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## Article

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## ENERGY EFFICIENCY POLICIES IN NON-RESIDENTIAL BUILDINGS: THE CASE OF THE UNIVERSITY OF BARI ALDO MORO

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### Abstract

The increase in global energy consumption gives rise to several issues with regard to limited energy resources, supply difficulties and environmental impacts. The main concern is that this trend does not cease to curb its growth, while the common challenge is to reduce energy consumption, thus mitigating its impacts on climate change. In particular, Building Energy Efficiency requires particular attention, as the building sector is responsible for approximately 35% of global energy consumption. Thus, European Union policies have been interested in this field, promoting diverse actions in order to pursue and achieve sustainability across the building sector, such as the allocation of funds for restructuring and for energy refurbishment, as well as regulations and directives concerning energy certification and reduction in the consumption of natural resources. This paper has two main objectives. First, to analyze the role of the building sector at a global and European level and its contribution to climate change, highlighting the main differences between residential and non-residential buildings. Second, to present an ex-ante analysis and an ex-post preliminary results obtained from the energy requalification program applied to an Italian public non-residential building: the Economy Campus of the University of Bari Aldo Moro, with regard to economic (monetary cost reduction) and environmental (energy benefits and greenhouse-gases reduction) savings.

**Keywords:** building energy efficiency; energy policy; energy indexes; sustainability

**JEL Classification:** P28, Q01

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**Introduction**

The increase in global energy consumption gives rise to several issues with regard to limited energy resources, supply difficulties and environmental impacts, while the main concern is that this trend does not stop. Comparing key energy indicators (table no.1), the gravity of this problem appears immediately clear despite the different actions, measures, regulations and agreements existing and/or proposed across national and international energy and environmental policies. Primary energy, electrical energy consumption and CO<sub>2</sub> emissions continue to grow at a rate higher than population increase and consequentially their associated per capita values. At the same time, Gross Domestic Product (GDP) growth is higher than population one, resulting in a considerable increase in per capita personal income with a direct increase of goods and service demand. More than forty years after the first global energy crisis, current global energy and socio-economic systems seem to be still unsustainable.

**Table no.1: Global energy key indicators and their variation ratios in 1973, 1993, 2003, 2013 and 2016**

Index	Years					Ratio (%)		
	1973	1993	2003	2013	2016	1973 - 1993	1993 - 2013	1973- 2013
Population (millions)	3,938	5,540	6,349	7,173	7,429	40.6	29.4	82.1
GDP (billion 2010 USD)	22,506	39,743	53,567	71,519	77,362	76.5	79.9	217.7
Energy production (Mtoe)	6,034	8,912	10,688	13,486	13,764	47.7	51.3	123.5
Total Primary Energy Supply (Mtoe)	4,606	8,928	10,708	13,445	13,761	93.8	50.5	191.9
Per capita Primary Energy Supply (toe/capita)	1.5	1.1	1.6	1.8	1.8	5.2	16.7	22.8
Electricity consumption (TWh)	6,105	11,517	15,400	21,582	23,107	88.6	87.3	253.5
Per capita electricity consumption (MWh/capita)	1.5	2.0	2.4	3.0	3.1	34.1	44.7	94.1
CO <sub>2</sub> emissions (Mt of CO <sub>2</sub> )	15,673	20,696	24,933	32,288	32,316	32.0	56.0	106.0
Per capita CO <sub>2</sub> (t CO <sub>2</sub> /capita)	3.9	3.7	3.9	4.4	4.3	-6.2	20.1	12.5

*Source: IEA, 2018; 2019*

The common challenge is to reduce this unsustainability in terms of energy consumption, at the same time mitigating economic and environmental consequences, especially on climate change. For this reason, Building Energy Efficiency (BEE) requires particular attention, as the building sector is responsible for approximately 35% of global energy consumption (IEA, 2017). Moreover, building stock is widely composed by poor energy performance buildings. Thus, it is not a coincidence that European Union (EU) policies have been widely concerned with this field, promoting different actions in order to pursue and achieve sustainability across the building sector (e.g. allocation of funds for restructuring and energy refurbishment, energy certification, reduction of natural resources).

