*Agronomy Research* **19**(S2), 1159–1166, 2021
https://doi.org/10.15159/AR.21.052

# Building performance analysis of a dairy factory in South Iraq: appraisal of a local bio-based envelope

S. Simonini[1], G. Rossi[1,*], V. Becciolini[1], S. Camiciottoli[1], L. Conti[1], P.F.P. Ferraz[2], G.A.S. Ferraz[2] and M. Barbari[1]

[1]University of Firenze, Department of Agriculture, Food, Environment and Forestry, 13 Via San Bonaventura, IT 50145 Firenze, Italy
[2]Federal University of Lavras, Department of Agricultural Engineering, Campus Universitário, PO Box 3037 - CEP 37200-000 Lavras, Minas Gerais, Brazil
[*]Correspondence: giuseppe.rossi@unifi.it

Received: February 4th, 2021; Accepted: April 24th, 2021; Published: April 29th, 2021

**Abstract.** Buildings have a relevant impact on the environment, and building materials cause environmental impacts during all life cycle stages: production, utilization, management and demolition. The global request for more efficient buildings with less environmental impacts has grown during the last years. Among various technologies, thermal insulation has proven to be helpful in reducing emissions by increasing energy conservation. This paper intends to show how the Building Performance Analysis (BPA) supports the decision-making process in many areas where common insulation materials are not available and there is a general reluctance to use local natural materials. A building located in the city of Al Chubaish in Dhi Qar Province in Iraq is examined as a case study. The construction is designed for processing buffalo milk. It was built in the first decade of the century, during the Iraqi conflict, using only the materials available at that time, most of which, concrete bricks, mortar and plaster. Currently, this dairy factory is a very inefficient structure in terms of energy saving. But because its elementary form, it is a perfect example to investigate how a simple exterior wall insulation can improve building performance in extreme environmental conditions. Accordingly, two different models have been created. One is the replica of the real building without any upgrading. The second instead presents a thermal insulation realized with reed bio-based material locally available. Through advanced simulation engines and building performance analysis data integrated into Autodesk Revit, each model has been tested to identify significant improvements in terms of energy savings in this particular stressed background.

**Key words:** Building performance analysis (BPA), reeds, bio-based, thermal insulation, Iraqi Marshlands.

## INTRODUCTION

As the standard of living increases in many areas of the world, so does the need for air conditioning. At present time, the amount of electricity to keep buildings cool in US is the same that Africa use for everything. However, China and India and Middle East are growing fast.

Within 30 years, world population will use more energy for cooling than heating. Energy demand for residential air conditioning in summer is projected to increase more than 30-fold: from nearly 300 terawatt-hours (TWh) in 2000 to about 4,000 TWh in 2050 and more than 10,000 TWh in 2100, stated Pachauri et al. (2014) of the Intergovernmental Panel on Climate Change, with a fast increase in tropical and subtropical areas.

Therefore, sustainability is becoming a key factor in the decision-making process of infrastructure projects throughout their lifecycles. In particular, the Environmental Impact Assessment (EIA) is becoming a matter of significant importance, for both public and private sectors, given the long-term impacts of design decisions on the environmental performance of infrastructure projects (van Eldik et al., 2020).

Building Information Modelling (BIM) is a powerful methodology in automating processes due to the parameterization capabilities of BIM objects and the ability to obtain measurements, quantities and costs directly from the BIM model (Maia et al., 2015).

Since BIM allows for multi-disciplinary information to be superimposed within one model, it creates an opportunity to conduct these analyses accurately and efficiently as compared to the traditional methods (Azhar et al., 2011). In addition to driving a more efficient overall design process, BIM is powerful for sustainable design because it can help to achieve the Building Performance Analysis (BPA), even if there are still critical issues to overcome about standardization (Patacas et al., 2020) and full interoperability between BIM and energy simulation tools has not yet been achieved (Bracht et al., 2021).

The appropriate selection of materials and systems to reduce environmental impact, minimize harmful emissions and prevent the depletion of non-renewable resources is one way of alleviating the impact of building construction or retrofitting. The construction industry and the community in general will benefit from an integrated tool that will help optimize the process (Barnes & Castro-Lacouture, 2009), since several types of information are necessary to manage a facility or to perform retrofit measures in buildings (Becerik-Gerber et al., 2012; Volk et al., 2014), as well as maintenance history since completion (Nicolle & Cruz, 2011). Echenagucia et al. (2015) performed a multi-objective search to minimise the building total energy need for different climates and urban contexts.

