OUTPUT 3.1

REQUIREMENTS FOR INTEROPERABLE MODELS, NOMENCLATURE AND SCHEMES TO BE USED FOR THE PILOT ACTIONS

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SUMMARY

A3.1.1 STATE OF THE ART ANALYSIS ON HBIM AND INTEROPERABILITY

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Abstract

The output provides an overview of the adoption of Heritage Building Information Modelling (HBIM) for the energy and environmental improvement of historical buildings. After a general state of the art on sustainable conservation of built heritage with the use of HBIM and building performance simulation, each partner presented the current situation in its country, focusing on the most interesting methods, legislation and case studies. Thus, the output helped establish a common framework among the partners to set up and harmonize the project workflow depending on local specificities.

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Summary

1. BIM AND HBIM PROCESSES FOR ENERGY IMPROVEMENT OF EXISTING AND HISTORICAL BUILDINGS (EE-HBIM)

Sustainable development is a basic principle of social action, introduced by the Brundtland report to the United Nations General Assembly in 1987 (WCED 1987) which divided it into the three dimensions (economic, environmental and social) and focused on the balance between them, in order to pass on a liveable world to the future generations. The current approach chosen by the UN to pursue sustainable development is to break down the vision of the Brundtland report into a series of specific measurable and achievable objectives (Allen, Metternicht, and Wiedmann 2016; UN 2015b). It is interesting to note that cultural heritage is important for several of the 17 objectives (Laine et al. 2019d), to the point that the cultural dimension can be considered the fourth dimension of sustainable development (Laine et al. 2019d) and it is increasingly recognised as a fundamental driver for achieving its objectives (AA. VV. 2013b; H2020 Expert Group on Cultural Heritage 2015; Laine et al. 2019d).

2. SUSTAINABLE CONSERVATION OF THE BUILT HERITAGE

2.1. Energy Efficiency of existing buildings

The construction sector plays a decisive role in the challenge for sustainable development: in Europe and the US, it is responsible for a final energy consumption of around 40%, which drops below 20% in China and is slightly above 30% as the world average (Belussi et al. 2019). The low cost of energy, together with the development of modern air conditioning systems for indoor spaces, has led in the last century to the overshadowing of investments in the energy efficiency of buildings. The situation began to change with the oil crisis of 1973 and the rise in energy prices after 2000, which made the investment in energy efficiency more convenient and demonstrated how the strong dependence on imports of fossil sources from external countries could pose a threat to a country's political independence and prosperity (Troi, Zeno, and Wedebrunn 2015). In parallel, awareness has also grown on the devastating risks associated with human-caused climate change (IPCC 2014), which triggered a series of international actions that started with the Earth Summit in Rio de Janeiro in 1992, continued with the Kyoto protocol of 1997 and reached the Paris agreement of 2015. Sustainability has thus become a central pillar in contemporary life (Laine et al. 2019d) from which derives the key role of energy efficiency in the 2030 Agenda for Sustainable Development (UN 2015b), and its sub-theme related to improvement of the energy performance of buildings which is now a central aspect in energy policies around the world.

To reduce the energy consumption of buildings and their environmental impacts, various international institutions and governments have introduced specific regulations. The European Commission has recently published the third Energy Performance Building Directive (*Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency (Text with EEA Relevance)* 2018) after Directive 2002/91/EC and 2010/31/EU, which adds up to Directive 2012/27/EU amended by the Directive (EU 2018). The directives introduce a series of policies for improving the energy performance of buildings, from long-term strategies, to the promotion of smart technologies, to sustainable mobility, to the introduction of energy performance requirements, to comfort, to energy performance certificates, to the concept of Nearly Zero Energy Buildings and to financial measures to support the improvement of the energy efficiency of buildings. The Commission recommendations (AA. VV. 2019b) on building renovation then confirmed the objectives of reducing greenhouse gas emissions by 40% by 2030, an increase in the share of renewable energy in the energy mix and attention to energy efficiency. The recommendations focus on three fundamental aspects, that of long-term strategies, financial incentives and the calculation of the energy performance of buildings (AA. VV. 2019c). Moreover, the Clean energy for all Europeans package presented in March 2019 introduced legislative certainty to facilitate public and private investments in the transition to clean energy (EC 2019a). In December 2019, the President of the European Commission Ursula Von der Leyen proposed a European Green Deal (EC 2019) to be implemented within 100 days from taking office, which foresees 47 actions to be implemented between 2020 and 2021 to achieve the Union's carbon neutrality goal by 2050 and the investment plan for a sustainable Europe which envisages the mobilization of a trillion of investments over the course of 10 years combining public and private investments (von der Leyen 2019).

Energy Retrofit of existing building

The energy retrofit of a building refers to the actions necessary to increase its energy and environmental performance. The problem of the energy retrofit of a building consists in applying the most profitable set of technologies to obtain an improved energy performance while maintaining satisfactory levels of service and internal thermal comfort under a given set of operating constraints (Ma et al. 2012). The heterogeneity of the existing building stock, the continuous evolution of technologies and markets and the variability of the actors are responsible of the complexities linked to the decision-making process concerning energy retrofits (De Boeck et al. 2015; Murto et al. 2019). Despite the numerous actions taken at the public level, the energy retrofit rate is still lower than expected (Friege and Chappin 2014), to the point that to achieve the 2050 objectives it should be doubled if not tripled (BPIE 2019).

Energy improvement of the built heritage

Although Europe is one of the "early mover" markets for energy retrofit of buildings, the built heritage is still substantially exempt from the Energy Building Performance Directives because of the difficulties in finding energy efficiency solutions compatible with historical and architectural values. As stated in the EBPD (EP 2010), "*Buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance*" may in fact be excluded from attaining energy performance requirements. Moreover, historical buildings are usually protected both by national regulation and international conventions, which introduces additional levels of protection that hinder energy retrofit interventions. Historic buildings are neither the largest portion of buildings (Economidou et al. 2011) in the European building stock nor the most energy-intensive (Martínez-Molina et al. 2016; Historic England 2018; Pretelli and Fabbri 2016), and at first the fear that the measures for energy efficiency could damage or impact the historical heritage has slowed down the disciplinary integration process between conservation and sustainable design.

However the growing number of research projects (SECHURBA, CLIMATE FOR CULTURE, 3ENCULT, RIBUILD, EFFESUS to name a few, see § 6) and studies on the topic (Laine et al. 2019d; Martínez-Molina et al. 2016) has shown that the potential for this kind of interventions is high (Elena Gigliarelli, Calcerano, and Cessari 2017) and can contribute significantly to achieve the European CO_2 reduction targets (Laine et al. 2019d). One of the most complete documents on this topic is certainly the Strategic Research Agenda of the European Joint Programming Initiative Cultural Heritage and global Change (SRA-JPICH). Within the SRA-JPICH, one of the three main objectives is precisely to manage the relationship between tangible heritage and climate change with a focus on the use of energy, sustainable materials and optimised passive design (JPICH 2014). The key role of cultural heritage as a driver for sustainable development is now also underlined by other international reports such as the Cultural Heritage Counts for Europe (Europa Nostra 2015), Getting Cultural Heritage to Work for Europe (H2020 Expert Group on Cultural Heritage 2015) and Heritage Research Matters (Laine et al. 2019d).

Approach to energy improvement of the built heritage

The key element in starting an energy improvement process of a historic building is the approach, as finding the right balance in these interventions requires a holistic view aimed at understanding the building, its context, its historical-artistic values, its passive behaviour and its use of energy (Historic England 2018; Carbonara 2017). This method allows the creation of a shared knowledge framework between the actors involved in the process (Historic England 2018) and guarantees that the chosen solutions are appropriate for the historic building.

In dealing with a historical building, we can make at least two fundamental clarifications that concern the improvement approach of the interventions and the guiding principles of restoration:

1. According to the current Italian debate on the topic (de Santoli 2015; Carbonara 2015), the concept of "energy improvement intervention" is to be preferred to "energy regulatory compliance/ adjustment/ adaptation". The Architectural Restoration scholar Giovanni Carbonara maintains that the concept of improvement is antithetical to the one of "adjustment" that refers to regulatory compliance, including safety and comfort. The improvement concept has been firstly introduced in the field of structural consolidation of the built heritage with excellent results, i.e. without losing the general scope of an intervention on the built heritage that is its preservation for the future generation (or the ones related to the concept of "Integrated conservation" expressed in the Declaration of Amsterdam (AA. VV. 1975). Therefore, the concept of improvement can also be applied to energy efficiency and historical buildings as the energy and environmental behaviour of an historical building (both active and passive), can be improved through appropriate and well-balanced solutions without leading to a disruption of the building, which would be the case should one wrongly assume that the building has to be "adjusted" to current legislations and requirements, as if it were the case of a new or recent construction. If the "adjustment" can change the building and make it

unrecognizable, destroying or impairing its cultural values (Carbonara 2015), the improvement can help rebuild the natural functioning processes of historical and architectural structures, enhancing at the same time their distinctive characteristics and identities linked to the local microclimate (Gigliarelli, Calcerano, and Cessari 2017; GBC 2017a). The conflict between environmental design and heritage conservation is finally over and energy efficiency measures are now fully recognised as a key protection tool to support the conservation process (Carbonara 2015).

2. The solutions adopted must be in line with the guiding principles introduced by the international restoration charters. These are universally recognised principles produced by the critical debate on restoration, starting around the nineteenth century and developed through the international restoration charters. A brief summary of these principles is given below (Carbonara 2017):
    a) *minimum intervention:* the energy improvement design should aim at preserving the original material as much as possible and avoid unnecessary interventions;
    b) *reversibility:* the interventions must be reversible in the future, whenever possible;
    c) *distinguishability:* new works should be distinguishable against the existing one;
    d) *physical-chemical and figurative compatibility:* the interventions must guarantee compatibility between ancient and new materials, new design solution and historical and architectural features. This applies also to energy improvement project (for example, understanding the building's bioclimatic functioning - also through historical and architectural insights on the technologies used - is vital to reconstruct and optimise its passive behaviour);
    e) respect for the material and figurative authenticity of the building.

2.2. Regulatory framework of International and European policies on energy efficiency and climate change

Europe has always had a leading role in the development of policies relating to the fight against climate change and is one of the most important supporters for the discussion and adoption of international treaties on the issue which then follow the classic process of adoption and transposition at UE level and then to the single member state.

Below is a general scheme from the European Commission (2019) on energy efficiency and climate change:

	International commitments				EU domestic legislation				
	Kyoto Protocol		UNFCCC	Paris Agreement	Climate and Energy Package		Climate and Energy Framework		
					EU ETS	ESD	EU ETS	ESR	LULUCF
Target year of period	First commitment period (2008-2012)	Second commitment period (2013-2020)	2020	2030	2013-2020		2021 – 2030		
Emission reduction target	-8 %	-20 %	-20 %	At least -40%	-21 % compared to 2005 for ETS emissions	Annual targets by MS. In 2020 -10 % compared to 2005 for non-ETS emissions	-43% for EU ETS sectors	-30% for ESR sectors (translated into individual binding targets for MSs)	No-debit target based on accounting rules
Further targets	-	-	Conditional target of -30 % if other Parties take on adequate commitments	-	Renewable Energy Directive: 20 % share of renewable energy of gross final energy consumption; Energy Efficiency Directive : Increase energy efficiency by 20 %		A binding renewable energy target for the EU for 2030 of at least 32% of final energy consumption, including a review clause by 2023 for an upward revision of the EU level target. A headline target of at least 32.5% for energy efficiency to be achieved collectively by the EU in 2030, with an upward revision clause by 2023.		

Table 1: European Regulatory framework on energy efficiency and climate change.

Global Agreements

Global agreements are the highest level of discussion on the fight to climate change. Below a list of the most important agreements, conferences and studies:

Scientific evidence

The Intergovernmental Panel on Climate Change[1] (IPCC) is an intergovernmental body of the United Nations whose aim is to provide the world with scientific information relevant to understanding the basis of the risk of climate change, its impacts and possible responses. Its first report drafted in 1990 (Houghton, Jenkins, and Ephraums 1990) and reviewed in 1992 (McG Tegart and Sheldon 1992) served as the basis for the United Nation Framework Convention on Climate Change. The fifth assessment report was published in 2014. IPCC produces also special reports focused on specific issues like emissions (IPCC 2000) or global warming (IPCC 2018).

United Nations Framework Convention on Climate Change (UNFCCC)

The "United Nations Framework Convention on Climate Change", also known as UNFCCC, FCCC or also as Rio agreements (UN 1992), is an agreement signed on 4 June 1992 in Rio de Janeiro within the "United Nations Conference on Environment and Development" (UNCED, informally known as Earth Summit). The aim of the agreement (that entered into force on the 21st of March 1994) was to reduce greenhouse gas emissions, although without imposing mandatory limits and therefore not being legally binding. The agreement envisaged to hold successive conferences (COP Conference of the Parties) to produce further deeds (called protocols) that should impose mandatory limits for reducing emissions. With the adoption of the UNFCCC, the UNFCCC secretariat (UN Climate change) was established to facilitate intergovernmental climate change negotiations and now works to advance the implementation of the Convention, the Kyoto Protocol and the Paris Agreement.

[1] https://www.ipcc.ch/

COP 3: Kyoto Protocol

The Kyoto Protocol was drawn up on the 11^{st} of December 1997 during the UNFCCC COP 3 held in the Japanese city and is a legally binding treaty, which commits the signatory countries, in the period 2008-2012, to reduce their emissions by an average of 5% compared to 1990 levels. The protocol entered into force on 16th February 2005 and is currently ratified by 192 Parties (UN 2020). However, given that many of the actors responsible for the emissions were not part of it, the Kyoto 1^{st} commitment period only affected around 18% of global emissions (AA. VV. 2012).

COP 18: Doha Amendment to the Kyoto Protocol

On the 21^{st} of December 2012, during the UNFCCC COP 18 in Doha, the Doha amendment to the Kyoto protocol established a new period (2013-2020), in which the acceding countries committed to reduce their emissions by setting new limits and to reach a new global action plan by 2015, that sets targets to be achieved in the 2021-2030 period (UN 2012).

COP 21: Paris Agreement

On the 12^{nd} of December 2015, during the COP 21 of the UNFCCC in Paris, an agreement, requested by the Doha conference 2012, was reached on a new global action plan which commits the adhering parties to take measures in the period 2021-2030 and goals in response to climate change (UN 2015a). The agreement entered into force on the 4^{th} of November 2016.

According to the provisions of article 2, the agreement "aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" (UN 2015a, 3). To do so, the agreement requires parties to commit to hold the increase of the global average temperature below 2°C above the pre-industrial level (aiming at a 1.5°C increase), to increase the adaptation capability to climate change impacts fostering climate resilience and reducing greenhouse gas emission, to support these action with a consistent finance flow. The agreement also underlines the importance of the principle of equity, which translates into a common but differentiated responsibility according to the capabilities of each signatory country, depending on its national context.

The 2030 Agenda for Sustainable Development (2015)

The 2030 Agenda (UN 2015b), with its 17 Sustainable Development goals (SDGs) and 169 targets, was adopted on the 25^{th} of September 2015 in a special UN summit and constitutes, with its commitment to eradicate poverty and achieve sustainable development by 2030 world-wide, a landmark achievement, as it provides a shared global vision towards sustainable development for all. The scale of the undertaking is unprecedented and its applicability is universal, as it take into accounts national realities and local contexts and challenges. The agenda integrates the three dimension of sustainable development (economic, social and environmental) and includes strong follow-up and review mechanism to ensure its progress and long-term accountability (European Commission 2015).

An overview of the sustainable development goals is reported below (source: https://sustainabledevelopment.un.org).

Figure 1: Overview of the goals of 2030 Agenda for Sustainable Development.

<u>European Union Strategies</u>

Lisbon Strategy

On the 23rd and 24th of March 2000, the European Council held in Lisbon approved a cross-sectoral reform agenda aimed at strengthening the development of employment, economic reforms and social cohesion in the context of a knowledge-based economy. In the period 2000-2010, the EU should have become "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion". The Lisbon strategy is followed by the “Europe 2020” strategy, which refers to the period 2011-2020[2].

First ECCP: The implementation of the first phase of the European Climate Change Programme

Communication from the Commission of the 23th of October 2001 [COM(2001) 580]

The Communication from the Commission of the 23rd of October 2001 confirms the commitments of the Gothenburg European Council of June 2001, also linked to the objectives of the Kyoto Protocol. The Communication focuses on four types of measures: cross-cutting, energy, transport and industry and plans to present proposals

[2] For further information: https://portal.cor.europa.eu/europe2020/Profiles/Pages/TheLisbonStrategyinshort.aspx

in 2002 in the energy field concerning energy management and minimum energy efficiency requirements[3].

Second ECCP: Winning the battle against global climate change

Commission Communication of the 9th of February 2005 [COM(2005) 35]

In this communication, the strategy to combat climate change is refined in its four dimensions relating to climate risk itself and the political will to tackle it, the necessary international participation, the required innovation and the adaptation measures to deal with its inevitable effects. One of the most significant contribution of the ECCP is the European Union Greenhouse Gas Emission Trading Scheme (ETS), the largest in the world[4].

Action Plan for Energy Efficiency: Realising the Potential

Communication from the Commission of the 19th of October 2006 [COM(2006) 545]

The Action Plan for Energy Efficiency of 2006 aims to mobilize all stakeholders (policy makers, general public and market actors) to transform the European internal energy market in order to provide EU citizens with the most efficient energy systems and infrastructures in the world, including buildings. The goal is to achieve primary energy savings of 20% compared to the energy consumption forecasts for 2020 by 2020. To reduce the heat loss of buildings, the Action Plan extend the application of the Energy Performance Building Directive to small buildings, providing minimum energy performance standards applicable to new construction and existing buildings for the promotion of passive houses[5].

Limiting Global Climate Change to 2 degrees Celsius - The way ahead for 2020 and beyond

Communication from the Commission of the 10th of January 2007 [COM(2007) 2]

The Communication from the Commission of the 10th of January 2007, to limit the global temperature rise within 2°C defines three energy targets for 2020: 20% reduction in emissions compared to 1990 levels, 20% improvement in the European Union's energy efficiency (already set in the previous Action Plan) and 20% increase of renewable energy within the energy mix for 2020. These targets are then included in the Europe 2020 strategy of the 3rd of March 2010 and in subsequent commitments made in the context of the Doha amendment to the Kyoto protocol[6].

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[3] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al28118

[4] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al28157

[5] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al27064

[6] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al28188
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:l27067

2020 Climate & Energy Package

Approved by the European Parliament in December 2008 and transposed into national legislation in 2009, the 2020 Climate & Energy Package is a series of binding rules aimed at ensuring that the EU achieves its climate and energy targets by 2020.

The main European legislative instruments for the implementation of the Climate & Energy Package are: a Directive revising the EU Emission Trading Scheme (ETS Directive 2009/29/EC); an Effort-Sharing Decision setting binding national targets for emissions from sectors not covered by the ETS (Decision 2009/406/EC); a Directive setting binding national targets for increasing the share of renewable energy sources in the energy mix (Renewable Energy Directive 2009/28/EC); a Directive creating a legal framework for the safe and environmentally sound use of carbon capture and storage technologies (Carbon capture and storage - CCS Directive 2009/31/EC); the Fuel Quality Directive (Directive 2009/30/EC); a Regulation setting emission performance standards for new passenger cars (Regulation 443/2009)[7].