Firstly, the BEE primary aim has to combine human physiological and safety needs in terms of indoor and outdoor comfort with building features towards energy savings and

related greenhouse-gases (GHG) reduction. Moreover, since each human being spends more than 90% of its life within domestic, commercial or recreational buildings, Kibert (2012) and Yudelson (2008) stated that an energy efficient building should have “*healthy facilities designed and built in resource-efficient manner, using ecologically based principles*” and should be a “*high-performance property that considers and reduces its impact on the environment and human health*”. For this reason, the EU has been concerned with BEE, promoting several interventions such as the allocation of funds for building renovation and energy refurbishment, as well as regulations and directives regarding audit and energy certifications. In the first place, the EU has introduced Directive 2002/91/UE and Directive 2010/31/EU on buildings energy performance, promoting “Zero Energy Buildings” (ZEB) and “Near Zero Energy Buildings” (NZEB), requiring the mandatory construction of new buildings with an energy balance near or equal to zero. More precisely, NZBE became an EU mandatory standard for new public buildings starting from 2019 and for all new buildings starting from 2021. Furthermore, the Italian Legislative Decree 102/2014 has implemented BEE both for existing and new buildings at a national level. The last legislative intervention has been Directive 2018/844/EU, amending part of Directive 2010/31/EU and introducing new elements such as the support of initiatives called “energy performance of buildings standards” (EPB standards) (OJEC, 2002; OJEU, 2010b GURU, 2014; OJEU, 2018).

According to EU policies, most interventions aim at improving buildings energy performance and impose several conditions, such as “*cost-effective deep renovations, which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by significant percentage compared with the pre-renovation levels*”. For this reason, the EU requires energy efficiency measures encouraging energy refurbishment and primary energy (PE) reduction, defining PE as total energy demand in terms of natural resources used to energy final use production. More in detail, PE is considered as a current indicator for BEE (OJEU, 2012; Ballarini et al, 2017; Lidberg, 2018).

This paper has two main objectives. First, to analyze the role of the building sector at a global and European level, as well as its contribution to climate change, thus highlighting the main differences between residential and non-residential buildings. Second, to present an ex-ante analysis and ex-post forecast of results obtained from the energy requalification program applied to an Italian public non-residential building: the Economy Campus (EC) of the University of Bari Aldo Moro, with regard to economic (monetary cost reduction) and environmental (energy benefits and greenhouse-gases reduction) savings.

## 1. Review of the scientific literature

### 1.1. Residential and Non-Residential building sector

Building energy efficiency represents a serious problem in terms of limited energy resources, supply difficulties and environmental impacts. Thus, as a preliminary step in such analysis, it is important to set some definitions.

There is a wide difference between residential and non-residential buildings in terms of global energy consumption and energy consumption by end-use. According to the European Commission (2013), residential buildings are “*characterized as multi-family apartment houses or individual houses which are primarily used for housing and can be owner-occupied from the private rented sector or social housing*” while non-residential

ones “are based on their use by public services and include schools, hospitals and administrative offices”. Moreover, OECD (2001) states that in non-residential buildings, the lesser part of them could be used for dwelling purposes, covering different sectors such as industrial, commercial, educational, health, and others. One more similar definition is given by Eurostat (2018c), stating that non-residential buildings are other than dwellings and include fixtures, facilities and equipment, which are integral parts of the structures and include the costs of site clearance and preparation (D’Agostino, Cuniberti, Bertoldi, 2017). However, the non-residential building heterogeneity does not give the chance to attain an agreed definition. Non-residential buildings account for an average of 25% in terms of energy consumption of total EU building stock, and can be split into the following categories: wholesale and retail (28%), offices (23%), educational (17%), hotels and restaurants (11%), hospitals (7%), sport facilities (4%), other (11%). Moreover, non-residential consumption related to lighting, ventilation, heating, cooling, IT equipment and appliances vary from one category to another (Bertoldi and Quevy, 2012; Belussi et al., 2019). Over the last decade (2000 – 2008), energy consumption has increased by 2.5% per year and still continues to grow at a 1.1% rate per year. According to energy consumption by end-use, across the same period the electricity consumption has increased in average of more than 70%, due to the growing number of new technological appliances, such as IT devices, new telecommunication and air conditioning systems (Gynther et al., 2015; Bertoldi et al., 2018; Zancanella, Bertoldi and Boza-Kiss, 2018).