By doing an investigation of the insulation capacity of reed bio-based material to retrofit a building in the South of Iraq, the aim of the research is to make evident that BPA is a powerful tool in decision-making process because it generates simple values for real building in real locations which can be used even in challenging environment countries.

## MATERIALS AND METHODS

The construction (Fig. 1) is located in the town of Al Chubaish in Dhi Qar Province in Iraq. The area is categorised as hot desert (BWh) by Köppen e Geiger classification with an average annual rainfall of 101 mm. The summer temperatures are very high, in August the average daily temperature is 34.3 °C. For 7 months of the year, the average maximum temperature is above 30 °C, and for 5 of these above 40 °C. In July 22, 2016, Iraq achieved the record temperature of 53.8 °C in the city of Basra, around 100 km southeast from the location involved in the study. Nevertheless, the wintertime could be cold. In January, the average temperature is 11.7 °C, with minimum temperatures of 5.9 °C. Often in this month, premises are heated, using electricity as the main source.

The building is 14 m wide, 14 m long, 5 m height with a total area of 196 $m^2$. It is made of load-bearing pillars in reinforced concrete, infill walls in concrete blocks and rough finishing plaster. In the south side there are two horizontal windows 1.60 m large and 0.80 m high and one door 0.80 m large and 2.10 m high (Table 1). In the west side there are three 1.40 m square windows. In the north side there is one track door 3.00 m large and 2.50 m high and one door 0.80 m large and 2.10 high. In the east side is one 1.40 m square window and one track door 3.00 m large and 2.50 m high. The roof is 14.00 m large and 14.00 m long for a total 196.00 $m^2$ of surface.

**Figure 1.** Dairy factory building, south-west side.

**Table 1.** Physical properties of the fixtures in the building

| | Nr. | dimension l·h, m | Total area $m^2$ | Heat transfer coefficient $W(m^2K)$ | Thermal resistance $(m^2K)W^{-1}$ | Thermal mass $kJK^{-1}$ |
|---|---|---|---|---|---|---|
| Horizontal windows | 2 | 1.60·0.80 | 2.56 | 3.6886 | 0.2711 | |
| Square windows | 4 | 1.40·1.40 | 3.92 | 3.6886 | 0.2711 | |
| Track doors | 2 | 0.80·2.10 | 3.36 | 0.37021 | 0.2701 | |
| Doors | 2 | 3.00·2.50 | 15.00 | 0.37021 | 0.2701 | |
| Roof | 1 | 14.00·14.00 | 196.00 | 17.433 | 0.0574 | 8.42 |

It was intended to be a small dairy factory but it never work. In 2021 must be put back into operation, but the structure needs interventions, among which there is the possibility to add an envelope. The owner is a public body that must evaluate the restructuring and operating costs of the factory, so it need a BPA to support its decision making process.

