BUILDING ENERGY EFFICIENCY. THE ECONOMIC CAMPUS OF THE UNIVERSITY OF BARI ALDO MORO

Amicarelli Vera[1], Bux Christian[2], Lagioia Giovanni[3], Gallucci Teodoro[4]
[1) 2) 3) 4)] *University of Bari Aldo Moro, Bari, Italy*
E-mail: vera.amicarelli@uniba.it; E-mail: christian.bux@uniba.it;
E-mail: giovanni.lagioia@uniba.it; E-mail: teodoro.gallucci@uniba.it

Abstract
The current worldwide energy consumption increase imposes several problems in terms of limited energy resources, supply difficulties and environmental impacts. The common challenge is to reduce energy consumption mitigating at the same time impacts on climate change. In this context, *Building Energy Efficiency* (BEE) attracts increasingly attention, as building sector consumes on average over than 35% of global energy. Thus, it is not a coincidence that European Union (EU) framework has been interested in this topic promoting different actions to support sustainability in building sector. These actions include the allocation of funds for restructuring and for energy efficiency operations, as well as rules and directives concerning the methods of energy certification and reduction in consumption of natural resources with the common aim of sustainability.
The aim of this paper is the study of Economic Campus (EC) of University of Bari Aldo Moro energy requalification presenting both economic (monetary cost reduction) and environmental (energy savings and greenhouse gases reduction) benefits. After having analyzed the role of building sector on global and European energy consumption and its contribution to climate change, an ex-ante analysis and ex-post prevision of the case study proposed will be presented.

Keywords
Building energy efficiency; energy consumption; photovoltaic system; sustainability

JEL Classification
P28; Q01

Introduction

The current worldwide energy consumption increase imposes several problems in terms of limited energy resources, supply difficulties and environmental impacts. The common challenge is to reduce energy consumption mitigating at the same time impacts on climate change. In this context, Building Energy Efficiency (BEE) attracts increasingly attention, as building sector consumes on average over than 35% of global energy (IEA, 2017). Thus, it is not a coincidence that the European Union (EU) framework has been interested in this topic promoting different actions to support sustainability in building sector.
Primary BEE has to be able to combine human expectation of indoor comfort and well-being with building features in terms of energy savings and related Greenhouse Gases (GHG) reduction. Since each person spends about 90% of his time inside residential, working or recreational buildings, Kilbert (2012) and Yudelson (2008) established that

energy efficient buildings shall have "*healthy facilities designed and built in resource-efficient manner, using ecologically based principles*" while the second defines it as a "*high-performance property that considers and reduces its impact on the environment and human health*".
To pursue BEE, EU promoted several interventions and issues including the allocation of funds for restructuring and improving energy performance as well as rules concerning audit and energy certification. Directive 2002/91/UE and Directive 2010/31/EU on buildings energy performance promoting "Zero Energy Buildings" (ZEB) and "Near Zero Energy Buildings" (NZEB) with an energy balance near or equal to zero are particular interesting. NZBE became an EU obligatory standard for new public buildings afterwards 2018 and for all buildings constructed afterwards 2020. In Italy, Legislative Decree 102/2014 has implemented BEE (GURU, 2014; OJEC, 2002; OJEU, 2010). Each normative contemplates energy efficiency for both existing and new buildings.
The aim of this paper is the study of the energy requalification of the Economic Campus (EC) of University of Bari Aldo Moro highlighting both economic (monetary cost reduction) and environmental (energy savings and GHG reduction) benefits. After having analyzed the role of building sector on global and European energy consumption and its contribution to climate change, an ex-ante analysis and ex-post prevision of the case study proposed will be presented.

Building sector energy consumption
Worldwide, building sector energy use is on average less than 2,800 million of tons of equivalent oil (Mtoe) of which less than 2,100 Mtoe (72%) are consumed in residential buildings and less than 7500 Mtoe (28%) in non-residential ones. The total energy utilized by building sector was approximately 35% of global energy use estimated to be more than 8,000 Mtoe (IEA, 2017). Table n. 1 shows global average energy consumption by end-use in both building categories considered and illustrates that while space heating represents the highest energy consumption (32%) in both cases, the other values show deep differences. Non-residential buildings include more complex and heterogeneous final-destination typologies (e.g. hospitals, wholesale and retail, educational, etc.) compared to residential ones. For this reason, variations in usage pattern, energy intensity and construction techniques make the quantification of end-use average values complex to measure.