EUROPE 2020 A strategy for smart, sustainable and inclusive growth

COMMUNICATION FROM THE COMMISSION of the 3rd of March 2010 [COM(2010) 2020 final]

The Europe 2020 strategy aims to ensure that the economic recovery of the European Union, following the economic and financial crisis, is accompanied by a series of reforms that lay a solid foundation for growth and job creation between now and 2020. While addressing structural weaknesses in the EU economy and economic and social issues, the strategy also takes into account longer-term challenges such as globalization, resource warfare and aging.

The Europe 2020 strategy should allow the EU to achieve growth that is:

1. intelligent, through the development of knowledge and innovation;
2. sustainable, based on a greener economy, more efficient in resource management and more competitive;
3. inclusive, aimed at promoting employment and social and territorial cohesion.

To achieve this aspiration, the EU has set itself five major objectives to be achieved by 2020:

1. increase the employment rate of people aged between 20 and 64 to at least 75%;
2. invest 3% of the gross domestic product in research and development;
3. reduce greenhouse gas emissions to at least 20%, increase the share of renewable energy to 20% and increase energy efficiency by 20%;
4. reduce the dropout rate to less than 10% and bring the rate of young graduates to at least 40%;
5. reduce the number of people at risk of poverty or social exclusion by 20 million[8].

[7] For further information:
https://ec.europa.eu/clima/policies/strategies/2020_en

[8] For further information:
https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

A policy framework for climate and energy in the period from 2020 to 2030

Communication of the Commission to the Council and the European Parliament of the 28th of January 2014 [COM(2014) 15]

Within the Communication, the commission proposes targets for 2030, including: the full implementation of 2020 targets and a 40% reduction of greenhouse emission below 1990 level for 2030; the increase in renewable share at 27% (subsequently Revised upwards at 32% in the "Clean energy for all Europeans package"); a reform in Energy Trading System; further improvement in energy efficiency and a new European governance system for energy and climate policies based on Member State plans for the delivery of energy and climate objectives, along with key indicators to monitor the progress[9].

The energy union strategy (2015)

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank

A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy of the 25th of February 2015 [COM(2015) 80]

The strategy aims at building an energy union that gives EU consumers secure, sustainable, competitive and affordable energy on five interrelated dimensions: security and cooperation between EU countries, a fully integrated energy market, energy efficiency, climate action to decarbonise the economy, research innovation and competitiveness[10].

Clean energy for all Europeans package (presented on the 30th of November 2016 - finished adopting 22 May 2019)

On the 30th of November 2016, the European Commission presented a package of measures to facilitate the transition from fossil fuels to cleaner energy and to deliver the EU policy framework for climate and energy from 2020 to 2030 and the EU's Paris Agreement commitments. Key targets for 2030 are: at least 40% cuts in greenhouse gas emissions (compared to 1990 levels); at least 32% share for renewable energy (with an upward revision clause by 2023); at least 32.5% improvement in energy efficiency (with an upward revision clause by 2023). Non-ETS (Emission Trading System) sectors will need to cut emissions by 30% (compared to 2005 levels) – this has been translated into individual binding targets for Member States. As part of the European Green Deal, the Commission aims to propose raising this target to at least 50% and towards 55% in a responsible way. The package also introduces innovations in terms of governance and regulation including a robust new system for the energy

[9] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:2001_5
https://ec.europa.eu/clima/policies/strategies/2030_en
[10] For further information:
https://ec.europa.eu/energy/en/topics/energy-strategy/energy-union

union in which Member State are required to draft integrated 10-year national energy and climate plans, electricity market design to make it more flexible and better placed to integrate a greater share of renewables.

The Climate and Energy Package comprises eight legislative acts: directive amending the energy performance of buildings directive and energy efficiency directive (EU 2018/844); directive on the promotion of the use of energy from renewable sources recast (EU 2018/2001); directive amending energy efficiency directive (EU 2018/2002); regulation on Governance of the Energy Union and Climate Action (EU 2018/1999); regulation on internal market for electricity recast (EU 2019/943); directive on common rules for the internal market for electricity (EU 2019/944); regulation on Risk-Preparedness in the Electricity Sector (EU 2019/941); regulation establishing a European Union Agency for the Cooperation of Energy Regulators recast (EU 2019/942)[11].

2050 long-term strategy, A Clean Planet for all (2018)

Communication from the Commission. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy of the 28th of November 2018 [COM(2018) 773]

With this Communication, the European Commission reaffirms that EU aims to be climate-neutral by 2050, leading the global climate action through a long term strategy. The strategy does not launch new strategies nor changes the 2030 targets, but sets the direction of EU climate and energy policy, stating what EU considers its long-term contribution to achieving the Paris Agreement objectives and UN Sustainable Development Goals. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement[12].

The European Green Deal (2019)

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions of the 11st of December 2019 [COM(2019) 640]

The European Green Deal (EC 2019) is the latest and most ambitious package of measures, aimed at mobilising at least 1 trillion euro of investments over the course of 10 years, (European Commission 2020), to enable European citizens and businesses to benefit from sustainable green transition. The package includes measures and a roadmap of key policies supported by investments in green technologies, sustainable solutions and new businesses[13].

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[11] For further information:
https://ec.europa.eu/energy/en/topics/energy-strategy/clean-energy-all-europeans
https://ec.europa.eu/commission/presscorner/detail/en/IP_16_4009
https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition

[12] For further information:
https://ec.europa.eu/clima/policies/strategies/2050_en

[13] For further information:

Energy Directives (European Union)

Renewable Energy Directives

Directives on the promotion of the use of energy from renewable sources:

- Directive 2009/28/EC);
- Directive (EU) 2018/2001.

EPBD Directives

Directives on the Energy Performance of Buildings:

- Directive 2002/91/CE;
- Directive 2010/31/EU;
- Directive (EU) 2018/844

EED Directives:

Directive on Energy Efficiency:

- Directive 2006/32/CE;
- Directive 2012/27/EU;
- Directive (EU) 2018/2002

Other directives

- Directive 2009/125/EC: Establishing a framework for the setting of eco-design requirements for energy- related products;
- Directive 2010/30/EU: Indication by labelling and standard product information of the consumption of energy and other resources by energy- related products

Plans and reports required by the EU from Member States

EEAP (Energy Efficiency Action Plan)

The Energy Services Directive (2006/32/EC) required member states to improve their national energy efficiency by at least 9% by 2016; the same directive also required each member state to draw up in 2007, 2011 and 2014, the "Energy Efficiency Action Plan" (EEAP) containing the strategy set to achieve the 9% target and updates on the intermediate results achieved. Given the subsequent repeal of the directive, only EEAP 2007 and EEAP 2011 have been drawn up[14].

NEEAP (National Energy Efficiency Action Plan)

The Energy Efficiency Directive (2012/27/EU), which repeals the Directive (2006/32 / EC), demands that each member state sets a national target that allows the EU to achieve the target of 20% energy efficiency improvement by 2020. The directive asks each Member of drafting in 2014, and every three years thereafter, a National Energy Efficiency Action Plan (NEEAP) in which to "set out estimated energy consumption,

https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN

[14] For further information:
https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/national-energy-efficiency-action-plans

planned energy efficiency measures, long-term renovation strategies, and the improvements that individual EU countries expect to achieve "[15].

Annual Report on Energy Efficency

Required by the Energy Efficiency Directive (2012/27 / EU):"By 30 April each year as from 2013, Member States shall report on the progress achieved towards national energy efficiency targets, in accordance with Part 1 of Annex XIV" of Directive (2012/27/EU)[16].

National renewable energy action plans

Required by the Directive 2009/28/EC that is part of the 2020 Climate & Energy Package states that: "The national renewable energy action plans shall set out Member States' national targets for the share of energy from renewable sources consumed in transport, electricity and heating and cooling in 2020"and "Member States shall notify their national renewable energy action plans to the Commission by 30 June 2010"[17].

NECP (Integrated National Energy & Climate Plan)

Required by the Regulation (EU) 2018/1999 that is part of the Clean energy for all Europeans package. It states that "By 31 December 2019, and subsequently by 1 January 2029 and every ten years thereafter, each Member State shall notify to the Commission an integrated national energy and climate plan. The plans shall contain the elements set out in paragraph 2 of this Article and in Annex I. The first plan shall cover the period from 2021 to 2030, taking into account the longer term perspective. The subsequent plans shall cover the ten-year period immediately following the end of the period covered by the previous plan.[18]"

2.3. Selection of the Main Restoration Charters

<u>The Athens Charter for the Restoration of Historic Monuments – 1931</u>

The Athens charter was adopted during the International Conference of Architects in Athens and lays the foundations for an international and scientific approach to the

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[15] For further information:
https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/national-energy-efficiency-action-plans

[16] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=IT
https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/national-energy-efficiency-action-plans

[17] For further information:
https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:32009L0028&from=EN
https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020

[18] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN
https://ec.europa.eu/energy/en/topics/energy-strategy/energy-union
https://ec.europa.eu/clima/policies/strategies/2030_en

care and protection of the architectural heritage, to standardise legislation by not making private interests prevail over public ones, in favour of education to respect monuments. From a technical point of view, it admits the use of modern techniques and materials such as reinforced concrete and techniques such as anastylosis in specific cases. The Charter also takes a stand against complete remakes and integral restoration and in favour of regular and permanent maintenance and compatible use. The document strengthens the collaboration between conservatories, architects and representatives of the physical, chemical and natural sciences, establishes the principle of respect for the character and physiognomy of the city, promotes the inventory of monuments in the states, and international scientific and technical cooperation on the subject[19].

International Charter For The Conservation And Restoration Of Monuments And Sites (The Venice Charter 1964)

Also for psychological reasons, in order to minimize the destruction of World War II, the practice of integral restoration (or re-establishment) increased, rebuilding the built heritage even at the cost of involving non-historical addition and producing historical counterfeit. Once this phase was over, the debate switched again on questioning the scientific community on the correct practices. The focus of the Second International Congress of Architects and Monument Technicians (Venice, 25th-31st May 1964) concerns therefore restoration principles, historical values of the building and the urban environment.

In the document the notion of historical monument is extended to comprise not only an isolated creations but also urban or landscape environment, testimony of a civilisation, of a significant evolution or historical event. The importance of the relationship between conservation and technology and science, the safeguarding of historical evidence and systematic maintenance, the compatible use of the building are reiterated. The attention of the conservation experts also extends to the context in which the monuments are inserted, against the separation of the monument from the context, except for safeguard reasons. The exceptional nature of the restoration works is underlined, as well as its purpose of preserving and revealing the formal and historical values of the monument, based on respect for the ancient substance and authentic documentation. The restoration, always preceded by a historical study of the monument, must also stop where the hypothesis begin and any completion, considered essential for the historical or aesthetic instance (underlining however that the stylistic unity is not the purpose of the restoration) must be made recognisable. The removals of stratifications are allowed only if justified by a particular historical, archaeological or aesthetic reason, and the conservation works must always be accompanied by specific documentation[20].

[19] For further information:
https://www.icomos.org/en/167-the-athens-charter-for-the-restoration-of-historic-monuments
[20] For further information:
https://www.icomos.org/charters/venice_e.pdf

The Declaration of Amsterdam - 1975

The declaration comes with the end of the European year on architectural heritage and the approval of the European Charter of Architectural Heritage promulgated by the Committee of Ministers of the Council of Europe. The declaration highlights the link between conservation of existing buildings, saving resources and combating waste. The declaration also introduces the concept of "integrated conservation" which establishes the need for an integrated action capable of grasping and solving, through intervention on the built-up area, a series of technical, social, economic aspects, in order to make the intervention itself possible and not to trigger phenomena of social exclusion. To implement these actions, the charter also requires the development of legislative, administrative, financial and technical tools[21].

European Charter of the Architectural Heritage - 1975

The charter promotes a common European policy and a concerted action to protect the heritage set according to the principles of integrated conservation, taking into account the results of the European Year of Architectural Heritage in 1975. The document also defines the nature of European architectural heritage, its imports to the European Community and threats to the heritage[22].

Charter For The Conservation Of Historic Towns And Urban Areas (Washington Charter 1987)

The Washington Charter claims that all cities in the world are material expressions of the diversity of society throughout history and are therefore all historical. The charter concerns cities that, in addition to their quality as historical documents, have the peculiar values of traditional urban civilizations, now threatened by degradation, destructuring or destruction under the effect of non compatible urbanization processes of the industrial era. The charter completes the Venice Charter by defining principles, objectives, methods and tools aimed at safeguarding the quality of historic cities, and the measures necessary for their protection, conservation, restoration and coherent development and harmonious adaptation to contemporary life[23].

The Nara Document on Authenticity (1994)

The Nara Document addresses the need for a broader understanding of cultural diversity and cultural heritage in relation to conservation, to define the value of authenticity in a more objective way. Authenticity is essential to outline, evaluate and monitor cultural heritage; however, this concept varies from culture to culture, therefore, to introduce the concept of authenticity, the cultural object must be framed in its cultural context. The theme, dear to Japan where the meeting took place, also

[21] For further information:
https://www.icomos.org/en/and/169-the-declaration-of-amsterdam
[22] For further information:
https://www.icomos.org/en/charters-and-texts/179-articles-en-francais/ressources/chartersand-standards/170-european-charter-of-the-architectural-heritage
[23] For further information:
https://www.icomos.org/charters/towns_e.pdf

derives from the Japanese practice of rebuilding the wooden cultural structures by dismantling the old ones. With its insights, the charter helped to clarify a series of authenticity issues that complicated decision making process for the implementation of conservative practices[24].

The Aalborg Charter (1994)

The Aalborg Charter highlights the impossibility of reaching a sustainable life model in the absence of local communities that comply with the principles of sustainability. Historic cities represent the largest unit capable of dealing with many urban imbalances (concerning architectural social, economic, political, environmental and natural resources aspects) and at the same time the smallest scale at which these problems can be positively resolved, in an integrated, holistic and sustainable way. A management procedure based on sustainability allows decisions to be made not only on the basis of the interests of current users but also on future generations[25].

3. BIM and HBIM

3.1. BIM Introduction

What is BIM?

According to the EUBIM task group Handbook[26], "BIM is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects; and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment – the largest share of the sector" (EUBIM Taskgroup 2017, 4).

A more practical definition of BIM makes this acronym correspond to three different meaning:

1. Building Information Model. According to ISO 19650, a model is a set of structured and unstructured sets of information, defined as "information containers". For each building there can be several different models (typically architectural, structural and MEP-Mechanical Electrical and Plumbing), that can be "federated", i.e. assembled together through a coordination activity to create a single, complete building information model of an asset;
2. Building Information Modelling, that is the process needed to have a continuous development of one or more models enriched with all the information collected and shared during the lifespan of the building with contribution from several professionals;

[24] For further information:
https://www.icomos.org/charters/nara-e.pdf
[25] For further information:
http://www.sustainablecities.eu/fileadmin/repository/Aalborg_Charter/Aalborg_Charter_Eng lish.pdf
[26] http://www.eubim.eu/handbook/

3. Building Information Management, that is the whole process of management of the information related to the BIM models.

The term openBIM refers to the exchanging of BIM Data by using open standards, formats and workflows.

Advantages and value of using BIM

The list of advantages of a complete openBIM implementation is rising, because BIM develops the concept of industrialization and "assembly line" in a sector that has not yet taken full advantage of digitalization. An integrated use of openBIM can enhance the efficiency of the construction process: in fact, BIM allows for the creation and updating of a building digital information system that connects three-dimensional representation with a dynamic, continuously implementing database. The system defines geometric and semantic data through parametric libraries of BIM objects such as walls, windows, ceilings, heating systems, lightening systems, etc., that "simulate" the building components and their relationships.

One main advantage is the centralization of data that avoids redundancy and enhances consistency and robustness in the design and construction process: each modification to the model is instantaneously reflected in all outputs.

Another advantage is data sharing: the model can be developed as a common repository, where different operators (architects, environmental engineer, energy performance experts, structural engineers, security and safety expert, fire fighters experts) of the construction sectors can work together, often simultaneously, on the same project. Moreover, through the Common Data Environment (CDE, see § 3.3), specialists even not familiar with specific BIM software can contribute to the process by submitting documentation, comments, etc.

BIM also simplifies the analysis of different aspects of the construction process normally disconnected from design, that in a BIM process are called "dimensions", to underline their integration with the geometric three dimensional models (AA. VV. 2013a; FutureLearn 2019):

- 4D: A dimension involving the use of models in order to allow all the activities and **time management process** (planning, assessment and time controlling).
- 5D: A dimension involving the use of models in order to allow all the **activities and cost management** process (cost estimates, determination of the budget, cost control).
- 6D: A dimension involving the use of models in order to enhance sustainability (economic, environmental, energy, etc.).
- 7D: A dimension involving the use of models in order to carry out activities and **management process** and operations throughout the entire **building or facility lifecycle**.

All these aspects lead to improved efficiency of the construction process, reduced costs, reduced safety risks, reduced construction time.

Interoperability between different software (for example, between BIM modelling software and energy simulation software) is a very promising development, still facing some barriers, especially with BIM process applied to historical buildings. Besides, the majority of software for energy analysis are dealing only with the design phase and do not cover all the life cycle of a building, while major advantages on the use of BIM can be obtained during the building management phase.

3.2. Regulatory framework

International standards

At the international level, the subcommittee ISO/TC59/SC13 "Organization of information about construction works" is responsible for the standardization BIM models. The main objective of this subcommittee is the standardization of the BIM model to allow the exchange of information of all kinds, throughout the whole lifespan of the project, and among all the entities that participate in the process.

ISO 1950 series

The subcommittee ISO/TC59/SC13 published ISO 196501 in December 2018 as the standard for organizing information about construction works. It "sets out the concepts and principles for the business processes across the built environment sector in support of management and production of information during the lifecycle of built assets, when using building information modelling." And explains that: "These processes can deliver beneficial business outcomes to asset owners/operators, project clients, their supply chains, and those involved in project funding including reduction of risk and reduction of cost through the creation and use of asset and project information models."

BIM is presented not only as a 3D tool for managing digital information but also as a new approach to managing projects where digital information is being exchanged between contract parties at all stages of a project, including design, procurement, commissioning and construction. mutual understanding and trust (European Federation of Engineering Consultancy Associations 2020).

Up to now, two parts of ISO 19650 has been published, the first about concept and principles and the second about delivery phase of asset.

ISO 19650-1:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles

The document outlines the concepts and principles for information management at a stage of maturity described as building information modelling (BIM) and provides recommendations for a framework to manage information including exchanging, recording, versioning and organizing for all actors. It is applicable to the whole life cycle of any built asset, including strategic planning, initial design, engineering, development, documentation and construction, day-to-day operation, maintenance, refurbishment, repair and end-of-life and can be adapted to assets or projects of any scale and complexity.

ISO 19650-2:2018: Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets

The document specifies requirements for information management, in the form of a management process, within the context of the delivery phase of assets and the exchanges of information within it, using building information modelling.

ISO/TS 12911:2012 Framework for building information modelling (BIM) guidance.