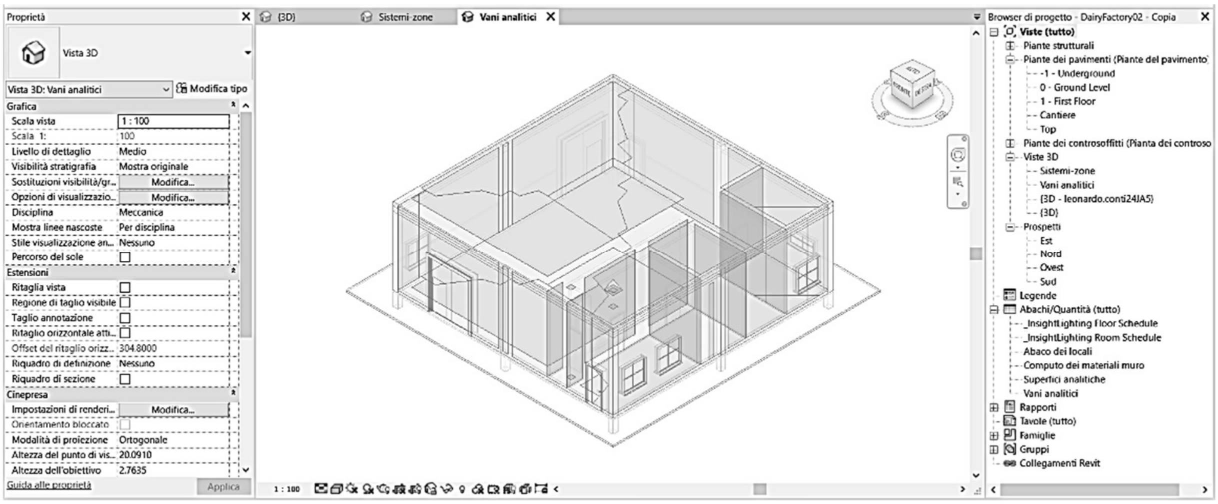


**Figure 2.** 3D model of the building in Revit.

Models in 3D (Fig. 2) of the edifice were recreated in Revit Autodesk 2021, which is a commercial CAD and Building Information Modeling (BIM) software capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later maintenance and/or demolition. Among these tools, there is Insight, a Building Performance Analysis (BPA) software that only operates by remote when Revit is connected to internet external database. Insight process the information of the model together with the climate data available in weather station closest to the building and the costs of energy in the region.

**Figure 3.** Traditional use of reeds in the Iraqi Marshlands.

For the goal of the research, two models were designed. They shared the entire supporting structure, fixtures and orientation (Fig. 3). The first was identical to the original building with infill walls made of concrete blocks 28 cm thick and 1 cm of plaster on each side (Tables 2 and 3). The second had an additional envelope of insulation material, which consisted in a 10 cm panel made by reeds, typical of the area but used for different purpose (jabasha جباشة). Reeds from the Marshland region consist of several types of plants whose stems differ in thickness, flexibility and chemical composition. The most popular reed used in the construction of Mudhif (Fig. 3) are 'Ihdri', the regional name of this very tall type of reed (Almusaed & Almssad, 2015).

**Table 2.** Physical properties of the materials used in the models

| Material | Thermal Conductibility W (mK)$^{-1}$ | Specific Heat J (g°C) | Density kg m$^{-3}$ |
|---|---|---|---|
| Plaster | 0.72 | 0.84 | 1,860 |
| Block | 1.30 | 0.84 | 1,800 |
| Fibers Insulated | 0.24 | 1.80 | 580 |

**Table 3.** Physical properties of the walls in the models

| Wall Structure | Thermal Resistance (m$^2$K) W$^{-1}$ | Thermal Mass kJ K$^{-1}$ | Transmittance W (m$^2$K)$^{-1}$ |
|---|---|---|---|
| Wall No insulated | 0.2223 | 40.06 | 4.4978 |
| Wall insulated | 0.6459 | 50.48 | 1.5481 |

Using the Revit database as reference, the final transmittance turned out to be 4.50 W (m$^2$K)$^{-1}$ for the wall not insulated and 1.55 W (m$^2$K)$^{-1}$ for the wall insulated.

After completing the two models, the simulation was launched using Insight for BPA online processing (Fig. 4) performing an analysis of the whole buildings taking into consideration orientation, external and internal walls, windows, doors, roof and their thermal properties (Fig. 5). The parameters for the test were fixed equal for both the models. Even though it was incorrectly classified under the Baghdad database, closest weather station was found in Al Chubaish town using right coordinates. Price of electricity in Iraq has been set as USD 0.05 (IQD 60.000), the rate for commercial use at December 27th, 2020. The main output of the simulation was the total annual costs of electricity per $m^2$ to keep the two buildings at an inside stable temperature of 15 °C, 24 hours a day 7 days a week, taking into account all the HVACR (Heating, Ventilation, Air Conditioning and Refrigeration) needed.