Table no. 1 Global average Energy Consumption by End-Use

End-use	Residential (%)	Residential (Mtoe)	Non-Residential (%)	Non-Residential (Mtoe)
Appliances	9%	188	0,5%	4
Cooking	29%	606	0,5%	4
Space Heating	32%	669	32%	233
Water Heating	24%	500	12%	86
Lightning	4%	85	16%	116
Cooling	2%	42	7%	50
Other (IT equipment, etc)	0%	0	32%	232
TOTAL	100%	2090	100%	725

Source: Personal elaboration by the authors on data Lucon et al., 2014 and Thewes et al., 2014.

In the same period, approximately 9.5 Gt of CO_2 (19% of global CO_2 emissions) have been released by building sector of which 3 Gt are direct emissions and the rest are indirect (Lucon et al., 2014).
In Europe, it is esteemed that building stock is close to 24 billion m^2 utilizing more than 720 Mtoe. Almost 27% (475 Mtoe) of EU energy consumption (1764 Mtoe) is spent by residential buildings (18 billion m^2) while approximately 14% (247 Mtoe) by non-residential ones (6 billion m^2). The average building consumption ranges between 0.015-0.028 toe/m^2 per year, recording deep differences between EU countries. Finland presents the highest value (0,027 toe/m^2 per year) while Bulgaria or Spain the lowest one (0,012 toe/m^2 per year).
Even EU energy consumption by end-use shows space heating as the highest quota with 57%, followed by water heating (25%), cooking (7%), lighting and other applications (11%) (Crawley, 2007). The huge difference between global and European energy consumption by end-use supports EU policies towards BEE.
EU building sector generates on average less than 1,35 Gt CO_2 emissions representing approximately 35% of total EU CO_2 emissions (3,7 Gt) (The World Bank, 2018).
BEE is composed by two different parts, the first one is linked to construction and/or requalification works while the second one to building management. It is estimated that approximately 30% of EU building CO_2 emissions (0,4 Gt) depends on construction and construction works, while 70% on building management (Eurostat, 2018). This means that BEE can be reached “connecting” materials used for construction, performing furniture and fixtures to improve thermal and acoustic performance, efficient lighting (LED one) and energy costs.
However, BEE implementations require higher initial investments varying from 0.4 to 11%. Such a wide range depends on the achieved level of energy efficiency providing monetary savings that can be ten times higher than the investment (Kats, 2006 and 2010; Rehm, Ade, 2013; Deng, Wu, 2013).

Methodological approach

In order to reach the scope of the analysis several documents have been considered such as national and international references, reports, studies and statistics regarding the building energy efficiency. Related to the case study presented, in addition to legislative references and official documents, also personal communications with specific business staff were considered.
First step was reference literature analysis for a better understanding of BEE general definition, its implications and benefits deriving from its implementation. Next, after having analyzed legislative framework, the authors investigated technical-architectural, technical-electric and official paperwork regarding the case study. This study, first part of a larger one, offers ex-ante analysis and first year preliminary results related to Economics Campus BEE.

The case study of the Economic Campus

EC is a two main building facility built in 1980s, distinct and different in size with a total volume of more than 370,000 m^3 and a surface of less than 23,000 m^2. A third smaller building was not included in the BEE. The first building, with a volume approximately equal to 110,000 m^3 (30% of total building volume and 45% of total surface) has 3 floors and hosts faculty classrooms. The second one, with a volume approximately equal to 260,000 m^3 (less than 12,500 m^2), has 7 floors and includes professor offices, main library and student common areas.
Works timeline can be split into two phases: the first of financing and the second of construction began on February 23rd, 2017 and lasted for approximately 18 months.

The whole project, accounting 6 million €, has been financed by EU funding program and the Italian Interministerial Economic Planning Committee authorized it on February 20th, 2015. Figure no.1 shows the cost sharing.
Ex-ante energy BEE diagnosis showed a Global Energy Performance (EPgl value) equal to 59.463 kWh/m^3 with 15.931 kg CO_2/m^3 related annual emissions. According to EU energy consumption *labelling* scheme and based on EPgl above mentioned value, ECC "gained" the lowest rate of G Class.