The document establishes a framework for providing specifications for the commissioning of building information modelling (BIM). It is applicable to any range of modelling of buildings and building-related facilities and to any asset type. BIM processes are applicable across the entire life cycle of a portfolio, facility or component, which can span inception to end-of-use. The main user of the framework is the information manager, who utilizes the framework to assist in structuring an international-, national-project- or facility-level BIM guidance document.

ISO 16739:2013, Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries

ISO/TS 12911:2012 establishes a framework for providing specifications for the commissioning of building information modelling (BIM). It specifies a conceptual data schema and an exchange file format for BIM data, representing an open international standard that is exchanged and shared among software applications used by the various participants in a building construction or facility management project. It consists of the data schema, represented as an EXPRESS schema specification, and reference data, represented as definitions of property and quantity names and descriptions.

<u>European standards</u>

The European Committee for Standardization (CEN) created a Working Group, CEN/BT WG215 (BIM), aimed at studying the relevance and convenience of creating a specific Technical Committee of Standardization about BIM, as well as to define its scope, structured according to a roadmap. The Technical Committee CEN/TC 442 is developing a structured set of standards, specifications and reports, to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other external data. The CEN/TC 442 Working Plan has the following aims:

1. adoption of the main BIM international standards (ISO) as European standards (EN). The procedures for the adoption of ISO Standards 12006-3: 2007 (IFD), ISO 16739: 2013 (IFC), ISO 29481-1: 2016 (IDM) and ISO 29481-2: 2012 (IDM) have been started.
2. cooperation with ISO in the development of new standards, such as the projects prEN ISO 19650-1 and prEN ISO 19650-2.

European regulations

The Directive 2014/24/EU of the European Parliament and of the Council on Public Procurement was the action took by the European parliament to digitalize the public administrations. In particular, for the public works, the Article 22: “Rules applicable to communication” states:

“For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar. […] The applications supporting file formats that are suitable for the description of the tenders use file formats that cannot be handled by any other open or generally available applications or are under a proprietary licensing scheme and cannot be made available for downloading or remote use by the contracting authority. […] Contracting authorities may, where necessary, require the use of tools and devices which are not generally available, provided that the contracting authorities offer alternative means of access.

Contracting authorities shall be deemed to offer suitable alternative means of access in any of the following situations, where they:

1. offer unrestricted and full direct access free of charge by electronic means to those tools and devices from the date of publication of the notice in accordance with Annex VIII or from the date when the invitation to confirm interest is sent. The text of the notice or the invitation to confirm interest shall specify the internet address at which those tools and devices are accessible;
2. ensure that tenderers having no access to the tools and devices concerned, or no possibility of obtaining them within the relevant time limits, provided that the lack of access is not attributable to the tenderer concerned, may access the procurement procedure through the use of provisional tokens made available free of charge online; or
3. support an alternative channel for electronic submission of tenders[27]”.

These requests set the use of Common Data Environment and openBIM in the construction sector, in order to enhance the efficiency of building processes and to comply with the Directive.

Since 2014, the different European member states started to use of BIM and a special BIM EU Task group has been established and the Handbook for the Introduction of Building Information Modelling by the European Public Sector (AA.VV. 2017b) has been produced[28].

EU Commissioner Elżbieta Bieńkowska, states that “the European construction sector is at the centre of a tough but also promising set of economic, environmental and societal challenges. The sector represents 9% of EU GDP and employs 18 million people. It is a driver for economic growth and home to 3 million enterprises, most of which are SMEs”. The challenges faced by the society and its governments concern “climate change, resource efficiency, greater demands on social care, urbanisation and immigration, an ageing infrastructure, the need to stimulate economic growth, as well as constrained budgets” (AA.VV. 2017b, 2), and the construction sector, that is now

[27] For further information:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0024

[28] The handbook is freely downloadable from this link: http://www.eubim.eu/handbook/.

finally involved in its digital revolution is crucial for tackling these challenges. BIM is probably at the centre of this revolution as a “strategic tool to deliver cost savings, productivity and operations efficiencies, improved infrastructure quality and better environmental performance” (EUBIM Taskgroup 2017, 2).

In its conclusions the Handbook states that (EUBIM Taskgroup 2017, 5):

1. there is a window of opportunity for harmonising a European wide common strategic approach for the introduction of BIM;
2. government policy and public procurement methods are recommended as powerful tools to support this step-change in the sector. The top-down leadership is needed to overcome the sector’s low and uneven adoption of information technology and unleash the full potential of the technology;
3. governments need to work with industry at European and national levels to achieve this digital transformation as the vision is to build together with the private sector a competitive and open digital construction market that sets the global standard;
4. it will take time and significant adjustments in order to tune and deliver a successful BIM adoption strategy.

In this framework, the BEEP project can be considered strategic for the vast cultural heritage that Europe owns with its possibility to demonstrate the use of BIM for the energy improvement of public historical or listed public building.

The handbook also summarise in the following table (EUBIM Taskgroup 2017, 21) why public organisations are adopting a common approach:

Benefit of a European approach	Description of the benefit
Accelerate national efforts	Through collaborative working and sharing of best practice, nations can accelerate their own BIM initiatives by learning from others.
Minimise costs	Wasted effort and investment can be minimised through the reuse of existing developments and knowledge.
Impactful and robust programmes	By drawing upon existing knowledge and practical experience of what makes programmes successful, individual nations can be informed to create and implement effective initiatives.
International critical mass	Taking a similar approach to neighbouring countries for the encouragement of BIM will increase the strength and effectiveness of each individual national programme.
Reducing trade barriers to growth	Alignment of a European approach will encourage trade and opportunity for growth across borders. Creating national specific approaches will likely confuse the construction sector, discourage cross border working and add a cost burden to the industry when complying with national different approaches.
Encourage international standards developments and software integration	Europe has the opportunity to collectively encourage the development of standards for use in international markets. This ensures open competition in the supply chain and the open sharing of information across software platforms.

Table 2: Common approach advantages.

The same can be asserted to the whole MED area. Moreover, the purpose of the BEEP project to propose standards for the energy performance of historical buildings at buildingSMART International "building room" is aligned to the objective of encouraging international standards developments and software integration.

The set of actions proposed in the handbook are synthetized in the following table (EUBIM Taskgroup 2017, 25):

Strategic Area	Action high level description
Public leadership	■ Define compelling drivers, a clear vision and goals ■ Describe the value of BIM to the public and private sector ■ Document the general approach for moving the industry towards the defined vision and goals ■ Identify a public sector champion to sponsor the initiative ■ Establish an implementation team to drive the programme. The value proposition and sponsor can unlock the required funding and resources
Communication and communities	■ Early and frequent engagement with industry stakeholders is essential to support the industry change process ■ Participate in and provide encouragement for regional and special interest networks to disseminate best practice ■ Use mass communication tools, such as online media, events, web and social media to reach audiences
Collaborative framework	■ Assess and address legal, regulatory, procurement and policy barriers in order to facilitate collaborative working and sharing of data. ■ Develop or use international standards for data requirements ■ Reference international standards for encouraging collaborative processes and sharing of data ■ Produce guidance and tools to support the upskilling of industry and development of academic curricula
Capability and capacity development	■ Run pilot projects and promote training to encourage early successes. ■ Increase the use of public procurement as a driver for industry capacity development ■ Measure progress, produce case studies to increase industry awareness and support

Table 3: BIM Handbook proposed actions.

and show the importance of running pilot projects as an instrument to the capitalization of BIM technology.

3.3. Interoperability, openBIM tools and standard formats

Within a BIM process, the collaborative generation and evolution of the models is a key aspect, as it provides stakeholders with a source of reliable geometric and semantic information that can be extracted and exchanged to support decision making (Lasarte et al. 2019). As multiple disciplines are involved in the activities of designing, constructing and maintaining a building, and usually each expert tends to use specific software for specific tasks, it would be ideal if every workflow could exchange information without parallel modelling or data loss, also considering that an overall software for all construction domains seems still pretty far from reality (Lasarte et al. 2019). Interoperability represents the possibility to ensure that data created by a party can be properly interpreted by all other parties (Shen et al. 2010; Pinheiro et al. 2016). With the growing importance of software solution in the construction industry, interoperability is becoming a major-issue, as the exchange of data, if performed inadequately, can become a waste of time and a cost on its own (Lasarte et al. 2019).

Few software houses have developed a suite of different software for different BIM applications in the construction industry. These different applications are theoretically interoperable within themselves, but generally not with other software. Operators who receives information in a given proprietary file format tends to be forced to use the same software for changes or implementations. File formats also tend to decay, as the possibility to open a file in a given software is not guaranteed after 10-20 years, that is a sound lifespan for building maintenance activities. When dealing with historical buildings, that are supposed to last indefinitely, this period is certainly longer.

Interoperability and data storage are the reasons why, at international level, stakeholders of the construction sector decided to promote the use of a standard, called “openBIM standard”, that allows the readability of files even if in a previous standard version, ensuring the interoperability among any software now and in the future if they are compliant with the specific file format. The non-profit organization buildingSMART International has tackled the challenge by developing the Industry FoundationClasses (IFC, ISO 16739-1:2018), that is the most widely recognised non-proprietary standard for BIM based data exchange.

IFC is a schema that defines a standardised digital description of the built asset for referencing and archiving model content. It represents a static copy of a BIM model that should not be edited, therefore it is often referred to as the “pdf” of BIM (bSI 2020).

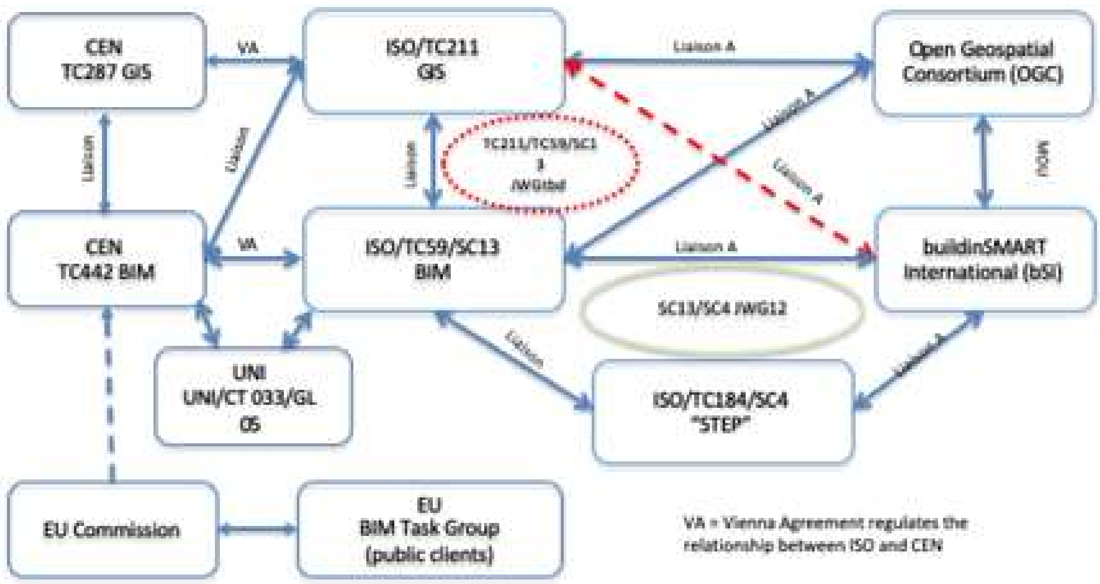

Figure 2: BuildingSMART process of standardization (source:BuildingSMART Internetional).

Figure 2 shows that buildingSMART International has also other liaisons with ISO TC 184, which has developed the language for IFC, and ISO TC 211, which develops the GIS standard necessary to geo-reference the building and all its components. What is important to notice is that EU BIM task group has an agreement with the technical committee developing BIM standards in Europe, but CEN is working in parallel with ISO committee developing BIM.
It is important to understand this scenario because working in the buildingSMART International framework can ensure that the standards are developed following the stakeholders needs and not the software house needs. Besides, the rules are established well in advance before the standard is published. This is the reason why BEEP partners wish to propose new requirements for the energy performance and historical buildings at buildingSMART International.
Figure 3 represents the process for IFC to become a national standard. The implementation process of a "candidate standard" is usually very long, because it needs to fulfil the ISO, CEN and national requirements for "public consensus". Each stage of the standard development needs time to gather and solve any comment, therefore usually it takes a few years before the standard is approved.

Figure 3: The process to implement IFC as a national standard (source: IBIMI).

To synthesize, openBIM standards are paramount for the building sector because they:

1. improve processes and workflows;
2. improve cost savings;
3. removes proprietary roadblocks;
4. supports open, transparent workflows, allowing operators to contribute to building processes regardless of their software tools;
5. creates universal, neutral platform for model file sharing and archiving, increasing platform interoperability while preserving geometry and maintaining data quality as much as possible;
6. promotes data repurpose and reuse;
7. sustains data for use throughout the asset lifecycle, avoiding redundant data input and errors.

<u>The CDE</u>

According to (EUBIM Taskgroup 2017) BIM represents a medium for collaboration among different professionals of the construction sector. Therefore the need for open standards and, at a management level, to develop a collaborative framework, aiming to define:

1. common understanding;
2. common data exchange;
3. common ways of working;
4. basis for consistent up-skilling, training and education.

When developing the collaborative framework, regulatory, procurement and legal aspects need to be considered, in order to clarify the terms relating to:

1. intellectual property ownership;
2. obligations and liabilities of suppliers;
3. purpose of information exchanges;
4. roles and responsibilities for information management.

Concerns about the exchange of information can be a barrier for the collaborative use of BIM across the supply chain as stated in the BIM EU task group handbook. Therefore, action taken to clarify the procurement and contracting process and requirements can unlock new ways of working, stimulating innovation and encouraging the exchange of digital data.

According to ISO 19650, managing of data and information within a BIM process should be set through a Common Data Environment (CDE), defined as the "agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process. It is a means of providing a collaborative environment for sharing and coordinating work as information can be transferred through information exchanges and managed through the CDE". A CDE should be adopted to allow information to be shared between all parties involved, across the asset lifecycle in delivery and operation of built assets. Productivity raises by sharing digital information and thereby improving collaboration between parties. It reduces the need for hard copies of deliverables, it re-uses information and it prevents the use of unreliable or obsolete information, thereby reducing financial losses. All the information, data and metadata can be verified in real time.

Collaboration between the operators involved in construction projects and in asset management is pivotal to the efficient delivery and operation of facilities. Organizations are increasingly working in new collaborative environments in order to achieve higher standards of quality and greater re-use of existing knowledge and experience. A major constituent of these collaborative environments is the ability to communicate, re-use and share data efficiently without loss, contradiction or misinterpretation.

True collaborative working requires mutual understanding and trust within the team and a deeper level of standardized process than has previously been experienced, if the information is to be produced and made available in a consistent timely manner. Information requirements have to descend down supply chains to the point where information can be most efficiently produced, and information has to be collated as it ascends up supply chains. At present, each year considerable resources are spent on making corrections to non-standard data, training new personnel in approved data creation techniques, coordinating the efforts of subcontractor teams and solving problems related to data reproduction. This is considered waste and can be reduced if the concepts and principles of the CDE are commonly adopted.

The EU BIM task group provides the following recommendations (EUBIM Taskgroup 2017):

	Highly Recommended	Recommended	Encouraged
Common Data Environment (CDE)	Apply the CDE principle as a means of allowing quality assured information to be managed and shared efficiently and accurately between all members of the project team – whether that information is geo-spatial, design, textual or numeric.		Security should be considered as part of the management process. Encourage the use of a managed environment to store shared asset data and information, with appropriate and secure availability to all individuals who are required to produce, use and maintain it.

Table 4: EU BIM task group recommendations on CDE.

BEEP project intends to provide guidelines for a CDE used for the renovation of historical public building. ISPC-CNR will manage the CDE for all the partners of the project so that a collaborative platform among the partners with different experience and knowledge will be the basis for the team building and an even growth of the consortium as a whole.

BIM and 6D

The main use of BIM for the entire lifecycle of a construction project are identified with different "dimensions" (AA. VV. 2013a; FutureLearn 2019). The main use of BIM for the entire lifecycle of a construction project are identified with different "dimensions" (AA. VV. 2013a; FutureLearn 2019). The first consideration of 6D appeared in 2012 (Redmond et al. 2012; Charef, Alaka, and Emmitt 2018). Even there is still no shared consensus between academics and practitioners on the definition of 6 and 7D as BIM dimensions (86% of professionals using 6D allocate to it the Sustainability while 85% of professionals using 7D allocate it to Facility Management, Charef, Alaka, and Emmitt 2018), this project follows for the 6D the association between BIM and sustainability (environmental and energy point of view) stated in previous researches (Redmond et al. 2012; Yung and Wang 2014).

Strictly linked to 4D (time) and 5D (cost), 6D BIM helps to analyze the impact of a building through its various stages, taking the industry a step beyond the conventional approach that just focuses on the upfront costs associated with a project, by focusing on the balance between environmental sustainability and cost-efficiency during the entire life cycle of an asset (AA. VV. 2013a).

The utilization of 6D-BIM technology can result in more complete and accurate environmental and energy estimates earlier in the design process. It also allows for measurement and verification during building occupation, and improved processes for gathering lessons learned in high performance facilities.

The energy analysis varies in different countries, as in each country /region the building codes addressing public health, safety and environmental protection may be very different. In large part, building codes establish a building's quality, safety and energy performance for years to come, because initial design and construction decisions determine operational and maintenance costs for the whole life span of the building. Building equipment and other components may be replaceable and upgradeable, but many aspects of building performance are permanently defined at the beginning, and are too expensive and difficult to change, especially in historical or listed buildings. Some requirements, such as fire safety codes and structural and seismic standards, affect citizens in obvious ways. Others, such as lighting quality, acoustics and air quality also have major effects on our health and productivity (EESI 2013). People spend nearly 90% of our lives inside buildings, according to the U.S. Environmental Protection Agency (Klepeis et al. 2001), which is why the EPA is concerned about the impact of indoor air quality on public health.

Model codes, a set of minimum requirements for building design, construction and operation to protect public health, safety and the natural resources that sustain us, help us "build it right" at the beginning (Lechner 1991). In the case of existing buildings the building codes can help to make our communities more resilient, sustainable and livable for generations to come, which lowers the price of mitigation for building owners. Model codes provide guidance on how to design, build and operate buildings to achieve these goals. They also provide an insurance industry grappling with the effects of climate change and extreme weather with a baseline for estimating and managing risk. This helps to control or lower the cost of insurance premiums. But model codes are effective only if they are enacted into law and enforced by state and local governments (EESI 2013). This is the reason why BEEP project is addressing also to the regulatory authorities.

6D BIM also involves detailed information that can support 7D BIM, which defines operations and facility management by building managers and owners. In 7D BIM approach, everything related to facility management process is collated at a single place within the building information model. The dimension is used to track important asset data such as its status, maintenance/operation manuals, warranty information, technical specifications, etc. to be used at a future stage.

Overview of BIM usage in Europe

European BIM market in EU was valued 1.8 billion in 2016, with a growth driven by integrated urban development trends and government policies and initiatives (ECSO 2019).