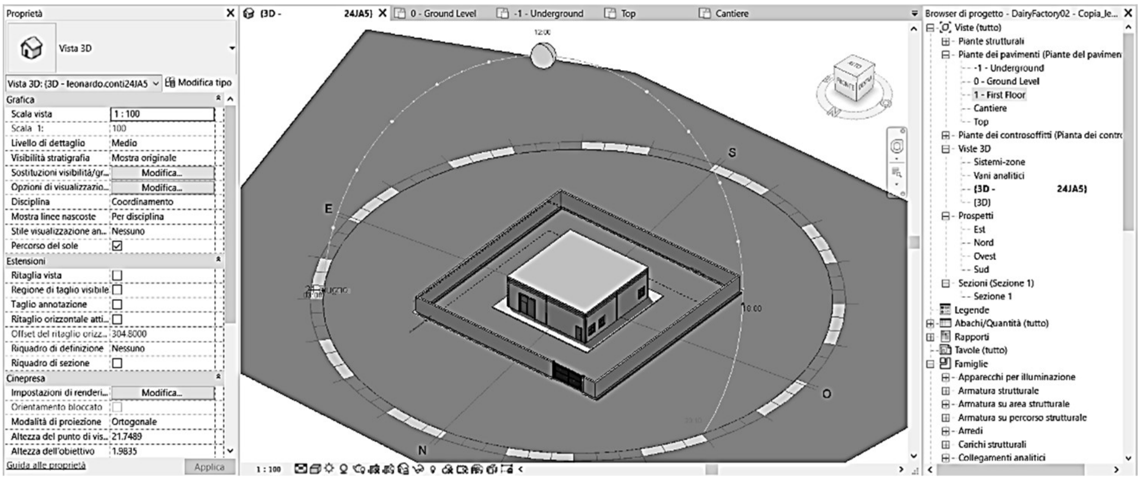


**Figure 4.** Orientation of the building before BPA.

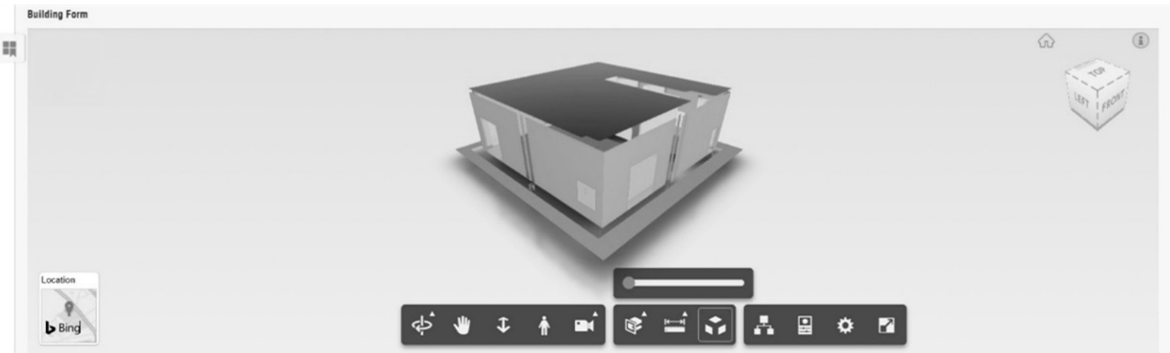


**Figure 5.** BPA of the model in Insight.

## RESULTS AND DISCUSSION

The BPA simulation in Insight returned the two values of the USD $m^{-2}$ per year of electricity to maintain the right temperature inside the two different models. The construction with the envelope entail an average costs of 22.20 USD $m^{-2}$ per year compared to the 29.90 USD $m^{-2}$ per year of the traditional construction, around 25% of difference (7.70 USD $m^{-2}$ per year), for a total 1,509.20 USD in terms of potential yearly savings. After having seen this monetary value, the public owner of the building immediately made the decision to proceed with the isolation. This approach based on simple cost indexes involves people more and helps them helps to make decisions (Ascione et al., 2015).