## 1.2. Building sector energy consumption

Worldwide energy consumption is estimated to be approximately 8,000 million of tons of equivalent oil (Mtoe), of which more than 35% is attributed to the building sector (on average, more than 2,800 Mtoe) in 2017. In particular, less than 2,100 Mtoe are consumed in residential buildings (72%) and more than 700 Mtoe in non-residential ones (28%) (IEA, 2017). Table no. 2 gives evidence of this phenomenon showing an average energy consumption by end-use within both building categories, recording one common highest value in space heating (32%) and wide differences when considering other end-uses. Moreover, taking into consideration non-residential buildings, it is important to underline that such category includes more complex and heterogeneous final-destination buildings such as hospitals, commercial and retail, or educational ones. Thus, energy consumption measurement becomes a complex task since energy intensity, construction techniques and usage patterns vary from one to another (IEA, 2017; Mengxue and Lai, 2019).

In terms of environmental consequences, worldwide data records more than 9.5 Gt of CO<sub>2</sub> released in the atmosphere deriving from the building sector in 2017 (approximately 20% of global CO<sub>2</sub> emissions). In particular, less than 3 Gt of CO<sub>2</sub> are direct emissions, while 6.5 Gt are indirect (Edenhofer et al., 2014).

In detail, Table no. 3 shows the final energy consumption percentage by end-use in the U.S., EU and China in residential and non-residential buildings. The case of China is significant, considering that this country, from 1990 to 2010, has roughly doubled its energy consumption (IEA, 2019).

Table no. 2: Global average energy consumption by end-use

Residential (%)	Residential (Mtoe)	End-use	Non-Residential	Non-Residential
			(%)	(Mtoe)
9	188	Appliances	0.5	4
29	606	Cooking	0.5	4
32	669	Space Heating	32	233
24	500	Water Heating	12	86
4	85	Lighting	16	116
2	42	Cooling	7	50
0	0	Other (IT equipment, etc.)	32	232
100	2090	TOTAL	100	725

Source: Authors' elaboration, based on Edenhofer et al., 2014; Thewes et al., 2014; Amicarelli, Bux, Lagioia and Gallucci, 2019

Table no. 3: Energy consumption by end-use in the U.S., EU and China

Residential	U.S. (%)	EU (%)	China (%)
Space Heating	37	66	31
Water Heating	25	14	40
Space Cooling	19	3	3
Lighting	8	3	2
Cooking	7	5	16
Appliances and others	4	9	8
Non-Residential	U.S. (%)	EU (%)	China (%)
Space Heating	27	39	47
Water Heating	8	13	21
Space Cooling	8	6	6
Lighting	12	8	13
Cooking	0	0	0
Appliances and others	45	34	13

Source: Authors' elaboration based on Gynther, Lapillonne and Pollier, 2015; Odysse Database, 2019

According to EU data (IEA, 2017; 2018; 2019), is it estimated that the building stock is composed by over 24 billion of m<sup>2</sup> with a global energy consumption of approximately 720 Mtoe, divided between residential buildings (18 billion of m<sup>2</sup>) and non-residential ones (6 billion of m<sup>2</sup>). In detail, approximately 475 Mtoe (27%) of EU energy consumption (1764 Mtoe) is attributed to residential buildings, while less than 247 Mtoe (14%) to non-residential ones. Moreover, the EU average building consumption ranges between 0.015-0.028 toe/m<sup>2</sup> per year, with wide differences between EU Member States (EUMS). The

highest value is in Finland (0.027 toe/m<sup>2</sup> per year) while the lowest ones are in Bulgaria and Spain (0.012 toe/m<sup>2</sup> per year).