The construction sector heavily affects the economic, environmental and social development as a whole (WEF 2016) and in Europe in 2016 provided for 18 million jobs and contributed for almost 9% of GDP (EC 2018) and is a key driver of the overall economy even if it is facing numerous challenges relating to competitiveness, lavour shortage, resource efficiency and productivity (ECSO 2019). Digitalisation of the AEC industry is seen as one of the potential game changer for the sector and could contribute significantly to the sustainable development and the EU2020 Strategy (ECSO 2019). The European Commission has therefore supported several policies and initiatives to foster the digitalisation of the construction sector (the Strategy for the Sustainable competitiveness of the construction sector and its enterprises EESC 2013), the EUBIM Taskgroup 2017, and the foreseen DigiPLACE, the Digital Platform framework for Construction in Europe) integrating it also in other policy areas such as the EU directive on Public Procurement (EU 2014) which promotes the use of BIM in construction projects (ECSO 2019).

As a result, EU member states (with heterogeneous levels of implementation) are gradually adopting the digital innovations with BIM as a forerunner, even if the potential is yet to be realised: 29% of construction companies use BIM 3D, while 61% never used it, as for BIM 4D only 6% of companies are implementing it (Berger 2016). BIM implementation is also fragmented along the value chain as it is mostly used in the design and construction phases rather in the operation and maintenance phases (BCG 2016).. One of the key obstacles affecting BIM implementation is the market structure and the size of companies as BIM implementation is generally led by large companies, that have more capacity and human and economic resources, are more likely to work on large and complex projects requiring strong coordination and making BIM benefits more tangible, and are more likely also to be requested to use BIM. Another obstacles lies in the lack of demand from project owners generally related to the lack of awareness of the BIM benefits especially in the operation and maintenance stages (ECSO 2019).

Policy recommendations for BIM implementation in the BIM in the EU construction sector report from European Construction Sector Observatory ECSO (2019) concerns:

1. the strengthening of the collaboration between public and private sector, even more crucial as BIM maturity level rises;
2. the need for policy makers to implement tailored support as different stakeholders have different cost-benefit views on BIM implementation;
3. the need to exploit different types of incentives
4. the need to leverage the knowledge and experience of the so called “BIM Champions”;
5. the need find the right narrative around BIM implementation in order to target also the issues affecting each stakeholders and not only general problems (like waste, workers shortage or productivity as shown above).

3.4. Overview of BIM usage in Middle East Area

The status of BIM adoption is under current evaluation in many regions, since the Smart market Report of 2007 (McGraw-Hill 2007). Usually “BIM adoption rate”, “depth of implementation”, “level of proficiency”, and “year of using BIM” are used a indicators of the BIM adoption (Jung and Lee 2015). In a recent study on BIM implementation in Middle East, nine countries 138 architect and contractors from 9 countries (Bahrain, Egypt, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia and United Arab Emirates), were surveyed on their level of BIM use.

In terms of BIM implementation (the firm percentage of project that involves BIM) the joint statistics of the countries Bahrain, Egypt, Jordan, Kuwait, Lebanon, Oman and Qatar record a 45% of Light BIM implementation (less than 30% of project involve BIM), a 15% of medium BIM implementation (between 30% and 60%) and a 41% of heavy BIM implementation (above 60%). In terms of years of experience, the same statistical segment answered with a 24% of 1-2 years of experience, a 47% of 3-5 years, a 6-10 years with 6-10 years and just a 6% with more than 10 years. In terms of BIM expertise level (where the sample was asked to self-describe their skill level as basic, moderate, advanced or expert), the answers returned 24% of experts, 35 of advanced, 32 of moderate and 9% of basic expertise level (Dodge Analytics 2017). Light implementation is currently the most common level across Middle East that is defined in the report an area in a relatively early phase of adoption (Dodge Analytics 2017). From the expert survey of the whole Middle East area, the industry education to build awareness of BIM benefits and the demonstration of the benefits of BIM during the construction management stage were highlighted as the key factors influencing BIM adoption and use, while the lack of people with BIM skills, the lack of time and budget to conduct BIM training and planning, and the initial costs of implementing the procedure were highlighted as major obstacles (Dodge Analytics 2017).

3.5. HBIM introduction

HBIM acronym refers to Heritage or Historical Building Information Model, that is the use of BIM methodology in the built heritage.

A historical building, beyond its physical and geometric characteristics, is represented by a large amount of heterogeneous information (Saygi and Remondino 2013; De Luca et al. 2011). Heterogeneity and accessibility of data have always been a problem in the field of conservation and enhancement of historic buildings (Bassier et al. 2016; Inzerillo et al. 2016; Elena Gigliarelli et al. 2017). As demonstrated by the growth of studies, mainly in the Italian and UK area (Pocobelli et al. 2018; Logothetis, Delinasiou, and Stylianidis 2015; López et al. 2018), BIM seems capable of triggering a new evolution in the management of all "knowledge documentation" (Negri 2008) aimed at the conservation project and beyond (Gigliarelli et al. 2017), and could answer to the growing demand of accessibility and management methods for multidisciplinary knowledge (Fai et al. 2011). Although BIM was initially designed for new buildings, its aptitude for accumulating interrelated semantic information makes it a tool with great potential also in application to existing buildings (Volk, Stengel, and Schultmann 2014), and to cultural heritage (S. Brusaporci and Maiezza 2016).

Despite its potential for the built heritage, the scientific literature on BIM still shows a strong predominance of BIM applied to new construction, with only a small part of scientific productions concerning BIM applications to existing buildings, a large part related to buildings with already available BIM model, (Volk, Stengel, and Schultmann 2014), and only a small part related to historical buildings (Logothetis, Delinasiou, and Stylianidis 2015). In the heritage field, in fact, the development and management of parametric geometries is harder due to the heterogeneous nature of existing objects, deriving, for instance, from a laser scanner survey (Garagnani and Manferdini 2013; Maxwell 2016a). The same also applies to information modeling, which refers to processes and data that can be very different from those related to the new buildings (Saygi and Remondino 2013). These deviations from a routine application involve the need for reflection on the appropriate objects and parameters for the historical building (Stefano Brusaporci 2017), which are not present in the available libraries or in the native software functions nor in the standards currently available. In recent years, guidelines have appeared for the transfer of the BIM process to the historical building.

For instance, the preliminary framework offered by the COTAC (Council on Training in Architectural Conservation) report of 2014 (Maxwell 2014) deals with the topic of digital technologies in support of the conservation of historic buildings (in particular with regard to geometrical survey) and potential additions with BIM technology, witha first attempt to transfer the BIM Maturity Levels defined by the BIM Task Group (BIM Task Group 2011) to the historical building.

The subsequent 2016 COTAC reports (Maxwell 2016a; 2016b) introduce a further reflection: while the architect's work for the new construction requires more and more skills in the selection, synthesis and integration of existing components, the architect's work for the built heritage requires different skills and knowledge. The reports first try to identify the common aspects in the field of conservation and new construction in terms of BIM development, while part 2 deals with the specific issues of historical construction through a three-step Framework Evaluation Criteria which aims to stimulate reflection for effective development of HBIM, such as aspects relating to the urban context, the cultural values of the building and the collection and storage of data. In its two reports from 2017, Historic England goes further retracing the progress of BIM in the new construction and then transferring it to the historical context, also contributing to the definition of a glossary, the identification of the most common procedures, and also an examination of case studies mainly English (Brookes 2017; Antonopoulou and Bryan 2017). The last Historic England Report instead dive into heritage asset management introducing the concept of Asset Information Model for a BIM information management approach of the built heritage, to help stakeholders consider how BIM can be used in the planning and delivery of conservation, repair and maintenance (AA.VV. 2019).

4. BUILDING ENERGY SIMULATION AS A TOOL FOR ENERGY IMPROVEMENT

Environmental energy simulations are among the most advanced tools for improving the energy efficiency of buildings, as they allow the creation of a behavioural model of a building at a given stage of its development and enhance its digital simulation to analyse its performance, to be returned in the form of results (Augenbroe 2002). The main innovation introduced by the simulations, with respect to previous methodologies of analysis and evaluation of the energy-environmental performance of buildings, is the possibility of treating them as an integrated system of related elements that can be optimized and not as the sum of elements designed and optimised separately (Hensen 2004). The purpose of simulations is not only to reveal the interactions between the building, occupants, HVAC systems and the outdoor climate, but also to facilitate the use of environmentally and energy-efficient design solutions (Hong, Chou, and Bong 2000). The simulations, in fact, support users in understanding complex phenomena by providing relatively rapid feedback on the performance implications of the design hypotheses (Clarke and Hensen 2015). The design of the built environment is complicated by the interaction of heterogeneous technical domains and pervasive uncertainties. The simulations provide a way to deal with complexity by allowing to explore the impacts of design parameters on solutions that target specific performance objectives within certain acceptable economic constraints (Clarke and Hensen 2015).

4.1. Building performance simulation and the built heritage

In the field of historical built heritage, environmental energy simulations are particularly interesting because they guarantee innovative non-destructive applications in both pre-diagnostic and diagnostic terms. These tools in fact:

1. facilitate the understanding and analysis of complex phenomena, dynamically studying the exchange of energy between the building and the surrounding environment including biophysical (water, soil, vegetation) and bioclimatic (solar radiation and ventilation) factors. This allows for innovative applications also in non-destructive analysis techniques;
2. provide retroactive feedback on the evolution of decay phenomena and on energy and environmental implications of conservation interventions. We refer to specific heat air and moisture transport software for predictive analysis in building envelopes, or to the possibility of dynamically studying the trend of physical quantities related to comfort (but also to the possible formation of degradation phenomena) within each single room.
3. allow, through the methods of environmental analysis, to investigate the constructive events of ancient architecture in ways so far completely unexplored, that are halfway between virtual and experimental archaeology, reconstructing models to be studied (e.g. allowing to study how the spaces were probably used in a building or how back in the day devices were used to improve comfort of occupants, provide further elements to a historical analysis).

The simulation-based study of the bioclimatic behavior of historic fabrics provides an added knowledge value to the explorative process of the building itself, allowing the possibility to model its natural functioning processes, paving the way for design solutions capable of enhancing its distinctive characteristics and identities linked to the local microclimate.

5. Energy Efficient HBIM: an overview on interoperability

5.1. HBIM and interoperability

When referring to interoperability in HBIM, at least two aspects can be highlighted. The first is linked to the lifespan of an historic building, which makes even more important the need to preserve and make usable over time the 3D-semantic organization of data of the HBIM model. The second refers to the already highlighted need for the heritage industry to integrate heterogeneous data in BIM modeling, but also complex diagnostic analyses for which it is not possible to derive semi-standardized workflows from applications in new construction and for which it is therefore necessary to work both at the diagnostic and HBIM modeling level to find effective ways of data management.

This is a field of research in itself, on which the first experiments (Pocobelli et al. 2018; Brusaporci et al. 2018; N. Bruno and Roncella 2019; S. Bruno 2018) are going in the direction of a semantic enrichment of the BIM file or its extended CDE platform, so that the knowledge is consistently and robustly structured and archived to be accessible even by non BIM experts (as in the case of web interfaces).

5.2. BIM and energy simulation interoperability approaches

Within a shared BIM process involving different operators of the construction sector, each using its specific methods and software, interoperability is paramount for a consistent, non redundant, efficient process. However, there is currently a lack of standardization in the use of open standards to share data (geometric and technical information) between BIM model software and energy analysis software.

To deal with energy analysis in a BIM process, three different scenarios can be identified:

A. Complete separation between authoring BIM model and energy model: the energy expert introduces manually all the information he needs in the energy analysis software
B. Manual or semi-automatic integration between authoring BIM model and energy model: The energy expert can partially import information from authoring BIM model to energy model, but he has to manually integrate specific data and tweak the result of import process
C. An extension of the IFC standard is proposed so that any software compliant with the standard will be able to exchange all the information he needs for that particular use of the model. A full interoperability is reached.

The scenario A is “one solution for once”, that is, any time a new evaluation needs to be performed, the information need to be inserted manually again.

The scenario B is "one to one solution", that is, the two software are partially interoperable but there is still manual control needed.

The scenario C is "many to many solution", that is it is fully interoperable with any software compliant to the openBIM standards. This scenario is currently not developed for energy simulation nor HBIM.

5.3. HBIM and energy simulation interoperability: ongoing researches

The joint applications of BIM and numerical simulations of the environmental energy performance of historic buildings (Energy Efficient Heritage BIM) are still not widespread in everyday professional practice. Even only the translation of the BIM approach or the application of simulations to the historical construction entails additional methodological reflections, aimed in both cases at maximising the potential offered by new technologies while being aware of their current limits of use. A similar argument also applies to their joint use which constitutes a complex variant of the studies that currently address the issue of interoperability between BIM and simulations on new construction. The same also applies to their joint use which constitutes a complex variant (Elena Gigliarelli et al. 2017; E. Gigliarelli et al. 2019) of the studies that currently address the issue of interoperability between BIM and simulations on new construction (Senave and Boeykens 2015; Maile et al. 2013; GSA 2012; Kamel and Memari 2019). One of the most significant case study in terms of joint use of the two technologies can be found in the Italian industrial research project METRICS Management and Requalification of Historic Centres and Buildings, funded by the PON Research and Competitiveness 2007-2013 (Elena Gigliarelli, Calcerano, and Cessari 2017). The objective of METRICS was the development of innovative approaches and methodologies for the energy improvement of historic centres. The project addressed the issue with a multiscale, multidisciplinary and holistic approach, which involved the use of HBIM technology as a basis for the environmental energy analysis of buildings and the development of intervention strategies both on the urban scale and on the individual building. Within the project specific focuses were developed on the interoperability between HBIM and dynamic simulations software ecologies (Elena Gigliarelli et al. 2017; E. Gigliarelli et al. 2019).

6. SELECTION OF RECENT RELATED EUROPEAN RESEARCH PROJECTS

6.1. Energy improvement of historical buildings

<u>HeLLo</u>

Heritage energy Living Lab onsite

Start date: 1 October 2018, End date: 30 September 2020

" HeLLo aims at spreading awareness about the most common energy retrofit solutions and increase knowledge of their application in historic buildings, hoping to contribute in the EU refurbishments strategies issues related to the historic heritage. There are two specific objectives: to check the compatibility of technologies already certified and applied to new buildings on historic constructions and, to create a structured dissemination programme that opens the doors of laboratory life to the outside of the academic boundaries[29]".

RIBuild

RI-Build Robust Internal Thermal Insulation of Historic Buildings

Start date: 1 January 2015; End date: 30 June 2020

"RIBuild will strengthen the knowledge on how and under what conditions internal thermal insulation is to be implemented in historic buildings, without compromising their architectural and cultural values, with an acceptable safety level against deterioration and collapse of heavy external wall structures. The general objective of RIBuild is to develop effective, comprehensive decision guidelines to optimise the design and implementation of internal thermal insulation in historic buildings across the EU. RIBuild focuses on heavy external walls made of stone, brick and timber framing, as most historic buildings are made of these materials[30]".

EFFESUS

Start date: 1 September 2012; End date: 31 August 2016

"The main goal of EFFESUS is to develop and demonstrate, through case studies a methodology for assessing and selecting energy efficiency interventions, based on existing and new technologies that are compatible with heritage values. A Decision Support System will be a primary deliverable. The environment in historic buildings and urban districts is controlled differently from modern cities and accordingly the project will also develop a multi-scale data model for the management of energy. In addition, new non-invasive, reversible yet cost-effective technologies for significantly improving thermal properties will also be developed. Finally, existing regulations and building policies may not fit cultural heritage specificities so the EFFESUS project will also address these non-technical barriers[31]".

3ENCULT

Efficient ENergy for EU Cultural Heritage

Start date: 1 October 2010, End date: 31 March 2014

"The project 3ENCULT bridges the gap between conservation of historic buildings and climate protection, which is not an antagonism at all: historic buildings will only survive if maintained as living space. Energy efficient retrofit is useful for structural protection

[29] https://cordis.europa.eu/project/id/796712.
For further information: https://hellomscaproject.eu/
[30] https://cordis.europa.eu/project/id/637268
For further information: https://www.ribuild.eu
[31] https://cordis.europa.eu/project/id/314678
For further information: https://www.effesus.eu/

as well as for comfort reasons - comfort for users and “comfort” for heritage collections.

The joint task of conservation and energy efficient retrofit is highly interdisciplinary. [...] The main objectives are the development of passive and active solutions for conservation and energy efficient retrofit including available products as well as new developments by involved SMEs, the definition of diagnosis and monitoring instruments, the long term monitoring (also for IEQ controlling) and the planning and evaluation tools and concepts supporting the implementation, the quality assurance and control of success of the energy retrofit measures”[32].

CLIMATE FOR CULTURE

Damage risk assessment, economic impact and mitigation strategies for sustainable preservation of cultural heritage in the times of climate change

Start date: 1 November 2009; End date: 31 October 2014

“CLIMATE FOR CULTURE project will couple completely new high resolution (10x10km) climate change evolution scenarios with whole building simulation models to identify the risks for specific regions. The innovation lies in the elaboration of a more reliable damage assessment by connecting the future climate data with whole building simulation models and new damage assessment functions. In situ measurements at UNESCO sites throughout Europe will allow a much more precise and integrated assessment of the real damage impact of climate change on cultural heritage. Appropriate sustainable mitigation/adaptation strategies, also from previous projects, are further developed and applied on the basis of these findings simultaneously. All these results will be incorporated into an assessment of the economic impacts[33]”.

SECHURBA

Sustainable Energy Communities in Historic URBan Areas

Start date: 1 September 2008; End date: 28 February 2011

This project aimed to look at these buildings on a community level and try to develop ways to encourage energy efficiency practices and renewable energy systems into these communities and set best practice examples to encourage other communities and local actors and policymakers to follow suit. The project showed cultural heritage as an opportunity to pave the way for carbon reductions rather than being considered a barrier. Audits were undertaken in each partner area and software developed for use by key players (Planners, Architects, Conservation Officers) to make decisions regarding sustainable energy intervention. The community were engaged with throughout the whole process to ensure that feedback was gathered and also that

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[32] https://cordis.europa.eu/project/id/260162
For further information: http://www.3encult.eu/en/project/welcome/default.html
[33] https://cordis.europa.eu/project/id/226973
For further information: https://www.climateforculture.eu/

there was a process of education regarding renewable technologies and energy efficiency methods[34].

6.2. BIM, energy efficiency, interoperability

HESMOS

Start date: 1 September 2010, End date, 31 December 2013

“HESMOS will achieve an industry-driven holistic approach for sustainable optimisation of energy performance and emissions (CO2) reduction through integrated design and simulation, while balancing investment, maintenance and reinvestment costs. The objective is to close the gaps between existing intelligent building/facilities data so that complex lifecycle simulation can easily be done in all design, refurbishment and retrofitting phases where the largest energy saving potentials exist[35]”.

HOLISTEEC

Holistic and Optimized Life-cycle Integrated SupporT for Energy-Efficient building design and Construction ()

Start date: Oct 1, 2013, End date: Sep 30, 2017

“The main objective of HOLISTEEC is thus to design, develop, and demonstrate a BIM-based, on-the-cloud, collaborative building design software platform, featuring advanced design support for multi-criteria building optimization. This platform will account for all physical phenomena at the building-level, while also taking into account external, neighbourhood-level influences. The design of this platform will rely on actual, field feedback and related business models / processes, while enabling building design & construction practitioners to take their practices one step forward, for enhanced flexibility, effectiveness, and competitiveness[36]”.