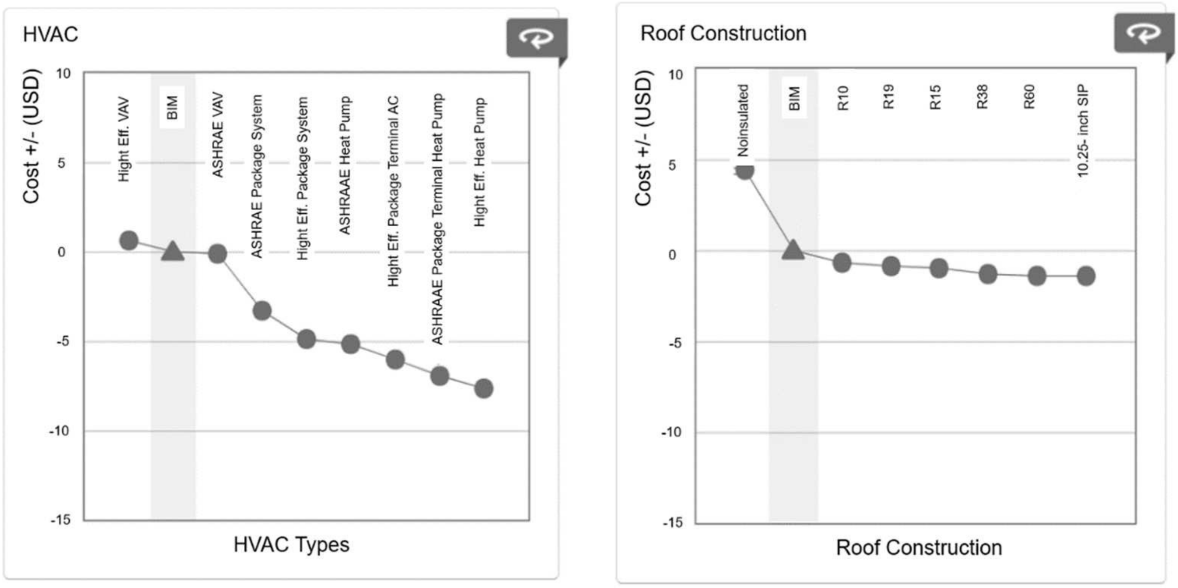


**Figure 6.** Left: HVAC propositions, Right: Roof Construction.

As results of the test, in addition to the synthetic parameter of the possible energy savings other values were generated by the BPA including specific analysis of individual components of the structure and some suggestions to increase energy savings. In particular (Fig. 6), a high efficiency air conditioning system was proposed to obtain further consumption savings even greater than 5%. In term of roof construction (Fig. 6), simulation confirmed that the 10 cm of natural based material generates good effects not only compared with the non-isolated roof but also with materials with high R-value (building industry term for thermal resistance 'per unit area') confirming the ability of the reed bio-based material to compensate for the lack of other insulating materials (Asdrubali et al., 2016).