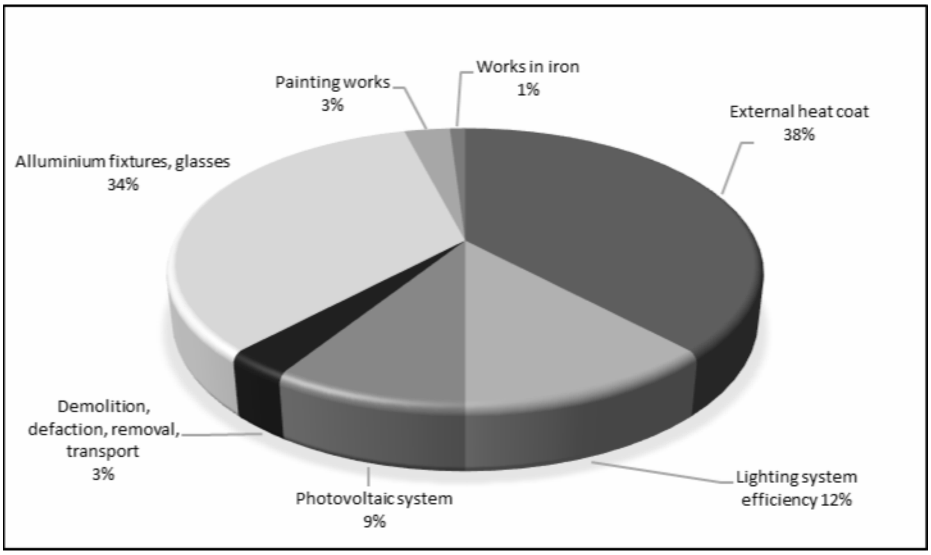

Fig. no. 1 Interventions cost sharing
Source: Personal elaboration by the authors based on official paperwork.

As previous studies stated, BEE can be achieved by two different kinds of approaches. The first one, defined as passive measurement, refers to optimization of architectural design and use of renewable energy resource, while the second one, defined as active measurement, requires innovative and much more efficient technologies in heating, cooling and lighting systems (Zhang et al, 2011). In EC specific case both measures have been integrated with regards to thermal energy utilized for heating systems and to electrical energy for cooling systems. BEE interventions regarded thermal envelope construction, electrical and lightning system improvement through LED bulbs substitution and photovoltaic plants installation in the car parking area. Ex-ante and ex-post details are summarized in table no. 2.

Results and discussion
Overall, there are five main benefit categories associated with BEE: lower operating costs, increased indoor comfort, health and productivity, increased social reputation, increased building market value and reduced environmental externalities (World Green Building Council, 2013; Yudelson, 2010; Zhang, 2015).
The case study gives evidence of part of them and some core improvements have been primarily observed:

1. Combination of architectural requirement and environmental protection
2. Savings energy monetary costs
3. Reduction in fossil fuel use and in GHG emissions.

Table no. 3 summarized these main results according to "Report del Bilancio Ambientale 2012-2018" [Report of Environmental Balance 2012-2018] of the University of Bari Aldo Moro. BEE implementations generate global energy savings of more than 2,000,000

kWh/year of which more than 70% due to thermal-coat and approximately 17% due to LED "relamping" avoiding more than 850 t of CO_2.
The amount of monetary savings at the end of the first year after BEE interventions is expected to be less than 150,000 € (Uniba, 2018).

Table no. 2 Building Status Before & After Requalification

Object	Before	After
Envelope	- Reinforced concrete with brick internal walls and plaster segments. - Insulation-free infill panels. - Situation of degradation and numerous walls materials detachments. - Considerable dispersing surface.	- Reduction of thermal transmittance. - Improvement of thermal performance through insulation of external curtain walls. - Roof slabs insulation with thermal-coat. - Excellent noise reduction.
	- Frames characterized by continuous glass windows with sliding belt.	- Replacement of global frames.
Electrical system	- Methane thermal power plants. - Single cooling and heating split-system.	- Centralized heating and cooling system and 120 single split-system removal.
Lightning	- Internal lightning system: linear fluorescent lamps. - External lightning system: street lightning poles and light towers.	- Internal and external lightning system: LED bulbs. - 2,170 news LED lamps: luminous efficiency 130-150 lm/W (compared to fluorescent lamps luminous efficiency of 70-80 lm/W). - 50,000 hours per lamp (five times higher than incandescent lamps useful life).
Photovoltaic system	- Not present.	- Solar car parks: non-integrated grid-connected photovoltaic plant. - Power: 97.500 kW/year - Production: 98.700 kWh/year - Installation of solar display system inside the building.

Source: Personal elaboration by the authors.

Conclusion

The analysis proposed demonstrates that EU building energy efficiency policy entails great utility and considerable benefits in terms of energy inputs and GHG reduction and monetary savings. Economic Campus example shows a total energy saving of over than 2,000,000 kWh/year corresponding to more than 170 toe/year of fossil fuel, more than 850 t of CO_2

avoided and monetary savings estimated in roughly 150,000 euros/year. Afterwards all these improvements and according to the "Report del Bilancio Ambientale 2012-2018", EC has been included among NZEB by the National agency for new technologies, energy and sustainable economic development (ENEA) responsible of the National Observatory of Italian NZEB.