DIMMER

District Information Modeling and Management for Energy Reduction

Start date: Oct. 1 2013, End date: Sep. 30 2016

“The DIMMER system integrates BIM and district level 3D models with real-time data from sensors and user feedback to analyze and correlate buildings utilization and provide real-time feedback about energy-related behaviors. It allows open access with personal devices and Augmented Reality (A/R) visualization of energy-related information to client applications for energy and cost-analysis, tariff planning and

[34] https://ec.europa.eu/energy/intelligent/projects/en/projects/sechurba
For further information: http://ec.europa.eu/energy/intelligent/projects/en/printpdf/projects/sechurba

[35] https://cordis.europa.eu/project/id/260088

[36] https://cordis.europa.eu/project/id/609138

evaluation, failure identification and maintenance, energy information sharing. All the following technologies are included: Real-time data collection; Advanced middleware technology for data integration; Simulation and virtual visualization; User/social profiling, visualization and feedback; Energy efficiency and cost analysis engine; Web interface and interaction"[37].

BIM4EEB

BIM based fast toolkit for Efficient rEnovation in Buildings

Start date: 1 January 2019, End date: 30 June 2022

"BIM4EEB aims to foster the renovation industry by developing an attractive and powerful BIM-based toolset able to support designers in the design and planning phase, construction companies to efficiently carry out the work and service companies to provide attractive solutions for building retrofitting. Additionally, public and private owners will be able to use a tool that eases decision making and asset management, thanks to the exploitation of augmented reality and the use of updated digital logbooks. BIM4EEB will deliver an innovative common BIM management system with linked data and a set of tools. This toolkit is the basic instrument for increasing semantic interoperability between software and stakeholders involved along the overall renovation process (design, planning, construction, performance assessment and management)[38]".

BIM4REN

Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings

Start date: 1 October 2018, End date: 30 September 2022

"If BIM is key to address the construction sector growing technical complexity, to overcome construction processes fragmentation and communication problems between stakeholders, to reduce on-site time and improve quality and affordability, its uptake for the renovation of the EU existing building stock is yet to come and already late. To face this BIM4REN starts from 3 workflows adapted to the construction sector segmentation (90% of companies are SMEs) presenting particular technical and organisational requirements and has adapted the project and consortium to provide adequate and innovative processes, methodologies, software and hardware tools & BIM developments for each one of them, backboned by state of the art BIM technologies like worldwide used BIM Server (open-source) and BIM Bots by TNO among many others[39]".

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[37] https://cordis.europa.eu/project/id/609084
For further information: http://www.drawingtothefuture.polito.it/projects/dimmer/

[38] https://cordis.europa.eu/project/id/820660
For further information: www.bim4eeb-project.eu

[39] https://cordis.europa.eu/project/id/820773
For further information: https://bim4ren.eu/

BIM-SPEED

Start date: 1 November 2018 End date: 31 October 2022

"The Horizon2020 project BIM-SPEED aims to address this challenge by developing a combination of methodologies and tools with one central information source at its core: the Building Information Model (BIM), a digital representation of a building. This model will be the catalyst for a smarter, more efficient, method of deep renovation for the residential building sector[40]".

6.3. HBIM

INCEPTION

Inclusive Cultural Heritage in Europe through 3D semantic modelling

Start date: 1 June 2015, End date: 31 May 2019

"INCEPTION realises innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, built and social environments. [...] INCEPTION's Inclusive approach comprises: time dynamics of 3D reconstruction ('forever'); addresses scientists, engineers, authorities and citizens ('for everybody'); and provides methods and tools applicable across Europe ('from everywhere'). [...] INCEPTION methods and tools will result in 3D models that are easily accessible for all user groups and interoperable for use by different hardware and software. It develops an open-standard Semantic Web platform for Building Information Models for Cultural Heritage (HBIM) to be implemented in user-friendly Augmented Reality (VR and AR) operable on mobile devices[41]".

[40] https://cordis.europa.eu/project/id/820553
For further information: https://www.bim-speed.eu/en
[41] https://cordis.europa.eu/project/id/665220
For further information: https://www.inception-project.eu/en

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8. ANNEXES

ANNEX 1: Energy efficiency and HBIM usage according to local best practices – Italy

ANNEX 2: Energy efficiency and HBIM usage according to local best practices – Spain

ANNEX 3: Energy efficiency and HBIM usage according to local best practices – Cyprus

ANNEX 4: Energy efficiency and HBIM usage according to local best practices – Jordan

ANNEX 5: Energy efficiency and HBIM usage according to local best practices – Palestine

ANNEX 6: Energy efficiency and HBIM usage according to local best practices – Lebanon

ANNEX 7: Energy efficiency and HBIM usage according to local best practices – Egypt

ANNEX 1 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF ITALY

Country:	Italy
Date:	25/02/2020
Prepared by:	BEN ISPC-CNR
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Index

1. GENERAL INFORMATION

1.1. General Italy data (population, official language, capital, area, GDP total/per capita, currency)

The Italian territory extends for a length of 1.200 kilometres between the 35th and 47th parallel north. The total area is 302.073 km² with a significant coastal development of about 7.458 km ('Italian National Energy Efficiency Action Plan 2017 - ANNEX 1 Upgrading the Energy Efficiency of the National Building Stock' 2017, 1); the resident population as of January 1st, 2019 is 60 million and 391 thousand residents (ISTAT 2019b).

Italy is divided into 7.954 Municipalities and 107 supra-municipal territorial units (of which 83 provinces, 14 metropolitan cities). The 20 regions, 5 of which with special status, are grouped together in geographical divisions of the Italian territory: North-West, North-East, Centre and South (consisting of the South and the two island regions). The average altitude is about 337 meters above sea level, the territory is mainly hilly (41,6% of the national surface) and mountainous (35,2%) with a smaller extension of the lowland areas (23,2 %), where the population is mainly concentrated (49,0%, while 38,8% of the population resides in the hill areas and only 12,2% in the mountain municipalities). The mountain and hill areas have been further divided into inland and coastal areas due to the mitigating action of the sea that acts on the latter. The coastal areas are more densely populated: 397 inhabitants per km² against 167 of the non-coastal ones (ISTAT 2019a).

The following table shows a general picture of surface, population and density treated according to the division into areas just described (ISTAT 2019a).

Geographical areas		Internal mountain	Coastal mountain	Internal hill	Coastal hill	Flat land	Italy
Italy	Surface	33,6%	1,6%	30,3%	11,3%	23,2%	302.073km²
	Populat.	9,9%	2,3%	23,2%	15,6%	49,0%	60.359.546
	Density	59	292	153	274	423	200 in/km²
North west	Surface	46,5%	0,8%	19,5%	2,2%	31%	
	Populat.	11%	4%	21,5%	4,5%	59%	
	Density	66	1359	307	568	529	
North east	Surface	45%	-	16%	0,7%	38,4%	
	Populat.	14,2%	0%	19%	2,3%	64,5%	
	Density	59	-	222	651	314	
Center	Surface	26,4%	0,5%	49,9%	14%	9,2%	
	Populat.	7,3%	1,3%	37,3%	18,2%	35,9	

	Density	57	522	155	269	805	
South	Surface	31,6%	3,1%	30,4%	15,1%	19,8%	
	Populat.	9,7%	1,5%	18,9%	30,5%	39,4%	
	Density	58	91	118	381	376	
Islands	Surface	15,9%	3,3%	37,9%	26,7%	16,3%	
	Populat.	4,6%	5,5%	18,4%	29,7%	41,7%	
	Density	39	222	65	148	341	

The geographical characteristics of the Italian peninsula give Italy a great climatic variability, from the Mediterranean subtropical climate in the South (with summer temperatures even above 40° C), to the temperate continental climate of the northern regions (with winter temperatures that can reach -20° C).

The D.P.R. August 26, (P.R. 1993), n. 412 has addressed this great variability by dividing the Italian municipalities into 6 climatic zones according to the degree days (ISO 15927-6: 2008 and UNI 10349-3:2016) of the typical year (ISO 15927-4: 2005) of the municipality. Belonging to a climatic zone determines the period of the year and the number of daily hours in which the heaters can be switched on. The "degree day" of Italian municipalities range from 568 in Lampedusa (Agrigento) to 5,165 in Sestriere (Turin).

Climate Zone	Degree Day (DD)	Number of municipalities	Residential population	% Residential population
A	DD≤ 600	2	22.989	0,04%
B	600 <GG ≤ 900	157	3.176.382	5,33%
C	900 <GG ≤ 1.400	989	12.657.407	21,25%
D	1.400 <GG ≤ 2.100	1611	14.970.952	25,13%
E	2.100 <GG ≤ 3.000	4271	27.123.848	45,53%
F	DD>3.000	1071	1.619.003	2,72%

National energy consumption for winter heating can be considered proportional to the the degree days and the population (ISO 15927-6: 2008, UNI 10349-3: 2016), therefore that climatic zone E, the most populated, has higher consumption, while climatic zones A and B have little impact on national consumption. The latitude difference between North and South also involves large differences in the values of global solar radiation on the horizontal surface ranging from 1.214 kWh/m² in Ahrntal (Bolzano) to 1.679 kWh/m² in Pachino (Syracuse), with an average of 1.471 kWh/m² (0,127 toe/m²). The UNI 10349 series of standards reports the values of the climatic monthly data of the various Italian municipalities that can be used for the energy performance calculations of buildings.

1.2. Description of Italy building stock

On the national territory, the buildings and complexes surveyed in 2011 amounted to 14.515.795, 13,1% more than in 2001. 84,3% of the buildings surveyed overall are residential (equal to 12.187.698), an increase of 8,6% compared to 2001. Among non-residential buildings, the largest part is made up of those destined for productive use (18.9%), followed by commercial ones (16,2%) and services (11,7%). The share of buildings for tourism / hospitality use is 4% as the one for management/service (ISTAT 2014).

Type of building	Climate zone	Number of buildings	Values %
Residential	A B C	3.412.000	28%
	D	2.803.000	23%
	E F	5.972.000	49%
	Total	12.187.000	100%
Non-residential			
Offices	A B C	18.525	28%
	D	18.265	28%
	E F	28.210	44%
	Total	65.000	100%
Schools	A B C	14.014	27%
	D	12.976	25%
	E F	24.914	48%
	Total	51.904	100%

Residential building

The number of houses registered in 2011 amounted to 31.208.161; 77,3% are occupied by at least one resident person, the remaining 22,7% comprises empty houses or is occupied only by non-residents. 51,8% of residential buildings are single dwellings (ISTAT 2014). Over 60% of this building stock is over 45 years old, and was built prior the first Italian law on energy efficiency (Law n. 3733 of 1976). Of these buildings, over 25%

record annual consumption from a minimum of 160 kWh/m² per year to over 220 kWh/m². An overview of the residential building stock is shown below divided by year of construction and climatic zone (NEEAP 2017).

Year of construction	Number of residential buildings	%
Pre-1918	1.832.504	15,0%
1919 - 1945	1.327.007	10,9%
1946 - 1960	1.700.836	14,0%
1961 - 1970	2.050.833	16,8%
1971 - 1980	2.117.651	17,4%
1981 - 1990	1.462.767	12,0%
1991 - 2000	871.017	7,1%
Post-2001	825.083	6,8%
Total buildings	12.187.698	100%

Climate zone	Number of residential buildings	%
A	4.875	0,04%
B	699.573	5,74%
C	2.710.544	22,24%
D	2.858.016	23,45%
E	5.191.960	42,60%
F	722.730	5,93%
Total	12.187.698	100%

Non-residential buildings

On the Italian territory there are about 435.000 non-residential buildings intended for use as schools, offices, shopping centres, hotels, etc., shown in the table below along with climate zone and related surface (MISE 2019).

Climate zone	number of non-residential building	m^2
zone A	148	173.490
zone B	22.515	23.421.687
zone C	84.233	83.915.666
zone D	102.264	95.050.723
zone E	206.451	125.487.887
zone F	19.119	13.231.516
Total	434.730	341.280.969

As regards hospitals (not included in the previous table), from the statistical yearbook of the National Health Service, in 2016 there were over 27.000 accredited public and private health facilities in Italy (MISE 2019).

Public owned buildings

From the report on public administration real estate (containing data up to year 2016) published by the MEF, it appears that the buildings of the public administrations surveyed at 2016 are 1.056.404 (MEF 2018).

The estimate of the value of this real estate asset, carried out on 1.029.471 buildings of 340.434.000 m^2 of estimated surface, is equal to € 284.190 million.

By dividing the stock into two categories of buildings, residential and commercial on one side (houses, cellars / garages, commercial premises) and institutional buildings on the other (structured offices, barracks, sports facilities, schools, etc.), it appears that the Approximately 76% of the real estate units are "residential and commercial", however these constitute only 15% of the total area declared. On the contrary, the "institutional purposes" category represents approximately 24% in terms of size and 85% of surface area as shown on the table below (MEF 2018).

Cluster	Cadastral units	Declared area	Estimated area (*)	Asset value
	(number)	sqm/1000	sqm/1000	(€/mln)
Office	48.376	39.434	39.434	71.369
Housing	594.337	45.242	45.453	48.703
Historical palaces	8.386	9.909	9.909	18.267

Warehouses[1]	66.657	20.912	20.912	11.717
Collective residences	6.123	7.290	7.290	5.954
Box and parkings[2]	184.532	8.780	8.780	5.198
Shops	28.794	2.828	2.828	5.132
Hotels	2.181	1.713	1.713	1.999
Roadman's house	1.891	271	271	134
Prisons	378	3.000	3.003	2.451
Barracks	13.931	23.321	24.015	22.932
Schools	46.429	90.006	92.001	46.454
Hospitals	11.731	40.457	39.566	39.371
Sport facilities	15.725	45.260	45.260	4.508
Total Cluster subject to estimate	1.029.471	338.422	340.434	284.190
Buildings not subject to estimate	26.933	23.597		
Total registered assets	1.058.404	362.018		

(*) surfaces with declared values equal to zero or anomalous with respect to the type have been estimated.

Buildings declared unused represent 7% in terms of size and 4 per cent in terms of area (MEF 2018).

<u>Energy consumption evaluation</u>

The estimate of average consumption for the various uses has been developed with reference to the distribution of buildings by climate zone and construction period, as well as on the basis of consumption data derived from statistical surveys on a representative set of buildings. The table below shows climate-weighted average yearly annual consumption for intended use (MISE 2019).

Intended use	Electricity consumption (kWh/m^2 yearly)	Heating consumption (kWh/m^2 yearly)	Total consumption (kWh/m^2 yearly)

[1] Includes the types: "Buildings for production activities", "Warehouses and storage rooms", "scientific laboratories".
[2] Includes the types: "Collective parking", "Box, covered and uncovered parking spaces, cellars".

single-family residential	21	124	145
multi-family residential	21	123	144
Schools	17	89	106
Offices	111	45	156
Hotels	110	150	260
Retail			448
Public administration	55	143	198
Hospitals	253	385	638

1.3. Description of Italy construction industry

The Italian economy has experienced a great recession over the last decade and, unlike the majority of European countries, has not yet recovered its pre-crisis levels. In the past year, in fact, GDP closed on a 4,1% reduction compared to 2007 (against + 11,3% in France and + 15,5% in Germany). The growth rate recorded in 2019 by the Italian economy was close to zero (ANCE 2020). According to recent forecasts of the European Commission, by 2020 Italy should grow by 0,3% (EC 2020). In this context, the fundamental contribution of the construction industry, which in recent years has experienced a profound crisis, is still lacking and is not able to the economy as it had happened in the previous expansionary cycle 1998-2008: +28,4% investment in construction and +16,1% GDP (ANCE 2020).

The Italian construction industry gross value added (GVA) accounted for 16,7% of Italy's 2018 GDP and is among the key sectors in the national economy. Comparing 2018 with 2010, companies decreased by 7,2%, production fell by 30,9% and workers by 21,1%. This decline is also highlighted by the drop in residential building permits (-58,4% between 2010 and 2017) and house price index (-16,5% between 2010 and 2018). Since 2014 the housing market has shown signs of recovery thanks to low interest rates and improved households mortgage lending (EC 2019b).

Issues and barriers in the construction sector

There are a number of problems that slow down the transition to a sustainable construction industry model in Italy. Firstly, the access to finance continues to be limited, with a 46% reduction in loan to the construction sector between 2010 and 2018 (from EUR 170,6 billion to EUR 92,1 billion). Another problem is related to late payment that raises question about the liquidity available in the sector. A number close to 70% of companies reported delays in payments by the public administration in 2017 with an average waiting time of 156 days, in a sector that has one of the worst payment practices in the general economy with only 2,8% of total payments being settled by due date in 2018. The third issue is productivity, that is impaired by challenging business environment, inefficiencies in public administration and fragile institutional structures, and is still far below the EU-28 average (EC 2019b).

Economic drivers of the construction sector

In 2017, the budget law introduced strong measures to stimulate public and private investment in infrastructure also including seismic safety measures (up to 85% of deduction) and energy efficiency. The budget law of 2019 provided additional resources and contributed to refinance the Development and Cohesion Fund establishing also two new funds to revive public investments and community policies implementation. EU funding is also another crucial driver (3,4 billion of European Regional Development Fund for network infrastructure in transport and energy alone during 2014-2020, (EC 2019b)

Ratio between new construction and interventions on existing buildings

The National Association of Construction Companies (ANCE) reports an increase of 5,4% in terms investments in new homes between 2018 and 2019, confirming a positive trend that began in 2017. In previous years, this specific sector has undergone a drastic contraction in production levels of about 70%, resulting in the most penalized by the long and heavy crisis (ANCE 2020). Investments in the redevelopment of housing stock confirm the positive dynamics of previous years, coming to represent around 37% of the value of investments in construction. Compared to 2018, growth of 0,7% in real terms is estimated for investments in this sector. This estimate takes into account the extension, until the end of 2020, foreseen in the latest Budget Law, of the 50% increase in the tax deduction for building renovations and the 65% tax deduction for the energy redevelopment of buildings. The result of 2019 also includes the first effects on production levels, albeit limited, deriving from the earthquake-bonus and eco-bonus destined for entire buildings (ANCE 2020).