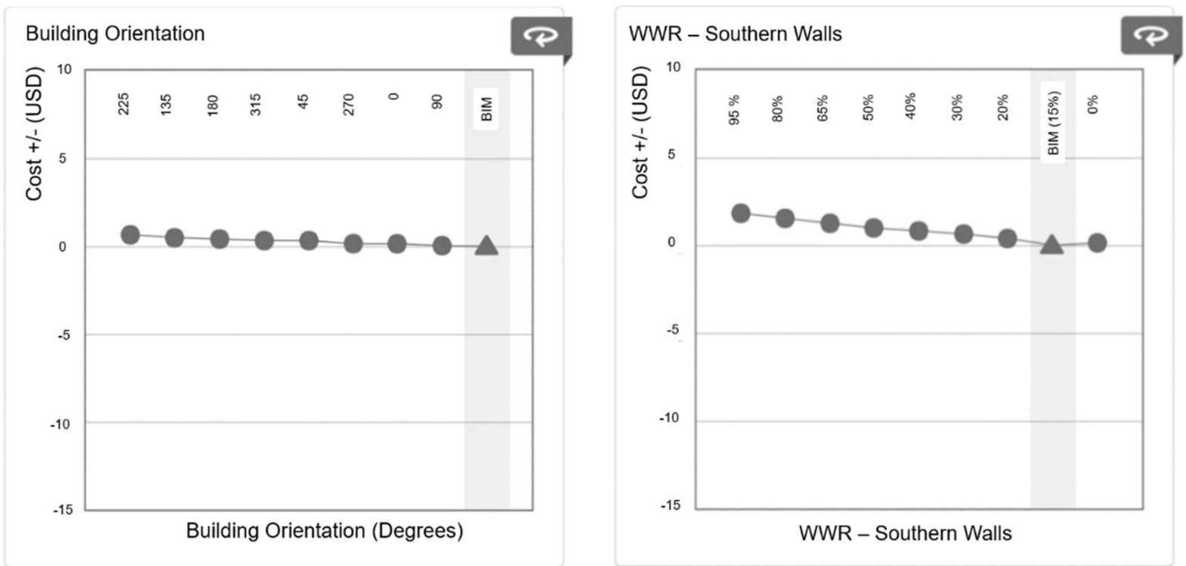


**Figure 7.** Left: Building Orientation, Right: WWR Southern Walls.

Albeit with very little difference, the test also confirmed that orientation of the dairy factory was well decided in the first place (Fig. 7). Same validation for the Window Wall Ratio (WWR) of the existing building, the percentage of windows and their distribution around the build were well planned. Mistakes in the Easter and Western Walls Ratio would have greatly compromised the building's efficiency (Fig. 8).

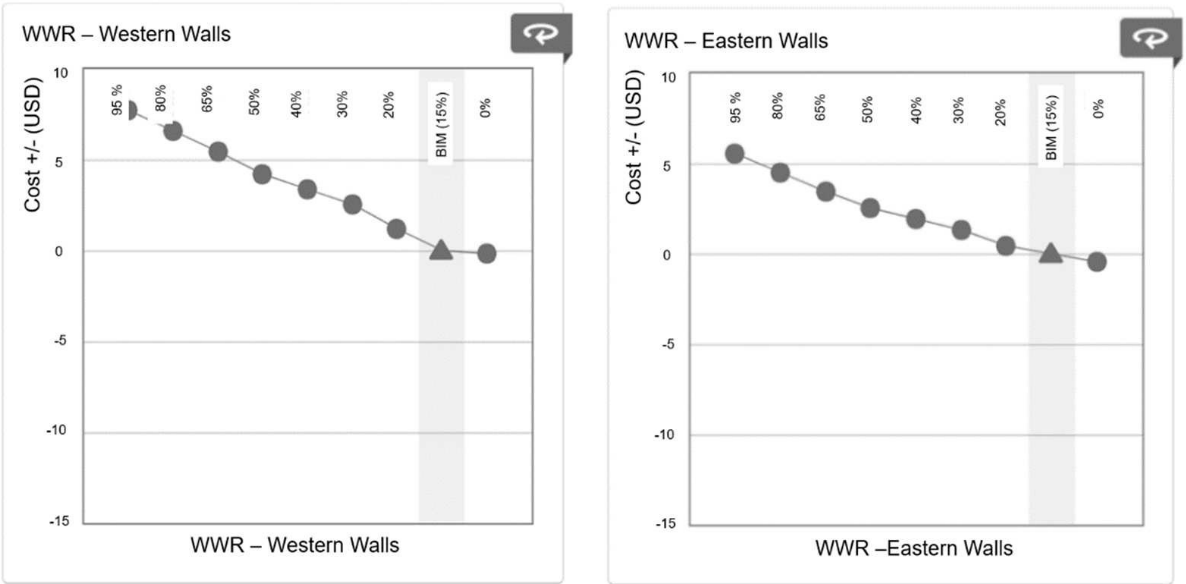


**Figure 8.** Left: WWR Western Walls, Right: WWR Eastern Walls.

## CONCLUSIONS

The purpose of this case study was to demonstrate how the simplicity of the BPA results can help the process of decision making. The USD $m^{-2}$ per year is a synthetic index well understandable by many. This specific experience pointed out how even a small intervention with local material can generate important savings. Thermal insulation with natural local material has proven to be a good solution to improve energy conservation even in countries where the energy cost are very low.

The additional suggestions of the BPA and the specific exploration of each components of the building are also potentially useful both for engineer designer and decision makers.

ACKNOWLEDGEMENTS. This work was supported by the Italian Agency for Development Cooperation (AICS) under the project Enhancement of the production and processing chain of water-buffalo milk in South Iraq, AID 011772/01/4.