For instance, according to EU energy consumption by end-use, table no. 3 shows space heating as the highest quota both in residential and non-residential buildings (66% and 39%). However, in non-residential ones the second highest energy consumption by end-use regards appliances and other uses (34%), while in residential buildings it regards water heating (14%) (Crawley, 2007; Cao, Xilei and Liu, 2016). If compared to global and EU consumption by end-use, the wide difference between them supports the implementation of EU policies towards BEE.

Moreover, the EU building sector registers on average more than 1.35 Gt of CO<sub>2</sub> emissions, which represents approximately 35% of total EU CO<sub>2</sub> emissions (3,7 Gt) (The World Bank, 2018). In particular, these emissions are linked to two different phenomena: the first one is referred to construction and/or requalification works, while the second one to building management. It is estimated that less than 30% of EU buildings CO<sub>2</sub> emissions (0,4 Gt) are attributed to construction and construction works, while more than 70% on buildings management (Eurostat, 2018a, 2018b).

This data demonstrates that BEE can be pursued choosing efficient construction materials, as well as high-performance furniture and fixtures, so as to enhance thermal and acoustic performance and innovative lighting (LEDs). However, such refurbishment operations require expensive initial investments which vary from 0.4 to 11% of global requalification costs. This wide range depends on the desired level of energy efficiency and provides monetary savings which can be ten times higher than the initial investment (Kats, 2006, 2010; Rehm and Ade, 2013; Deng and Wu, 2013).

### **1.3. EU building energy consumption trends**

The EU building sector accounts on average for more than 35% of total energy consumption, and for approximately 55% of electricity. According to IEA data (2017, 2018, 2019), this is the largest energy consumption sector, followed by transport (32%), industry (26%) and agriculture (2%). Moreover, even if two-thirds of buildings are generally residential, while only one-third is non-residential, some EUMS (e.g. Italy or Portugal) record non-residential buildings consuming more than half of the total building energy consumption (Gynther et al., 2015; Belussi et al., 2019).

According to the Odysse database (2019), the EU energy consumption shows some trends. First, electricity intensity and energy consumption have increased due to new small electrical technologies use. Moreover, even if non-residential buildings energy consumption has increased until 2008, nowadays showing a decreasing trend due to economic turndown (on average 1.5% per year), electricity consumption continued to grow at a rate of 1.1% per year. However, dwelling energy consumption for lighting has decreased in half of EUMS thanks to LED bulbs development. For this reason, higher energy consumption is counterbalanced by energy efficiency improvements which accounted energy savings for more than 60 Mtoe in 2012 (Bertoldi et al., 2018; Gynther et al., 2015).

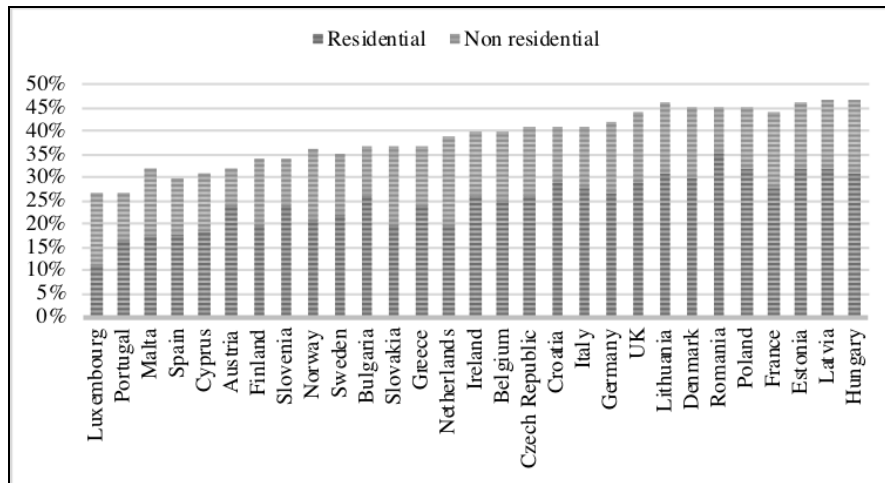
Figure no. 1 shows EU buildings in final energy consumption, referred to 2012. Building energy use in final energy consumption records the highest quota in Hungary, followed by