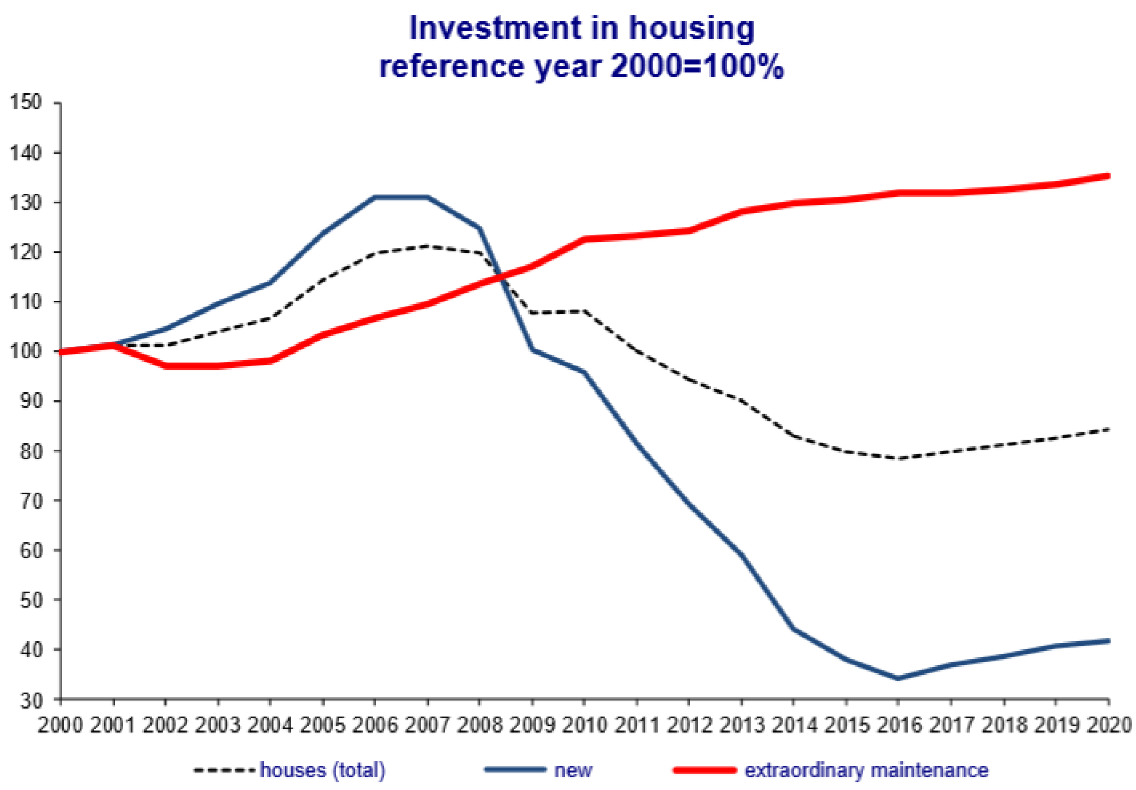


Figure 1: Investments in housing over time.

Innovation in the construction industry

Investments rising in R&D is one of the key factors contributing to the growth in innovation and the shift towards sustainable models in the construction sector among Italian companies. Italy's innovative strengths are represented by international scientific co-publications and SMEs innovating in house. Moreover, the permeation of BIM technology in the construction industry continues to rise and BIM processes will be mandatory for all public tenders by 2025 (and are already mandatory for public tenders over 50 mln euro, (MIT 2017).

The market for energy efficient renovation is also thriving on account of the Renovation Bonus and Eco Bonus, offering tax deductions of up to 65% on eligible renovation interventions. Italian construction companies are also known to be globally competitive" (ECSO 2019).

Italy regulatory framework and policies

Since the signing of the Kyoto Protocol in 1997, the European Union has engaged in a path of community and national policies and measures to decarbonise the economy. During the first period of the protocol (2008-2012), the EU committed itself to achieving the goal of reducing emissions by 8% compared to the 1990 level (against a 5% request expressed by the Protocol) and Italy contributed by committing to a 6.5% reduction in emissions. In 2006, the European Union outlines a new strategy (later merged into the directives contained in the "2020 climate & energy package" approved in 2009) in which for 2020 (compared to 1990 levels) a 20% reduction in emissions, a 20% improvement in energy efficiency (compared to estimated consumption values for 2020) and 20% of the energy needs derived from renewable sources are set as objectives. These objectives are then adopted by the "Europe 2020 strategy" and also represent the commitments made by the EU in the second period of the Kyoto Protocol which runs from 2013 to 2020 (see § 2.2 of the "State of the art analysis on HBIM and interoperability" Report).

In 2014, the package of directives contained in the "Clean energy for all Europeans package" (whose adoption is completed on 22 May 2019) were defined with the Communication from the European Commission "A policy framework for climate and energy in the period from 2020 to 2030" (EC 2014), the objectives to be achieved for the following decade (following the international agreements "Paris Agreement", COP 21 of December 2015) and the long-term strategy of zero net greenhouse gas emissions by 2050 (2050 long-term strategy, A Clean Planet for all November 2018).

The main energy and climate targets set for 2020 and 2030 by the EU and the Italian response with their national targets are set out below (source, MISE 2019).

	2020 Goals		2030 Goals	
	EU	ITALY	EU	ITALY (MISE 2019)
Renewable Energy Sources (RES)				
Share of energy from RES in Gross Final Energy Consumption	20%	17%	32%	30%
Share of energy from RES in Gross Final Consumption of energy in transport	10%	10%	14%	22%
Share of energy from RES in Gross Final Consumption for heating and cooling			+1,3% yearly (approximate)	+1,3% yearly (approximate)
Energy Efficiency				
Reduction of primary energy consumption compared to the PRIMES3 2007 scenario	-20%	-24%	-32,5% (approximate)	-43% (approximate)
Final consumption savings through mandatory energy efficiency schemes	-1,5% yearly (without transport)	-1,5% yearly (without transport)	-0,8% yearly (with transport)	-0,8% yearly (with transport)
Greenhouse gas emissions				
GHG reduction vs 2005 for all energy systems bound by ETS regulations	-21%		-43%	
GHG reduction vs 2005 for all non-ETS sectors	-10%	-13%	-30%	-33%
Overall reduction of greenhouse gases compared to 1990 levels	-20%		-40%	
Electrical interconnectivity				

[3] "The PRIMES model is an EU energy system model which simulates energy consumption and the energy supply system. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. This includes consistent EU carbon price trajectories" (EC 2016).

Electrical interconnectivity level	10%	8%	15%	10%
Electrical interconnection capacity (MW)		9.285		14.375

Currently, buildings account for approximately 40% of the EU's energy consumption and 36% of its CO_2 emissions. (ECSO 2018). For this reason, many of the measures to achieve European and National Goals concern the construction sector.

Regarding regulation, the directives most closely related to this sector can be divided into three groups: Renewable Energy Directives, Energy Performance of Buildings Directives (EPBD) and the Energy Efficiency Directives (EED).

Below are the European directives belonging to the three groups and the transposition into Italian legislation:

RENEWABLE ENERGY DIRECTIVES	
EUROPEAN DIRECTIVES	ITALIAN TRANSPOSITION LAWS
Directive 2009/28/EC (23 April 2009)	**D.Lgs. 28/2011** (3 march 2011)
Regarding the targets to be achieved, the Member State shall: ● collectively ensure that the share of energy from renewable sources in the Union's gross final energy consumption in 2030 is at least 20 % ● “ensure that the share of energy from renewable sources in all forms transport in 2020 is at least 10 % of the final consumption of energy in transport in that Member State.” ● “notify their national renewable energy action plans to the Commission by 30 June 2010. (...) The national renewable energy action plans shall set out Member States’ national targets for the share of energy from renewable sources consumed in transport, electricity and heating and cooling in 2020” Regarding the measures to be taken to achieve these targets, the Member States shall: ● “By 31 December 2014, (...) require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation. Member States shall permit those minimum levels to be fulfilled, inter alia, through district heating and cooling produced using a significant proportion of renewable energy sources.” ● “ensure that new public buildings, and existing public buildings that are subject to major renovation, at national, regional and	The law provides: ● In the case of new buildings or buildings undergoing major renovations, the thermal energy production systems must be designed and built in such a way as to guarantee coverage of 50% of the consumption expected for domestic hot water with renewable energy. For interventions subsequent to 1 January 2018, the threshold of 50% of the sum of the consumption expected for domestic hot water, heating and cooling has also been added. ● In the case of new buildings or buildings undergoing major renovations, the electrical power of plants powered by renewable sources that must be installed on or inside the building or in its pertinences, measured in kW, is calculated according to the following formula: P = 1 / K * S. (Where S is the plan area of the building at ground level, measured in sqm, and K is a coefficient that is worth 50 sqm/kW for interventions subsequent to January 1, 2017). ● For buildings in historic centers, the mandatory quotas for the use of energy from renewable sources are reduced by 50%. ● Buildings protected by the code of cultural heritage subjected to major renovations may not comply with the obligations on the use of renewable energies if the designer shows that compliance with the requirements implies an

local level fulfil an exemplary role in the context of this Directive from 1 January 2012 onwards. Member States may, inter alia, allow that obligation to be fulfilled by complying with standards for zero energy housing, or by providing that the roofs of public or mixed private-public buildings are used by third parties for installations that produce energy from renewable sources."	alteration that is incompatible with its identity and appearance, with particular reference to historical and artistic values.
Directive (EU) 2018/2001 (11 December 2018)	Awaiting transposition
Regarding the targets to be achieved, the Member State shall: ● "collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32 %. The Commission shall assess that target with a view to submitting a legislative proposal by 2023 to increase it" ● "set an obligation on fuel suppliers to ensure that the share of renewable energy within the final consumption of energy in the transport sector is at least 14 % by 2030 (minimum share)" ● "set national (...) as part of their integrated national energy and climate plans" Regarding the measures to be taken to achieve these targets, the Member States shall: ● "require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation" ● "endeavour to increase the share of renewable energy in that sector by an indicative 1,3 percentage points as an annual average calculated for the periods 2021 to 2025 and 2026 to 2030, starting from the share of renewable energy in the heating and cooling sector in 2020" ● "ensure that new public buildings, and existing public buildings that are subject to major renovation, at national, regional and local level, fulfil an exemplary role in the context of this Directive from 1 January 2012. Member States may, inter alia, allow that obligation to be fulfilled by complying with nearly zero-energy building provisions as required in Directive 2010/31/EU, or by providing for the roofs of public or mixed private-public buildings to be used by third parties for installations that produce energy from renewable sources." ● "promote the use of renewable heating and cooling systems and equipment that achieve a significant reduction of energy consumption.	

To that end, Member States shall use energy or eco-labels or other appropriate certificates or standards developed at national or Union level, where these exist, and ensure the provision of adequate information and advice on renewable, highly energy efficient alternatives as well as eventual financial instruments and incentives available in the case of replacement, with a view to promoting an increased replacement rate of old heating systems and an increased switch to solutions based on renewable energy in accordance with Directive 2010/31/EU. "	

ENERGY PERFORMANCE OF BUILDINGS DIRECTIVES (EPBD)	
EUROPEAN DIRECTIVES	ITALIAN TRANSPOSITION LAWS
Directive 2002/91/EC (16 December 2002)	**D.Lgs. 192/2005** (19 August 2005), **D.Lgs. 311/2006** (29 December 2006), **D.P.R. 59/2009** (2 April 2009), **D.M. 26/06/2009** (26 June 2009)
Article 1 lists the objectives of the directive: "This Directive lays down requirements as regards: (a) the general framework for a methodology of calculation of the integrated energy performance of buildings; (b) the application of minimum requirements on the energy performance of new buildings; (c) the application of minimum requirements on the energy performance of large existing buildings (total useful floor area over 1000 m^2) that are subject to major renovation; (d) energy certification of buildings (when buildings are constructed, sold or rented out); and (e) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old." The major renovation interventions are defined as follows: "Major renovations are cases such as those where the total cost of the renovation related to the building shell and/or energy installations such as heating, hot water supply, air-conditioning, ventilation and lighting is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or those where more than 25 % of the building shell undergoes renovation." In addition, Article 4 indicates the following:	The complex of these legislative acts regulates a series of issues concerning the energy point of view of buildings: ● minimum requirements regarding the energy performance of buildings modulated according to the type of intervention (but not in reference to the historical-artistic value of the building) ● Obligation to produce the Energy Certification (ACE) for new and existing buildings in the case of redevelopment interventions, real estate transactions, leasing and, in the case of public buildings, the stipulation of new or renewed plant management contracts of air conditioning. ● National guidelines for the energy certification of buildings. ● Methodology for calculating the energy performance of buildings (based on the technical standards of the UNI / TS 11300: 2008/2010 series) ● Obligation to insert solar thermal panels.

<table>
<tr><td>“Member States may decide not to set or apply the requirements referred to in paragraph 1 for the following categories of
buildings:
— buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance,
— buildings used as places of worship and for religious activities, (...)”</td><td></td></tr>
<tr><td>Directive 2010/31/EU (19 May 2010)</td><td>L. 90/2013 (3 August 2013, converte in legge il D.L. 63/2013) e D.M. 26/06/2015 (26 June 2015, Decreto attuativo L. 90/13)</td></tr>
<tr><td>Article 2 lists the objectives of the directive:
“This Directive lays down requirements as regards:
(a) the common general framework for a methodology for calculating the integrated energy performance of buildings and building units;
(b) the application of minimum requirements to the energy performance of new buildings and new building units;
(c) the application of minimum requirements to the energy performance of:
(i) existing buildings, building units and building elements that are subject to major renovation;
(ii) building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are retrofitted or replaced; and
(iii) technical building systems whenever they are installed, replaced or upgraded;
(d) national plans for increasing the number of nearly zero-energy buildings;
(e) energy certification of buildings or building units; (it is issued for buildings or building units which are constructed, sold or rented out to a new tenant and buildings where a total useful floor area over 250 m^2 is occupied by a public authority and frequently visited by the public)
(f) regular inspection of heating and air-conditioning systems in buildings; and
(g) independent control systems for energy performance certificates and inspection reports.”
Article 9 provides the following for zero-energy buildings:
“Member States shall ensure that:
(a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and</td><td>The subject of these legislative acts are:
● The calculation method for the energy performance of buildings (based on the technical standards of the UNI / TS 11300: 2014/2019 series).
● The minimum requirements regarding the energy performance of buildings in case of new construction, major renovations, energy retrofit).
● The definition of nZEB buildings (near Zero Energy Building) and the related obligations: by December 31, 2020 all new buildings or buildings subject to a first level renovation will have to meet almost zero energy requirements; the obligation is brought forward to December 31, 2018 for public buildings.
● The definition of a new Energy Performance Certificate (Attestato di Prestazione Energetica- APE) for buildings and real estate units.
● The development of financial instruments and the removal of market barriers to promote the energy efficiency of buildings.
● The use of renewable energy sources in buildings.
● The creation of a coordinated system of periodic inspection of thermal systems in buildings.
● Among the buildings excluded from the application of this law are religious buildings and historical listed buildings (the latter only if compliance with the requirements implies a substantial alteration of their identity or appearance, with particular reference to historical, artistic and landscape values; for these buildings, however, the provisions for the certification of the energy performance of the buildings and the operation, maintenance and inspections of the technical systems remain valid).</td></tr>
</table>

(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings." The major renovation interventions are defined as follows: "major renovation means the renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25 % of the surface of the building envelope undergoes renovation; Member States may choose to apply option (a) or (b)" In addition, Article 4 indicates the following: "Member States may decide not to set or apply the requirements referred to in paragraph 1 to the following categories of buildings: (a) buildings officially protected as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance; (b) buildings used as places of worship and for religious activities; (...)"	
Directive (EU) 2018/844 (30 May 2018)	Awaiting transposition
The directive modifies the previous Directive 2010/31/EU and in part also the Directive 2012/27/EU on energy efficiency. The changes do not concern the contents of the previous EPBD directive listed above but for the most part they are indications to the member states for planning the measures necessary to achieve the objectives by 2050. The target set for the energy requalification of existing buildings is particularly ambitious: "Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings.(...) the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990.(...)The roadmap shall include indicative milestones for 2030, 2040 and 2050." With regard to the tools provided for achieving these objectives, the most important novelty is	

the introduction of the building smart readiness indicator: “The Commission shall establish the definition of the smart readiness indicator and a methodology by which it is to be calculated, in order to assess the capabilities of a building or building unit to adapt its operation to the needs of the occupant and of the grid and to improve its energy efficiency and overall performance.” The directive also provides for measures that favor the installation of recharging points for electric vehicles in the parking lots of buildings both of new construction and subject to renovation.	

<table>
<tr><th colspan="2">ENERGY EFFICIENCY DIRECTIVES (EED)</th></tr>
<tr><th>EUROPEAN DIRECTIVES</th><th>ITALIAN TRANSPOSITION LAWS</th></tr>
<tr><td>Directive 2006/32/EC (5 April 2006)</td><td>D.lgs. 115/2008 (30 May 2008)</td></tr>
<tr><td>The directive provides for each member state a national energy saving target of 9% for 2016.
The directive requires member states to carry out an "Energy Efficiency Action Plan" on planned measures to achieve the 9% target. The first to be presented in 2007 must also contain intermediate targets for 2010, the subsequent ones, 2011 and 2014 must report an analysis of the results achieved.
The directive also requires energy efficiency measures for public buildings, promotion of energy diagnoses, incentives to subsidize energy efficiency improvement programs.</td><td>Among the contents of the decree:
● The tools for the promotion of energy efficiency are defined (in particular the white certificates and deduction volumes).
● The adoption of the criteria for the calculation methods of the energy performance of the buildings with the national technical standards UNI / TS 11300.
● For public buildings “public administration obligations generally include:
a) the use, even in the presence of external service,of financial instruments for energy saving interventions up to the energy performance contracting (contratti di rendimento energetico), which provide for a measurable and predetermined reduction in energy consumption;
b) energy audits of public buildings or buildings for public use, in the case of renovations of heating systems, including the replacement of generators, or building renovations that concern at least 15% of the external surface of the building envelope that contains the gross heated volume;
c) the energy certification of public or public buildings, if the total useful floor area exceeds 1000 square meters "
● Distribution or retail energy companies or companies ensure that end customers of electricity and natural gas receive individual meters that accurately reflect their actual</td></tr>
</table>

	consumption and provide information on the actual time of use.
Directive 2012/27/EU (25 October 2012)	**D.lgs. 102/2014** (4 July 2014)
This Directive repeals the directive the Directive 2006/32/EC. "The Directive establishes a common framework of measures (...) to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency". The directive requires member states to have an "annual report" on the progress made (every year since 2013) and a National Energy Efficiency Action Plans on planned measures and expected energy savings (starting from 2014 every 3 years). Regarding the measures to be taken to achieve these targets, the Member States shall: ● "ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements (...). The 3 % rate shall be calculated on the total floor area of buildings with a total useful floor area over 250 m^2". ● "facilitate the establishment of financing facilities, or use of existing ones, for energy efficiency improvement measures to maximise the benefits of multiple streams of financing." ● "ensure that enterprises that are not SMEs are subject to an energy audit carried out in an independent and cost-effective manner by qualified and/or accredited experts or implemented and supervised by independent authorities under national legislation by 5 December 2015 and at least every four years from the date of the previous energy audit." "Enterprises that are not SMEs and that are implementing an energy or environmental management system - certified by an independent body according to the relevant European or International Standards - shall be exempted from the requirements of paragraph 4 (concerning the obligation to perform energy audits), provided that Member States ensure that the management system concerned includes an energy audit" ● "ensure that (...) final customers for electricity, natural gas, district heating, district cooling and domestic hot water are provided with competitively priced individual meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use."	● "Starting from the year 2014 and until 2020, (...) interventions have been carried out on the buildings of the central public administration (...) capable of achieving the energy retrofit at least equal to 3% per year of the air-conditioned useful gross area or that, alternatively, result in a cumulative energy saving in the period 2014-2020 of at least 0.04 Mtep" ● The central public administrations comply with the minimum energy efficiency requirements during the procedures for the stipulation of contracts for the purchase or new rental of properties; ● Large companies perform an energy diagnosis (...) by December 5, 2015 and every 4 years thereafter (...). This obligation does not apply to large companies that have adopted EMAS compliant management systems and to ISO 50001 or EN ISO 14001 standards, provided that the management system in question includes an energy audit (...). ● Energy-intensive companies are required to carry out energy audits by 5 December 2015 and every 4 years thereafter regardless of their size and to implement progressively, within reasonable time, the efficiency measures identified by the diagnoses themselves or as an alternative to adopt management systems compliant with ISO 50001 standards. ● "In condominiums and multifunctional buildings supplied by a central heating or cooling source or by a district heating network or by a centralized supply system that feeds a plurality of buildings, installation of sub-meters to measure the actual consumption of heat or cooling or hot water for each real estate unit by 31 December 2016 by the owner is mandatory ". ● "In cases where the use of sub-meters is not technically possible or is not efficient in terms of costs and proportionate to the potential energy savings, for the measurement of heating (...) it is mandatory the installation of individual thermoregulation and heat accounting systems to quantify the heat consumption in correspondence with each heating terminal". ● The tools for promoting energy efficiency are defined (in particular white certificates,