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

## REFERENCES

Almusaed, A., Almssad, A., Homod, R.Z., Yitmen, I. 2020. Environmental Profile on Building Material Passports for Hot Climates. *Sustainability* **12**(9), 3720. doi.org/10.3390/su12093720

Almusaed, A. & Almssad, A. 2015. Building materials in eco-energy houses from Iraq and Iran. *Case Studies in Construction Materials* **2,** 42–54. doi.org/10.1016/J.CSCM.2015.02.001

Ascione, F., Bianco, N., Stasio, C., Mauro, G.M., Vanoli, G.P. 2015. A new methodology for cost-optimal analysis by means of the multi-objective optimization of building energy performance. *Energy and Buildings* **88**, 78-90. doi.org/10.1016/j.enbuild.2014.11.058

Asdrubali, F., Bianchi, F., Cotana, F., D'Alessandro, F., Pertosa, M., Pisello, A.L., Schiavoni, S. 2016. Experimental thermo-acoustic characterization of innovative common reed bio-based panels for building envelope. *Building and Environment*. **102**, 217–229. doi.org/10.1016/j.buildenv.2016.03.022.

Azhar, S., Carlton, W.A., Olsen, D. & Ahmad, I. 2011. Building information modeling for sustainable design and LEED® rating analysis. *Autom. Constr.* **20**(2), 217–224. doi.org/10.1016/j.autcon.2010.09.019

Barnes, S. & Castro-Lacouture, D. 2009. BIM-enabled integrated optimization tool for LEED decisions. In: *Proceedings of the 2009 ASCE International Workshop on Computing in Civil Engineering*. Austin, Texas, United States. doi.org/10.1061/41052(346)26

Becerik-Gerber, B., Jazizadeh, F., Li, N. & Calis, G. 2012. Application areas and data requirements for BIM-enabled facilities management. *J. Constr. Eng. Manag.* **138**, 431–442. doi.org/10.1061/(ASCE)CO.1943-7862.0000433

Bracht, M.K., Melo, A.P. & Lamberts, R. 2021. A metamodel for building information modeling-building energy modeling integration in early design stage. *Autom. Constr.* **121**, 103422. doi.org/10.1016/j.autcon.2020.103422

Echenagucia, T.M., Capozzoli, A., Cascone, Y. & Sassone, M. 2015. The early design stage of a building envelope: Multi-objective search through heating, cooling and lighting energy performance analysis. *Applied Energy* **154**, 577–591. doi.org/10.1016/j.apenergy.2015.04.090

Maia, L., Mêda, P. & Freitas, J.G. 2015. BIM Methodology, a New Approach - Case Study of Structural Elements Creation. *Procedia Engineering* **114**, 816–823. doi.org/10.1016/j.proeng.2015.08.032

Nicolle, C. & Cruz, C. 2011. Semantic Building Information Model and Multimedia for Facility Management. In: *Filipe J., Cordeiro J. (eds) Web Information Systems and Technologies. WEBIST 2010. Lecture Notes in Business Information Processing* **75**, Springer, Berlin, Heidelberg. doi.org/10.1007/978-3-642-22810-0_2

Pachauri, R.K., Allen, M.R., Barros, V.R., Broome, J., Cramer, W., Christ, R., Church, J.A., Clarke, L., Dahe, Q.D., Dasqupta, P., Dubash, N.K., Edenhofer, O., Elgizouli, I., Field, C.B., Forster, P., Friedlingstein, P., Fuglestvedt, J., Gomez-Echeverri, L., Hallegatte, S. & van Ypersele, J-P. 2014. *Climate change 2014 synthesis report. Contribution of working groups I, II, and III to the fifth assessment report of the Intergovernmental Panel on Climate Change.* IPCC, Geneva, Switzerland, pp. 151. ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

Patacas, J., Dawood, N. & Kassem, M. 2020. BIM for facilities management: A framework and a common data environment using open standards. *Autom. Constr.* **120**, 103366. doi.org/10.1016/j.autcon.2020.103366

van Eldik, M.A., Vahdatikhaki, F, Oliveira dos Santos, J.M,O., Visser, M. & Doree, A. 2020. BIM-based environmental impact assessment for infrastructure design projects. *Autom. Constr.* **120**, 103379. doi.org/10.1016/j.autcon.2020.103379

Volk, R., Stengel, J. & Schultmann, F. 2014. Building Information Modeling (BIM) for existing buildings - Literature review and future needs. *Autom. Constr.* **38**, 109–127. doi.org/10.1016/j.autcon.2013.10.023