Table no. 3 Economic & Environmental Benefits after Requalification

Intervention	Economic/material benefits	Environmental benefits
Thermal-coat	- Savings of more than 80,000 € due to thermal insulation. - Savings of more than 35,000 € (due to 111,800 m^3 of natural gas per year saved) per year.	- Reduction of energy lost in the heating of approximately 1,471,400 kWh/year causing the passage from class G (58.099 kWh/m^3 year) to class A+ (38,321 kWh/m^3 year)
Photovoltaic system	- Savings of more than 20 tep per year. - Income of approximately 6,000 € due to national grid kWh exchange.	- 48,955 CO_2 kg/year avoided.
LED lightning	- Savings of more than 10,000 € per year.	- Reduction in electrical energy consumption of approximately 170,800 kWh/year) with replacement of 2,170 LED lamps.
Single split-system removal	- Savings of approximately 21,000 € per year.	- Reduction in energy consumption of more than 350.000 kWh/year.

Source: Personal elaboration by the authors.

Moreover, EC moved from G class to A+ class (Uniba, 2018). The main general conclusion is related to BEE role in non-residential buildings since their average energy consumption is equal to 0.041 toe/m^2 compared to residential one equal to 0.026 toe/m^2. This deep difference demonstrates how BEE improvements, especially in non-residential buildings, contribute towards sustainability.

References

Crawley, B., D., 2007. *Estimating the impacts of climate change and urbanization on building performance*, Conference: Building Simulation 2007, Beijing, China, pp. 1115-1122.

Deng, Y. and Wu, J., 2013. Economic returns to residential green building investment: The developers' perspective. *Regional Science and Urban Economics, 47, pp.35-44.*

Eurostat, 2018. *Emissions of greenhouse gases and air pollutants from final use of CPA08 products – input-output analysis*, ESA 2010. [online] Available at: <http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_io10&lang=en> [Accessed 4 April 2019]

GURU, 2014. Decreto Legislativo 4 Luglio 2014, n.102, Attuazione della direttiva 2012/27/EU sull'efficienza energetica che modifica le direttive 2009/125/CE e

2010/30/UE e abroga le direttive 2004/8/CE e 2006/32/CE. *Gazzetta Ufficiale della Repubblica Italiana*, Serie Generale, 165. *Gazzetta Ufficiale della Repubblica Italiana*, Serie Generale, 165.

IEA, 2017., *Key World Energy Statistics*. France: IEA Publications, International Energy Agency.

Kats, G., 2006. *Greening America's Schools: Costs and Benefits*. Washington, DC: Capital E Report.

Kats, G., 2010. *Greening our built world: Costs, Benefits, and Strategies*. Washington, DC: Island Press.

Kibert, G.J., 2012. *Sustainable Construction: Green Building Design and Delibery*. New Jersey, USA: John Wiley & Sons Inc.

Lucon, O. et al., 2014. *Climate Change 2014*: *Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp.671-738.

OJEC, 2002. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. *Official Journal of European Union*, 46, pp.65-71.

OJEU, 2010. Directive 2010/31/EU of the European Parliament and the Council of 19 May 2010 on the energy performance of buildings. *Official Journal of the European Union*, 53, pp.13-35.

Rehm, M. and Ade, R., 2013. Construction costs comparison between "green" and conventional office buildings. *Building Research & Information*, 41(2), pp.198-208.

Uniba (Università degli Studi di Bari Aldo Moro), 2018. Report del Bilancio Ambientale 2012-2018. Università degli Studi di Bari Aldo Moro, Bari. [online] Bari: Università degli Studi di Bari Aldo Moro, Bari. Available at: <https://www.uniba.it/ateneo/programmazione-bilanci/bilancio-ambientale> [Accessed 2 April 2019]

Thewes et al., 2014. Field study on the energy consumption of school buildings in Luxembourg. *Energy and Buildings*, 68(A), pp.460-470.

The World Bank, 2018. *CO_2 emissions (kt)*. [online] Tennessee, United States: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory., Tennessee, United States [online]. Available at: <https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?locations=EU> [Accessed 2 April 2019]

Yudelson, J., 2008. The Green Building Revolution. *Journal of Real Estate Literature*, 16(2), pp.253-255.

Zhang, L., Wu, J. and Liu, H., 2017. Turning green into gold: A review on the economics of green buildings. *Journal of Cleaner Production*, 30, pp.1-12.