● "In multi-apartment and multi-purpose buildings with a central heating/cooling source or supplied from a district heating network or from a central source serving multiple buildings, individual consumption meters shall also be installed by 31 December 2016"	"National Fund for energy efficiency" and deduced volumes) "
Directive (EU) 2018/2002 (11 December 2018)	Awaiting transposition
The directive amends some articles of Directive 2012/27 / EU. The Directive establishes "its 2030 headline targets on energy efficiency of at least 32,5 % are met and paves the way for further energy efficiency improvements beyond those dates." "Each Member State shall set indicative national energy efficiency contributions towards the Union's 2030 targets (and) notify those contributions to the Commission as part of their integrated national energy and climate plan." Are not affected by the changes the articles containing the following indication on the Member States that shall: ● "ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements (...). The 3 % rate shall be calculated on the total floor area of buildings with a total useful floor area over 250 m^2". ● "facilitate the establishment of financing facilities, or use of existing ones, for energy efficiency improvement measures to maximise the benefits of multiple streams of financing." ● "ensure that enterprises that are not SMEs are subject to an energy audit carried out in an independent and cost-effective manner by qualified and/or accredited experts or implemented and supervised by independent authorities under national legislation by 5 December 2015 and at least every four years from the date of the previous energy audit." "Enterprises that are not SMEs and that are implementing an energy or environmental management system - certified by an independent body according to the relevant European or International Standards - shall be exempted from the requirements of paragraph 4 (concerning the obligation to perform energy audits), provided that Member States ensure that the management system concerned includes an energy audit"	

In the amended articles the directive provides that, regarding the measures to be taken to achieve the targets, the Member States shall: ● “Member States shall ensure that (...) for electricity and natural gas final customers are provided with competitively priced individual meters that accurately reflect their actual energy consumption and that provide information on the actual time of use.” ● “In multi-apartment and multi-purpose buildings with a central heating or central cooling source or supplied from a district heating or district cooling system, individual meters shall be installed to measure the consumption of heating, cooling or domestic hot water for each building unit” ● “meters and heat cost allocators installed after 25 October 2020 shall be remotely readable devices. (...) Meters and heat cost allocators which are not remotely readable but which have already been installed shall be rendered remotely readable or replaced with remotely readable devices by 1 January 2027”	

Incentives to promote energy efficiency

In terms of incentives for the promotion of energy efficiency, Italy already boasts a large set of measures in the building sector, described in detail in the 2017 (MISE 2017a) EEAP. These measures have made it possible to achieve as early as 2016, particularly in the residential sector, over 80% of the savings target set for 2020 (MISE 2017b).

The tools specifically dedicated to the promotion of energy efficiency in force and monitored for the purpose of achieving the savings target referred to in Article 7 of the EED Directive are as follows (MISE 2019):

1. the mandatory scheme of the White Certificates;
2. tax deductions for energy efficiency measures and the recovery of the existing building stock;
3. the Thermal Account (Conto Termico);
4. the National Fund for Energy Efficiency (FNEE);
5. the Business Plan 4.0;
6. the Program for the Energy Redevelopment of the buildings of the Central Public Administration (PREPAC);
7. the Program of energy efficiency interventions promoted by the cohesion policies 2021-2027;
8. the National Information and Training Plan for Energy Efficiency (PIF).

<u>Outlook (strength and weaknesses)</u>

According to the European Construction Sector Observatory, a “modest recovery in the construction sector is expected in 2020, mainly led by rising private consumption, lower energy prices, investment in infrastructure including through EU funds. However, existing systemic bottlenecks such as employment decline in the sector, late payment by public administrations and inefficiencies in public procurement practices may discourage private investment in the future" (EC 2019b).

2. ENERGY RETROFIT OF EXISTING BUILDINGS

2.1. Implementation level of energy efficiency of the construction sector

The ENEA 2019 annual report on energy efficiency shows 2018 data on the amount of energy saved by Italy through the various tools designed to achieve the 2020 objectives (ENEA 2019).

In the table below (ENEA 2019): annual energy savings achieved by sector during the period 2011-2018 and expected by 2020 (final energy, Mtoe / year)

Sector	White certificates	Tax deductions*	Thermal account	Enterprise 4.0 *	Cohesion policy	Information campaigns	Marebonus	Legislative Decree N° 192/05 e DM 26/6/15 **	Community Regulations and High Speed	Energy savings		Target achieved (%)
										Achieved 2018	Expected by 2020	
Residential	0,67	2,70	-	-		0,03		1,34	0,30	5,04	3,67	137,3
Tertiary	0,14	0,03	0,08	-	0,02	0,01		0,04	-	0,31	1.23	25,6
Industry	1,97	0,04	-	0,44	0,20	0,03		0,08	-	2,75	5.10	54,0
Transport	0,01	-	-	-	0,00		0,06	-	0,22	2,29	5.50	41,6
Total	2,79	2,76	0,08	0,44		0,07	0,06	1,46	2,52	10,39	15.50	67,0

** Estimate for 2016.*

*** The residential sector includes savings from replacing large domestic appliances. The transport sector includes savings resulting from high-speed transport. Source: ENEA processing of data from the Ministry of Economic Development, ISTAT, Gestore dei Servizi Energetici SpA, ENEA, FIAIP, GFK .*

As can be seen in 2018, the 2020 target has already been abundantly reached and exceeded in the residential sector, while in the tertiary sector the goal is very far. The data on energy efficiency interventions of buildings that have benefited from the

Ecobonus tax deductions in the period 2014-2018 tell us that over 1.700.000 interventions have been carried out, of which over 334.000 in 2018. Of the latter, the most frequent ones concerned the replacement of windows (140.000 interventions), the replacement of the winter air conditioning system (90.000) and the installation of solar shading (more than 90.000). The savings obtained thanks to the interventions carried out in 2018 are due for 33% to the replacement of the windows, for 28% to the insulation of floors and vertical closures and significantly also from the interventions on winter air conditioning systems (MISE 2019). The March 2018 MISE report (communicated to the EU in accordance with Directive 2010/31 / EU) reports a cost-benefit assessment of widely used energy efficiency measures has been reported (MISE 2018).

The report also analyses the results obtaining some general considerations on the envelope, on the technical systems and on the costs of the optimal configurations. Major interventions on the envelope (such as external insulation or replacement of windows) are optimal for new buildings and only in a few cases for existing ones referring to a period of construction between 1946 and 1976. In other cases, the high cost due to the works connected to the implementation has favoured other types of interventions such as those on systems or on horizontal surfaces. The integral use of heat pump for air conditioning (heating and cooling) and domestic hot water (full electric building) was optimal only for new buildings, of the single-family type and offices. In other cases, the selected system solution is always based on the integration of heat pump, gas boiler (condensation) and multi split. The installation of photovoltaic modules made it possible to achieve 50% - 70% coverage for residential new building, and 10% - 30% for existing ones. The level of coverage achieved for offices is lower, between 40 - 50% for new buildings and 15% - 20% for existing ones.

Energy retrofit of public owned buildings

Directive 2012/27/EU provides that the Member States shall "ensure that, as from 1 January 2014, 3% of the total floor area of heated and / or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements. The 3% rate shall be calculated on the total floor area of buildings with a total useful floor area over 250 m^2. The figure below shows the trend of the areas for which the redevelopment was planned and financed, and those that remain to be redeveloped. The data ranging from 2014 (at the beginning of the obligation), to 2018 are final, while for the following years and up to 2030 it is assumed that the minimum rate of 3% set by the EED Directive is respected (MISE 2019).

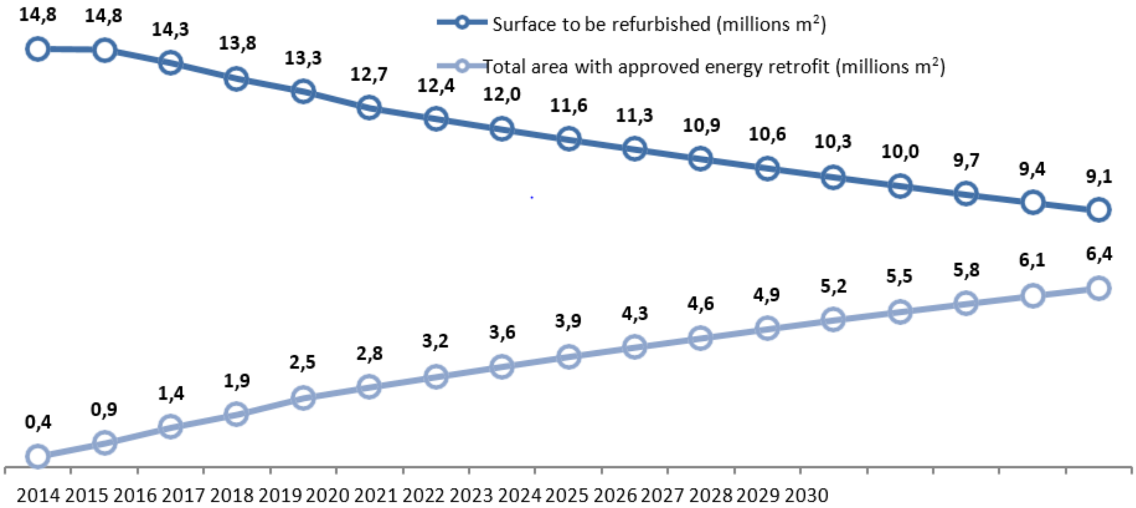


Figure 2: Redevelopment trend of the central public owned real estate stock (Mln of square meters).

2.2. Regulation and approaches in the energy efficiency of the building stock

Energy Performance Certificate (Attestato di Prestazione Energetica - APE)

Law 90/2013 defines the Energy performance Certificate (APE), the cases in which this document is required are described in art.6 of Legislative Decree 192/2005 and the guidelines for its implementation are contained in the D.M. 06/26/2015.

The APE is a tool for immediate understanding and evaluation, in relation to the energy performance of a property, of the economic convenience of buying and renting. It also constitutes an effective tool for assessing the convenience in carrying out energy retrofit intervention on the property (MISE et al. 2015).

For the purposes of classification, the energy performance of the property is expressed through the non-renewable global energy performance index EPgl,nren. This index takes into account the non-renewable primary energy requirement for winter and summer air conditioning (EPH,nren and EPC,nren), for the production of domestic hot water (EPW,nren), for ventilation (EPV,nren) and, in the case of the non-residential sector, for artificial lighting (EPL,nren) and the transport of people or things (EPT,nren) (MISE et al. 2015). With regard to the calculation of parameters, energy performance indices and yields, the reference technical standard is the UNI/TS 11300 series, which defines the methods for the national application of UNI EN ISO 13790:2008 and other regulations.

Minimum energy performance requirements for buildings and nZEB (Nearly Zero Energy Buildings)

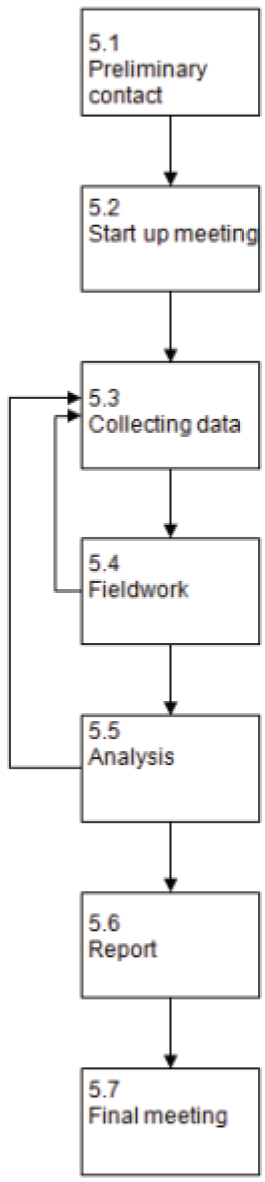
Law 90/2013 provides for minimum energy performance requirements for buildings that have been identified in the Ministerial Decree 06/26/2015. The minimum requirements stated by the Decree depend both on the scope of application (i.e. new building or building undergoing an expansion, renovation, or energy requalification) and on the classification of the building according to the Presidential Decree 412/93 (residential, office, hospital, etc.). There are both generic "provisions" and "requirements", which consist in comparing the values of some parameters calculated for the building being analysed with the same parameters attributed to a reference building defined by the same decree. For the calculation of the parameters, the reference technical standard is the UNI/TS 11300 series, which defines the methods for the national application of UNI EN ISO 13790: 2008 and other standards. The Decree also describes the characteristics of the nZEB buildings, which consist of respecting both a series of provisions and requirements described by the Decree and of the mandatory integration of energy production from renewable energy sources expressed in Annex 3, paragraph 1, letter c), of Legislative Decree no. lgs. 28/2011. (see the "Integration of renewable sources" section below).

Energy Audit

Legislative Decree no. 102/2014 obliges large and energy-intensive companies to carry out Energy Audits by the 5th of December 2015 and every 4 years thereafter. In this case, the same Decree requires that the diagnosis is carried out by certified ESCOs (according to UNI CEI 11352), Energy Auditor (according to UNI CEI EN 16247-5) and EGE (according to UNI CEI 11339).

For public owned buildings, Legislative Decree 115/2008 provides for the obligation of Energy Audits in the event of renovations of the heating systems, including the replacement of generators, or building renovations that concern at least 15% of the external surface of the building envelope that encloses the heated gross volume. Again for public owned buildings, the Minimum Environmental Criteria (Criteri Ambientali Minimi - CAM) decree provides for the obligation of energy audit for important first-level renovation projects and for important second-level (according to an internal classification method) renovation projects of buildings with a usable surface equal to or greater than 2500 m^2.

Because of the obligation of Legislative Decree 115/2008 and CAM, the audit must be developed by a professional (i.e. any member of a professional register). In residential buildings, the D.M. 26/06/2015 requires an Energy Audit, drawn up by a professional, in the case of renovation or new installation of heating systems with a nominal heat output of the generator greater than or equal to 100 kW, including the disconnection from the centralized system of even one user. The Legislative Decree 141/2016, which amends the Legislative Decree 102/2014, makes the UNI 10200 standard mandatory as a procedure for the sharing of expenses for the accounting of condominium heat. This standard provides for the possibility of an Energy Audit. The methodology for carrying out an Energy Audit of buildings is described in the UNI CEI EN 16247-2 standard (as shown in the image on the right, source UNI CEI EN 16247-2).



The Energy Diagnosis, or Energy Audit, is one of the most effective tools available today for those who want to promote energy requalification actions of properties aimed at obtaining a drastic reduction of energy consumption (and therefore of management costs). The Energy Audit ensure the valorisation of the building intended as an increase in the market value, and its improvement from the point of view of environmental sustainability.

The systematic procedure adopted to achieve these results requires a preliminary contact with the client to establish the purpose and accuracy of the diagnosis and a start-up meeting to plan the field operations and collect the available data. A phase of survey and monitoring of the technical, performance, management and consumption characteristics follows. On the basis of the collected data an “ante operam” energy model of the building is developed with the calculation of the performances calibrated on real consumption. This analysis is then followed by a study of the possible measures to reduce energy consumption and an assessment of them on the basis of a cost-benefit analysis.

Energy management systems - Sistemi di gestione dell'energia (SGE)

Legislative Decree 102/2014 obliges energy-intensive companies to carry out an Energy Audit every four years and to implement progressively and quickly the efficiency measures identified by it or, alternatively, to adopt Energy Management systems (SGE) compliant with UNI CEI EN ISO 50001 standards. The energy management system is based on the “Plan-Do-Check-Act (PDCA)” continuous improvement framework and incorporates energy management into existing organizational practices. In the context of energy management, the PDCA approach can be outlined as follows:

1. Plan: the plan phase is needed to understand the context of the organization, establish an energy policy and an energy management group, consider actions to address risks and opportunities, conduct an energy analysis, identify significant uses of energy (USE) and establish energy performance indicators (EnPI), reference consumption(s) (EnB), energy objectives and targets and action plans necessary to obtain results that improve energy performance in accordance with the organization's energy policy.
2. Do: the phase is used to implement the action plans, the operational and maintenance checks and the communication considering the energy performance also in the design and supply point of view.
3. Check: the phase is used to monitor, measure, analyse, evaluate, conduct audits and carry out reviews of the management of energy performance and the SGE.
4. Act: in this phase actions are taken to address non-conformities and continuously improve energy performance and the SGE.

Figure 3: Plan Do Check Act Cycle, source UNI CEI EN ISO 50001.

Renewable energy sources integration

The use of energy from renewable sources is governed by Legislative Decree 28/2011 (see the related summary table on § 1.3).

2.3. Tools currently used in for energy efficiency design and interventions

Technical legislation

For the calculation of the energy performance of buildings for the APE or compliance with the minimum requirements, the reference standard is the UNI/TS 11300 series, which defines the methods for the national application of the UNI EN ISO 13790: 2008 and other standards, ranging from the calculation of the transmittance of opaque structures and window to the estimation of occupancy schedules of the indoor environments to the efficiency of the systems.

For climatic data for APE and system design, the reference series is the UNI 10349 while for hourly climatic data (useful for example for energy diagnoses) the databases of various entities are available to the public (e.g. the Comitato Termotecnico Italiano - CTI[4]) .

UNI EN ISO 13790: 2008 has currently been replaced by UNI EN ISO 52016-1: 2018 which develops the hourly dynamic calculation already present in the previous one. Member states are obliged to implement this legislation and develop national annexes. Once this procedure is finished, it will be up to the government to decide whether the hourly or monthly calculation of the new technical standard will be adopted for the EPA and performance indices.

[4] https://www.cti2000.it/

For the Energy Audit there are no legislative indications regarding the calculation method and in the case of the choice of dynamic-hourly calculation models, the new UNI EN ISO 52016-1: 2018 is already used.

Building survey and monitoring tools

For the purpose of drafting the APE and complying with the minimum requirements in renovations and energy retrofit, data collection through the use of instruments such as heat flux meters, thermal imaging cameras, blower door tests, instruments for internal or external environmental monitoring etc. is not required.

Even for the Energy Audit of buildings, it is not common to use field analysis, unless the specific situation requires it for specific building problems. For example, for historic buildings that, in conjunction with an energy improvement intervention, require other restoration actions, the use of diagnostic tools becomes appropriate.

Software for calculating energy performance

In Italy, there are various software houses and research bodies that have developed products related to national and community legislation. For the calculation of the APE and the minimum requirements, the two research bodies CNR and ENEA have developed the freely downloadable Docet software, but there are also other software on the market[5] that perform numerous functions related to legislation, in addition to those already mentioned. This software allow for example, the calculation of thermal bridges with finite elements method, system design, compliance with sustainability certification standards (LEED, ITACA) and the Minimum Environmental Criteria (CAM).