Latvia and Estonia. For instance, Italy is approximately in the middle, with more than 40% of final energy use, divided between more than 25% in residential buildings and less than 15% in non-residential ones.

In particular, the EU building energy consumption per capita is around 0.9 toe.

As stated before, EU building stock is around 24 billion m<sup>2</sup>. Three-quarters of them are residential buildings (18 billion m<sup>2</sup>) while one-quarter are non-residential ones (6 billion m<sup>2</sup>). In detail, two-thirds of residential stock are composed by single-family houses (12 billion m<sup>2</sup>), while one-third by flats (6 billion m<sup>2</sup>).

On average, EU buildings energy consumption is approximately 210 kWh/m<sup>2</sup>, ranging from approximately 280 kWh/m<sup>2</sup> in non-residential buildings to less than 190 kWh/m<sup>2</sup> in residential ones.



**Figure no.1: EU buildings in final energy consumption**

Source: Personal elaboration by authors on Gynther et al., 2015 and Odyssee Database 2019

## 2. Building Energy Efficiency in European policies

Since the building sector accounts for approximately 40% of EU final energy consumption and is responsible for more than 30% of EU CO<sub>2</sub> emissions, energy efficiency investments in buildings have been provided by national, sub-national and EU sources with the addition of some supra-national institutions (European Commission, 2013). In the 2007-2013 period, more than 120 national public funds have been identified in EU with a total allocation of 6.1 billion euros in 2013. In particular, the Czech Republic and Italy with an amount of 1.1 billion euros and Poland (578 million euros) accounted for the highest amount of EU funds. Moreover, the total commitments for projects investments for buildings energy efficiency is 6 billion euros, with approximately 840 million euros in Greece, 830 million euros in Italy and 710 million euros in the Czech Republic. Statistics show that 14 EUMS had a rate of project below 100%, 13 EUMS at or above 100% and only Greece, Latvia, Austria and Luxembourg of about 200% (Bertoldi et al., 2018).



In terms of public interventions for BEE, all of them targeted a wide range of buildings, including non-residential (public and commercial) and residential ones, as well as existing and new constructed buildings.

Two-thirds of said support schemes targeted residential buildings and regarded as instance obsolete blocks of flats, single or double dwelling family houses, social housing units and newly built residential houses. One-third of investments supported non-residential building in only 17 EUMS and some of these financing supported only specific types of public buildings (e.g. education institutions in Germany, Italy and Greece) (Bertoldi et al., 2018).

According to energy efficiency interventions typology, the most common measures included insulation of roofs, walls and basements, renovation and installation of doors and windows, installation of ventilation systems and modernization of the heating ones. Some measures were applied to electrical appliances replacements and lighting systems improvement.

As stated by literature and policy papers, the main rationales of public support to BEE improvements can be divided in primary and secondary benefits (or co-benefits) showed in table no. 4 (IEA, 2014).

In particular, three primary benefits have been identified: cost savings, climate change mitigation and energy security. Moreover, several co-benefits can be considered: collective economic benefits (e.g. GDP increase), private economic benefits (e.g. public authority budget cost savings), environmental benefits (e.g. air quality improvements, reduced particulate emissions, health benefits according to more appropriate heating plans, increased comfort).

In order to better understand the reason why several BEE policies included non-residential buildings, it is important to underline that a wide range of new technologies are becoming an integral part of buildings, demanding a huge amount of energy. For this reason, EU policies towards non-residential building have increased over the last years.

