy manager (who is paying for the energy bills) and the occupants (who is benefitting from the guaranteed comfort), the former could be interested not on the comfort level, of interest of the latter, but on the economic implication of a potential discomfort. Then, another KPI is defined borrowing the model developed in [10], reported in **Equation (3)**.

In particular, the function defines the level of performance in % based on the indoor temperature "*T*" (with 100% of performance around 22°C). The computation proposed in this paper is performed on an hourly-base, considering the hourly mean temperature per each working day as input. The productivity level is monetized by multiplying the percentual obtained thanks to this model for the hourly salary of an employee, as defined in **Equation (4)**.

$$p = (0.1647524 \cdot T - 0.0058274 \cdot T^2 + 0.0000623 \cdot T^3 + 0.4685328) \quad (3)$$

$$\sum_{d=1}^{n} \left(\sum_{i=1}^{Oh} (0.1647524 \cdot T_i - 0.0058274 \cdot T_i^2 + 0.0000623 \cdot T_i^3 + 0.4685328) \cdot L_i\right)_d \quad (4)$$

[€]

where "*d*" is for day of the monitoring period; "*n*": total number of days; "*Oh*" are the total daily hours; "*T*": hourly mean indoor air temperature per each hour *i*; "*L*": hourly salary of an employee per each hour *i*.

The KPI will be validated on the Slovenian demo case (some offices in the university building). The outcome represents the economic value of keeping proper temperature level in office spaces. If the energy bill for climatization (normalized over the number of occupants) is divided by the result of **Equation (4)**, both computed on data covering the same time span, new knowledge about the financial balance between the costs to keep comfortable indoor temperature (through climatization) and the benefits in terms of productivity can be disclosed.

Mobistyle Open User Platform (MOUP)

The Mobistyle platform collects all the methodologies and tools developed during the project. The bridge between the Mobistyle platform and the external market of stakeholders is represented by the Mobistyle Open User Platform (MOUP), a software service based on open standards. Its main value proposition lies in giving additional combined information from the gathered data to the stakeholders through new KPIs. Accordingly, the KPIs proposed in this paper will be tested and offered via the MOUP as benchmark values on combined information about buildings performances.

Conclusions

To summarize, the paper wanted to underline the contribution of the H2020 Mobistyle project in face of the two identified needs of i) taking into account the multiple benefits of renovation strategies; ii) educating occupants about their impacts on buildings energy consumptions to control the performance gap. In particular, new KPIs relevant for different stakeholder (policy makers, building occupants and building managers), which will we tested within (and offered via) the MOUP, has been discussed. ■

Acknowledgments

This work is part of the research activities of an international project financed by European Community MOBISTYLE – Motivating end users Behavioral change by combined ICT based tools and modular Information services on energy use, indoor environment, health and lifestyle. It has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No. 723032.

References

[1] European Commission, *A Roadmap for moving to a competitive low carbon economy in 2050*, COM (2011), 112, 2012, Brussels, Belgium.

[2] European Parliament, Energy Performance of Building Directive ("New EPBD") 2018/844/EU, Official Journal of the European Union, 2018, Brussel, Belgium.

[3] Buildings Performance Institute Europe (2019). *Building renovation in the Clean Energy Package: implications at local*, national and EU levels, 2019, Brussels, Belgium.

[4] Op't Veld P. et al. (2016). *MOBISTYLE MOtivating End-Users Behavioral Change by Combined ICT Based Tools and Modular Information Services on Energy Use, Indoor Environment, Health and Lifestyle*. Proposal of MOBISTYLE Horizon 2020 EU project.

[5] Fabi V., Barthelmes V. M., Becchio C., Corgnati S. (2017). *Detailed monitoring and information campaign parameters (objectives, data requirements, monitoring tools, information services) based on combined feedback about energy, IEQ and health*. Deliverable D 3.1 of MOBISTYLE Horizon 2020 EU project.

[6] van Marken Lichtenbelt W., Tisov A., d'Oca S., Vasilevskis S., Barthelmes V. M., Becchio C., Vetrsek J., Herczakowska J., Marciniak P. (2018). *Development indicators based on environmental conditions.* Deliverable D 3.2 of MOBISTYLE Horizon 2020 EU project.

[7] Barthelmes V. M., Becchio C., Fabi V., Litiu A. V., Vergerio G., Corgnati S. P. (2018). *Evaluation Method to Test the Effectiveness of the Combined Feedback Campaigns.* Deliverable D 3.3 of MOBISTYLE Horizon 2020 EU project.

[8] Ncube M., Riffat S. (2012). *Developing an indoor environment quality tool for assessment of mechanically ventilated office buildings in the UK e A preliminary study.* Building and Environment 53 (2012) 26-33.

[9] CEN (2007). *Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings- Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics*. EN 15251 Standard. Brussel: European Committee for Standardization.

[10] Seppanen O., Fisk W. And Lei Q. H. (2006). *Effect of temperature on task performance in office environment*, in Proceedings of Cold Climate HVAC conference, Moscow.