**Table no. 4: Primary benefits and co-benefits**

	<b>Primary Benefits</b>	<b>Co-benefits</b>
Economic	Less energy expenditure. More efficient resource allocation. Energy security (e.g. reduced vulnerability to price shocks and supply constraints, reduced energy imports and improved trade balance)	Exemplary role for public building investments.
Social	Not present.	Employment. Reduced fuel poverty. Increased benefits from improved heating. Health benefits from improved air quality.
Environmental	Climate change mitigation. Reduction of CO <sub>2</sub> emissions.	Improved air quality.

*Source: Authors' elaboration based on IEA, 2014*

### 2.1. Legislative framework towards Building Energy Efficiency

Historically, the first step towards BEE has been made through Directive 2002/91/EC (*Energy Performance of Buildings Directive*), distinguishing between existing building stock and new buildings. This Directive required energy use reduction in heating, cooling, ventilation, hot water and lighting, allowing EUMS to state minimum requirements in order to reach highest energy performance levels. Thus, EUMS introduced and implemented voluntary energy certification systems commonly based on energy performances (e.g. LEED, Leadership in Energy and Environmental Design; BREEAM, Building Research Establishment Environmental Assessment Method) or life cycle approach (e.g. EPD - Environmental Product Declaration - buildings) (Di Tivoli, 2008; OJEC, 2002; JRC, 2019). Subsequently, Directive 2010/31/EU introduced a homogeneous and harmonized calculation methodology to better allow EUMS to attain minimum energy performance requirements, later replaced by Directive 2018/844/EU (OJEU, 2010b; OJEU, 2018; JRC, 2019).

In the meantime, several Directives related to a heterogeneous range of possible solutions on BEE themes have been released by the EU. In particular, Directive 2006/32/EC (Energy Services Directive) established strong requirements and strategies for existing buildings, such as the renovation of 3% of the total floor area inside all government-owned public buildings per year, or the reduction in energy consumption among customers by 1.5% of final energy consumption per year (OJEU, 2006; JRC, 2019). Such Directive was replaced by Directive 2012/27/EU (Energy Efficiency Directive), which promoted the energy services market, new model contracts and the exchange of best practices and guidelines especially for non-residential buildings in the public sector.

Moreover, other Directives such as Directive 2009/125/EC and Directive 2010/10/30 introduced mandatory minimum energy efficiency requirements. For instance, Directive 2009/125/EC introduced particular eco-design requirements for energy-related products in order to maximize their performance during their entire life-cycle, while Directive 2010/10/30 introduced energy labelling requirements for industrial and consumer choices. (OJEU, 2009; OJEU, 2010a; JRC, 2019).

## 3. Research methodology

### 3.1. Methodological approach

The present analysis has been conducted across several documents, such as national and international references, reports, scientific studies and data focused both on BEE and buildings energy consumption themes. All examined databases are related to energy efficiency and consumption at either national or international level, in both residential and non-residential buildings. In particular, the presented case study analysis is based on a specific review of national and EU legislative framework, as well as official documents, personal communications with business-specific professionals and institutional paperwork.

First, the authors investigated reference literature in order to better understand and manage BEE general definitions, its positive and negative consequences, as well as economic and environmental benefits related to its implementation. Subsequently, after having reviewed related energy policies, technical-architectural, technical-electric and official paperwork, the authors have conducted the case study.

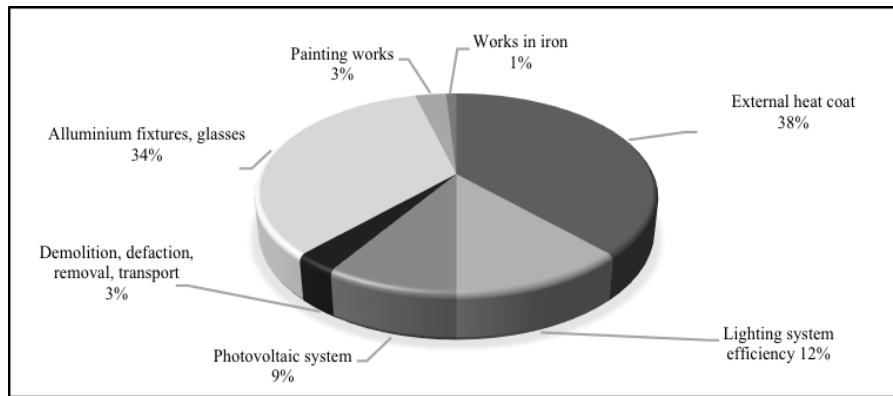
Thus, this case study offers ex-ante analysis and ex-post preliminary results related to the energy requalification of the EC of the University of Bari Aldo Moro.

**3.2. The case study of the EC of the University of Bari**

The EC is an Italian public non-residential building dating back to 1980s, divided into two main heterogeneous areas, different in size, with a total volume of more than 370,000 m<sup>3</sup> and a surface of less than 23,000 m<sup>2</sup>. A third smaller building was not included in the BEE. The first building, which has a volume of approximately 110,000 m<sup>3</sup> (30% of total building volume and 45% of total surface), has 3 floors and hosts faculty classrooms. The second one, with a volume of more than 260,000 m<sup>3</sup> (approximately 12,500 m<sup>2</sup>), has 7 floors and includes professor offices, the main library and student common areas.

According to the official time schedule, works execution has been split into two main phases: the first one regards financing, while the second one entails the actual construction, requalification and refurbishment works, which began on February 23<sup>rd</sup>, 2017 and lasted for more than 18 months. The project cost of 6 million euro has been financed by EU funding program and the Italian Inter-ministerial Committee for Economic Planning (CIPE) on February 20<sup>th</sup>, 2015.

In detail, Figure no. 2 shows the cost apportionment of interventions.



**Figure no. 2: Interventions cost sharing**

*Source: Amicarelli et al., 2019*

An ex-ante energy diagnosis yielded a Global Energy Performance (EPgl value) equal to approximately 59 kWh/m<sup>3</sup> with less than 16 kg of CO<sub>2</sub>/m<sup>3</sup> related annual emissions. According to the EU energy consumption labelling scheme and based on EPgl value, EC presented the lowest rate of G label.

As stated by previous studies, BEE can be achieved with two different kinds of approaches. The first one, defined as passive measurement, refers to optimization of architectural design and the use of renewable energy resources, while the second one, defined as active measurement, requires innovative and much more efficient technologies across heating, cooling and lighting systems (Zhang et al, 2011). Moreover, several studies tried to group all BEE intervention typologies. Thus, BEE technologies should be divided into three

categories: supply side management, demand side management and change of energy consumption pattern (Ballarini et al, 2017). These measures, related to the market side and the consumer side, underline the fundamental role that each person plays in BEE processes, being either institution or consumer, as instance recurring to renewable energy sources, improving energy technologies and changing personal behavior towards environmental and economic sustainability.

In particular, regarding EC energy requalification, both passive and active measures have been integrated in terms of thermal energy refurbishment for heating systems and electrical energy renovation for cooling ones. Moreover, BEE interventions included thermal coat construction, electrical and lighting system improvement (LED bulbs replacement) and photovoltaic plants installation within the car parking area.

Ex-ante and ex-post details are summarized in table no. 5.

**Table no. 5: Building Status Before & After Requalification**

Renovations	Before	After
Thermal Coat	Reinforced concrete with brick internal walls and plaster segments. Insulation-free infill panels. Numerous walls materials detachments with degradation of walls and considerable dispersing surface.	Reduction of thermal transmittance and improvement of thermal performance through the 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 all frames.
Thermal plant	Single cooling and heating split-system with methane thermal power plants.	Centralized heating and cooling system with 120 single split-system removals.
Lighting	Indoor lighting system with linear fluorescent lamps. Outdoor lighting system with street lighting poles and light towers.	Indoor and outdoor lighting system substitution with 2,170 LED bulbs (luminous efficiency of 130-150 lm/W and 50,000 hours of useful life each).
Photovoltaic plant	Not present.	Non-integrated grid-connected photovoltaic plant realized in car parking areas with solar display system inside the building. Power: 97,500 kW/year. Production: 98,700 kWh/year

*Source: Amicarelli et al., 2019*

#### 4. Results and discussion

Overall, five main benefit categories are associated to 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).

In detail, some core improvements have been primarily observed in the present case study such as:

- Combination of architectural requirements and environmental protection
- Monetary cost savings related to energy consumption reduction
- Fossil fuel use and GHG emissions reduction

Table no. 6 summarizes the main results related to “Report del Bilancio Ambientale 2012-2018” (Uricchio et al., 2018) of the University of Bari Aldo Moro. All BEE implementations generated global energy savings of approximately 2,000,000 kWh/year, of which more than 70% are attributed to thermal-coat and approximately 17% to LED “relamping”. Subsequently, more than 850 t of CO<sub>2</sub> emissions have been cut.

The amount of monetary savings at the end of the first year after BEE interventions is expected to be less than 150,000 € (Uricchio et al., 2018).

**Table no. 6: Economic & Environmental Benefits after Requalification**

Renovations	Economic/material benefits	Environmental benefits
Thermal-coat	Savings of approximately 80,000 € due to thermal insulation and savings of more than 35,000 € (due to 111,800 m <sup>3</sup> of saved natural gas per year) each year.	Reduction of energy loss in heating of more than 1,471,400 kWh/year. Improvement from G (approximately 59 kWh/m <sup>3</sup> year) to A+ label (roughly 38 kWh/m <sup>3</sup> year)
Photovoltaic plant	Savings of roughly 20 tep per year and income of more than 6,000 € due to national grid kWh exchange.	Cut of roughly 49,000 CO <sub>2</sub> kg/year.
LED lighting	Savings of approximately 10,000 € each year.	Replacement of 2,170 LED lamps with reduction in electrical energy consumption of more than 170,800 kWh/year.
Single split-system removal	Savings of more than 21,000 € per year.	Reduction in energy consumption of more than 350,000 kWh/year.

*Source: Authors' elaboration based on Uricchio et al., 2018*

As stated by table no. 6, column 2 (economic/material results) highlights BEE key-points. As the amount of yearly monetary savings is approximately less than 150,000 €, the highest savings percentage is attributed to thermal insulation (more than 50%), followed by natural gas savings (approximately 25%), heating and cooling systems benefits (about 15%), LED lighting savings (more than 6%) and photovoltaic plant benefits (approximately 4%).

### Conclusion

The present case study has exposed, through the EC example, how directives on building energy performances have boosted monetary cost reduction and environmental efficiency in non-residential buildings. Main results showed and explained the strategic role of BEE, mainly in non-residential buildings, starting from their calculated average energy

consumption as equal to 0.041 toe/m<sup>2</sup>, and compared to residential one as equal to 0.026 toe/m<sup>2</sup>. With regard to the EC of the University of Bari Aldo Moro, at the end of the first year after “energy requalification”, ENEA (the Italian National Agency for New Technologies, Energy and Sustainable Economic Development) in charge of the National Observatory of Italian NZEB, has included the EC among Near Zero Energy Buildings, moving from G to A+ label (Uricchio et al., 2018). This means that more than 170 toe/year of fossil fuel and roughly 150,000 euros/year are saved, and 850 t of CO<sub>2</sub> emissions are cut. BEE should be considered as a crucial step towards sustainability, even if it is a complex, long and expensive goal to achieve mostly in existing buildings rather than in new ones. Moreover, the implementation of energy certifications such as LEED, and the use of environmental III type certifications such as EPD based on life cycle approach, represent useful tools to achieve BEE.

In conclusion, to make this sector even more sustainable, greater attention should be paid to the following key solutions: a) the choice of eco-sustainable building materials, b) the increase of renewable energy sources, and c) funding or public policy subsidies.

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