In addition, some of these already implement the provisions of UNI EN ISO 52016-1: 2018 (both in the standard version and in accordance with the provisions of the Italian Annex), making it possible to carry out energy diagnoses in a dynamic hourly regime.

Other dynamic software such as Energy Plus, TRNSYS, DOE-2, IES VE, TAS, IDA ICE are also used for energy diagnosis or design. Plug-ins to manage data exchange between BIM and energy simulation software are under development.

Guidelines

ENEA (the national agency for new technologies, energy and economic development) has developed a guideline for the energy diagnosis of public buildings (Calabrese et al. 2019), a guideline for Energy Performance Contracts (EPC, Fasano et al. 2014), an application for smartphones and tablets for an expeditious analysis of condominium buildings.

[5] Termolog from Logicalsoft, Termus from Acca, Edilclima from Edilclima Engineering and Software to cite some.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

Italy is one of the most advanced countries in the application of measures aimed at improving the environmental and energy performance of historical buildings. As anticipated in the general introduction to the topic (see § 5 of the “State of the art analysis on HBIM and interoperability” Report), it is in Italy that the dialectic between regulatory compliance and energy improvement has been deepened and in a certain sense resolved, in favour of the latter (Carbonara 2015; Mazzarella 2015; Fabbri 2013). After a first moment of reticence, now several experts, led by the restoration scholar Giovanni Carbonara, begin to see energy efficiency and energy-environmental analyses as tools for the protection of historical heritage (Carbonara 2015).

In 2015, the MiBACT (Ministry of Cultural Heritage, Activities and Tourism) published the guidelines for the improvement of energy efficiency in cultural heritage (MIBACT 2015), prepared by an appointed working group, composed of MiBACT managers, officials and university researchers, with the aim of disseminating operational information to designers and technicians, both external and internal to the Ministry. The guidelines offer designers a tool for assessing the energy performance of the historical buildings in its existing conditions and technical criteria for the design of any energy redevelopment interventions, suitably calibrated to respect the specific peculiarities of cultural heritage. Ministry staff are offered a lean scientific document that allows a more conscious dialogue with designers and proposers. The idea behind the document is to guide the intelligence and sensitivity of the actors to achieve the primary objective of protecting and conserving cultural heritage, optimizing, where possible, the level of energy performance.

In the field of environmental certification in 2016, the Green Building Council Italy, the national chapter of the international body responsible for LEED certification, developed an environmental rating system for the certification of buildings subject to conservative interventions called GBC Historic Building (GBC 2017). The protocol was born with the idea of making the sustainability criteria of the LEED standard dialogue with Italian skills (world excellence) in the field of restoration. The document embrace the concept of energy improvement and the idea of sustainable design as a protection tool for the rediscovery and enhancement of ancient technologies. In particular, in the energy efficiency section, it is stressed the need for dynamic modelling, problematizing its use in historical contexts, as also confirmed by the most authoritative scientific sources on the topic (mostly of the Italian area). The substantial addition compared to the classic protocol was the "historical value" theme, which brings together specific topics regarding the conservative process. Within the 110 points obtainable in all LEED evaluation criteria, the historical value can be worth a maximum of 20 (and consequently the other scores have been reduced). The logic behind this value considers ten criteria, comprehending some of the fundamental principles inferred from the international restoration charters as of minimal intervention aimed at safeguarding the material, functional updating, reversibility of the intervention, compatibility and durability with attention paid to scheduled maintenance plan and sustainability of the restoration site, as to guarantee the quality of the restoration.

Case studies on energy improvement interventions on historical buildings

In Italy there are also some of the most interesting case studies from the point of view of scientific experimentation, both relating to the investigation tools and approach used and the complexity of the objects of study. Examples include the Intelligent Energy Europe project SECHURBA (AA. VV. 2011; Alongi et al. 2015; E. Gigliarelli, Calcerano, and Cessari 2018), or the European Seventh Framework Programme 3ENCULT (Troi and Bastian 2014) to name a few.

Below is a summary table of some of the most interesting case studies of the Italian panorama in terms of energy improvement and historical building.

Case study name	Reference
Public Weigh House, Bozen/Bolzano	(Exner et al. 2010; Roberti, Oberegger, and Gasparella 2015)
Palazzo d'Accursio, Bologna	(Faustini Fustini et al. 2010)
Palazzina della Viola, Bologna	(Colla et al. 2010)
Historical manufacturing facility, Rovereto	(Pernetti, Prada, and Baggio 2013)
Castle of Zena, Piacenza	(Alongi et al. 2015; E. Gigliarelli, Calcerano, and Cessari 2018)
Palazzo Ex-INPS, Benevento	(Ascione et al. 2015)
Ca’ S. Orsola, Treviso	(Dalla Mora et al. 2015)
Rocca Paolina, Perugia	(Castaldo et al. 2015)
Villa Mondragone, Monte Porzio Catone	(Cornaro, Puggioni, and Strollo 2016)
Basilica di Collemaggio, l’Aquila	(Aste et al. 2016)
Sanfilippo house, Agrigento	(Cellura et al. 2017)
Malatestiana Library, Cesena	(Tronchin and Fabbri 2017)
Palazzo Tassoni Estense, Ferrara	(Lucchi et al. 2019)
Casa Gioioso, Frigento	(Elena Gigliarelli et al. 2017; E. Gigliarelli et al. 2019)

4. BIM ADOPTION IN ITALY

At European level, the Directive on public tender N°2014/24/(EU 2014) invites the member state to introduce digitalisation in the construction sector. In Italy the BIM methodology (or as indicated by the standards the "electronic specific tools and methods for construction and infrastructure modelling") are regulated by the Ministerial Decree 560/2017), implementing decree of article 23, paragraph 13, of Legislative Decree no. 50/2016 (which implements the provisions of the European Directive 2014/24/EU). In this decree, the digitalisation, that from now on we will call with the acronym BIM, is already used for project with a budget over 100 million since the first January 2019, and for budget over 50 million by the first January 2020 and the amount will decrease every year till to any project by the year 2025.

In the same decree, the following three main objectives for the contracting authority are set:

1. the BIM processes need to be identified;
2. the technical officers need to be trained for the new processes in BIM;
3. hardware and software need to be adequate to the new processes.

Besides, it is clearly indicated that the documents need to be in open format. Public tenders are increasing, however, the level of maturity of public administrations is low and there is a minimum awareness of open standards:

1. some tenders required proprietary file so that many court appeals started;
2. public administrations were trained on the use of specific software without receiving proper training on the basic knowledge of the BIM, as buildingSMART International proposes;
3. many public administrations are not equipped with the right hardware and software so, from one side they still ask for printed copies and, on the other hand they ask to the contractor to make available a Common Data Environment for the management of the digital model .

The latter point is particularly vulnerable, especially for historical buildings as the public administration risks to lose any information and modelling uploaded in the platform when the contractor finishes his contract or even if there is a dispute (ASSOBIM 2019).

For this reason, the Italian partners decided to identify a building owned by the State Property Agency, which is developing a comprehensive BIM asset strategy, setting up a specific CDE to manage all the information of existing State buildings.

As regards the technical regulations, thanks to the "Vienna Agreement" stipulated between ISO and CEN (which provides for the automatic transposition of the ISO legislation first at CEN level and subsequently at individual member state level) in Italy the rules UNI EN ISO 19650-1 and UNI EN ISO 19650-1: 2019 are in force together with the pre-existing standards of the UNI 11337 series (part 1-4-5-6-7), which today stand as complementary standards to the former pending their rewriting and adaptation to the new regulatory framework.

4.1. HBIM adoption in Italy

Given its context in terms of built heritage, Italy is one of the most active countries on the subject of HBIM (Logothetis, Delinasiou, and Stylianidis 2015; E. Gigliarelli, Calcerano, and Cessari 2016), to the point that the national BIM standard (UNI 11337) specifies to the LOD for restoration (Pavan, Mirarchi, and Giani 2017; Ente Italiano di Normazione UNI 2017). The underlying idea is that the starting BIM model of an historical asset is a "survey model", from which the BIM “design model” is then developed. The survey model has the role of setting the “*ante operam*” state of the building: a digital as-built model at a specific date, which is defined by the Level of Development (LOD) F.

The regulation conceives possible abstractions to be used during the modelling of this “LOD F survey model”, to group families of similar objects or aggregations of coherent objects, while defining information on construction, historical data, facility management in great detail. Within an HBIM model, a possible separation between the Level of Geometry (LOG), that is the level of detail of the geometric attributes, and the Level of Information (LOI) that is as level of detail of the information attributes, is foreseen, attributing to the latter the role of supporting a lower LOG with more LOI information.

The objective of the "survey model" for restoration is the survey of existing information. The usage of the “survey model” for restoration is the extrapolation of data to support future planning of the interventions. The nature of the model is "composite", given the origin of the information from a series of heterogeneous sources (often on paper, even ancient ones). Therefore, for "survey model", the regulation therefore refers not only to the HBIM model, but more in general to the “Survey Common Data Environment” as a whole (ACDat in the wording of the Italian legislation) and to the interaction of the information contained therein regardless of the source of origin (Pavan, Mirarchi, and Giani 2017).

The progress of the Italian debate on the topic also translates into a series of both academic and professional experiments of which only a few indicative examples are reported.

Italy academic research on HBIM

The research Project of Relevant National Interest (PRIN) Built Heritage Information Modelling / Management – BHIMM, coordinated by the Politecnico di Milano, is perhaps the first structured attempt to address the issue of HBIM at national level (Della Torre and Pili 2020). The project was launched in 2011 and involved six research units: apart from the Politecnico di Milano, the universities of Rome, Genova and Brescia, the Politecnico di Torino and the National Research Council of Italy, and dealt with implementing BIM techniques within the heritage domain on several case studies. One of the most important of them is the Basilica of Collemaggio of L’Aquila on which a very interesting experimentation was carried out, also in terms of interoperability with structural analyses (Oreni et al. 2014).

The research branch relating to the *scan-to-bim process* and the HBIM implications in terms of survey and representation of the built heritage is also very active in Italy. The works of Brusaporci (2017), Lo Turco, Mattone, and Rinaudo (2017), Garagnani and Manferdini (2013), Bruno and Roncella (2019), Del Giudice and Osello (2013) stand out for their ability to debate on the critical node of the geometric modelling within a HBIM platform, that must be balanced between the detail for documentation and model uses for the HBIM process. This research area is also closely linked to the more specific theme of the documentation of historic buildings, for which it is possible to refer to projects such as INCEPTION.

Another interesting HBIM line of research is that relating to museum buildings, characterized by the relationship between the building as a "container" and the collection as "content, that can greatly benefit from an HBIM approach. The HBIM4MANN project by BHiLab ISPC-CNR on an ongoing HBIM implementation of the National Archaeological Museum on Neaples, and the works of the Politecnico di Torino (M. Lo Turco et al. 2018; Osello, Lucibello, and Morgagni 2018) are among the most representative cases.

In Italy there is also a line of studies relating to heritage buildings and urban fabrics management through an integration of BIM and GIS platforms, up to the concept of City Information Modelling (Saygi and Remondino 2013; Saygi et al. 2013; Elena Gigliarelli, Pontrandolfi, and Calcerano 2019; Vacca et al. 2018).

Another research field is related to the joint use of HBIM model and Virtual or Augmented Reality applications that usually connects with the facility management model use (Barazzetti et al. 2015; Osello, Lucibello, and Morgagni 2018).

Italy examples of HBIM interventions

Several application examples of HBIM processes applied to historical buildings are beginning to be developed in Italy. The first public tenders were launched in 2016 by the Presidency of the Council of Ministers for the restoration of the military shrines of Asiago and Redipuglia. Subsequently, the State Property Agency (Agenzia del Demanio) launched a series of HBIM tenders for recovery and redevelopment of historic buildings within its heritage building stock. A summary of three among the interesting case studies in terms of approach is reported above.

The first is the restoration intervention of the Pescherie di Giulio Romano in Mantua, an historical fish market built in 1536 where the regulation with LOD F for pre-restoration model and LOD G for restoration interventions was applied (Olivieri 2018). The case study involved a survey campaign and diagnostic investigations and then the HBIM modelling within which the elements to be modelled were differentiated into three categories based on a critical reflection on both their ease of modelling and their use inside the model itself for supporting the restoration intervention:

1. simple elements to be modelled as discrete elements within the BIM Authoring Tool;
2. complex elements to be modelled in a simplified way in the BIM Authoring tool following a critical reflection on their use within the model.
3. complex elements to be imported in the BIM model at the highest level of detail possible following a critical reflection on their use within the model.

Another intervention following a similar process is that of the recovery and seismic improvement of the Pento Gallery of Ferrara (Bagni 2019), a 16th century building. Also, in this case the starting point for the modelling was a critical reflection on the uses of the model that led to simplifying the model of some decorative architectural elements while modelling others that were necessary to better design the interventions. For complex elements like the vaults a computational design based approach was chosen instead.

Another example is the construction of the HBIM model of the Railway Museum of Pietrarsa, a nineteenth-century industrial building returned through a scan-to-bim process based on a model use for facility management with a detailed referencing of all the elements subject to scheduled maintenance.

4.2. HBIM and interoperability

In this field, Italy presents some experiments and research projects of absolute interest, following the ones already cited in the previous chapters.

The H2020 Research Project INCEPTION (Maietti et al. 2018) is one of the latest developments in terms of international research on the documentation and digitalisation of the built heritage, as the project "realises innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, built and social environments[6]". Concerning the HBIM research field, the BIM is seen mainly from a documentation point of view and one of its report goes deeply into addressing semantic web and ontology aspects of HBIM (Bonsma et al. 2018). This aspects are fundamental also for its interoperability, as shown also in the researches on the semantic enrichment of the universities of Sapienza, Parma and Ancona to cite some (N. Bruno and Roncella 2019; Quattrini, Pierdicca, and Morbidoni 2017; Acierno et al. 2017; Simeone, Cursi, and Acierno 2019).

Broadening the horizon of multidisciplinary BIM implementations, we can refer to: the researches on the relationship between BIM and diagnostics of the Polytechnic of Bari (S. Bruno, Fino, and Fatiguso 2017); on the integration between HBIM and historical-architectural investigation techniques, such as stratigraphic analysis of the University of L'Aquila (S. Brusaporci et al. 2018) or decay (Brumana et al. 2017); on the Italian Industrial research project IDEHA (Innovation for Data Elaboration in Heritage Areas), where a holistic digital platform is being developed both for asset managers and end users and where the HBIM model is one of the pivots of the platform itself.

4.3. BIM and energy efficiency

The Italian context already shows some attention to the 6D of BIM (see § 3.3 of the "State of the art analysis on HBIM and interoperability" Report) relating to the energy-environmental implications of the building process, e.g. in terms of sustainability assessments (Maltese et al. 2017).

Research on the integration between BIM and energy efficiency tools for new construction proceeds mainly with plugins developed by software houses that produce software compliant with the Italian legislation for energy certifications and audits. These plugins tend to facilitate data exchange between the most popular BIM authoring tools and the energy software in both directions, and with the possibility of exporting the

[6] https://cordis.europa.eu/project/id/665220

energy model to IFC. The research field, a bit like in the rest of the world, is however still in an embryonic phase of experimentation.
On the academic side, some Italian partners (both industry or research institutions) were part of the European research projects that dealt with the topic like the FP7 project HOLISTEEC[7] and DIMMER[8] and H2020 projects BIM-SPEED[9], BIM4REN[10] and BIM4EEB[11], other groups worked on the topic independently (De Angelis et al. 2015).
In September 2019, the International Building Performance Simulation Association (IBPSA) four-year international conference Building Simulation 2019 was held in Rome with two sessions dedicated to the topic of BIM and Building Energy Modelling (BEM) interoperability.

4.4. HBIM and energy improvement

In Italy ,there are also some researches in which attempts have been made to integrate energy considerations into a HBIM process (S. Bruno, De Fino, and Fatiguso 2018). One of the most interesting examples[12] concerns the Industrial Research project METRICS Management and Requalification of Historic Centers and Buildings, funded by the PON Research and Competitiveness 2007-2013 (Elena Gigliarelli, Calcerano, and Cessari 2017; E. Gigliarelli, Calcerano, and Cessari 2016), already mentioned in the general section of the report (see § 5 of the "State of the art analysis on HBIM and interoperability" Report). METRICS project developed an integration of environmental energy analyses and simulations and Decision Support Systems (DSS) at different scales (urban/external microclimate/ single building) within an HBIM platform of a historic centre in southern Italy.

The purpose of this experimentation was to keep the respective experts within their comfort zone in terms of workflow, while maintaining the active parametric link between the various models (Gigliarelli et al. 2019). This could reduce manual and error-prone parallel modelling and data re-input streamlining the process. At the urban and external microclimate scale, the project developed a pipeline that included: the acquisition of geometric data with a scan-to-bim process, the transfer of the (simplified) geometry to software for environmental energy simulations of the external microclimate and then the integration of the visual outputs of the simulation results back into the HBIM platform (Gigliarelli, Calcerano, and Cessari 2016; Gigliarelli, Calcerano, and Cessari 2017). At the scale of the individual building, the project developed an interoperable semi-automatic approach between HBIM and a dynamic hourly software of numerical simulations through the intermediate step of computational design. The process was tackled starting from different BIM authoring tools and testing both IFC and gbXML formats as possible interchange formats for the passage of data from BIM to simulations (Gigliarelli et al. 2017; Gigliarelli et al. 2019). The interoperability, for a free running simulation of a relatively small but still complex

[7] https://cordis.europa.eu/project/id/609138
[8] http://www.drawingtothefuture.polito.it/projects/dimmer/
[9] https://cordis.europa.eu/project/id/820553
[10] https://bim4ren.eu/
[11] https://www.bim4eeb-project.eu/partners.html
[12] Carried out by BEEP Project Coordinator CNR ISPC.

historical building, has allowed to highlight a series of problems that are typical of the heritage industry to be addressed both at the BIM and simulation levels laying the foundations for a more structured problematization of the BIM to BEM problem from a built heritage point of view. The latest results of the research were presented at the BIM session of the BS2019 international IBPSA conference held in Rome in September 2019, where there were works by all the most active international groups on the subject and where one of the sessions was moderated by one of the authors of the study.

5. BIBLIOGRAPHY

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ANNEX 2 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF SPAIN

Country:	Spain (ES)
Date:	23/02/2020
Prepared by:	PP2 IVE – Instituto Valenciano de la Edificación
Status:	Finished
Version:	v1
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Index

1. GENERAL INFORMATION

1.1. General Spain data (population, official language, capital, area, GDP total/per capita, currency)

Spain is the fourth largest country on the European continent, the second largest in Western Europe and the EU, and the largest country in Southern Europe. It has a surface area of 505,935 km² and a population of 47,007,367 inhabitants (2019), with a moderate population density (93 inhabitants per square kilometre).

Spain capital city is Madrid and the Spanish currency is the Euro (€). The official language of the country is Spanish and six of the seventeen Spanish autonomous communities also have other languages as co-official.

Spain is the 13th largest economy in terms of GDP (1,244,757 M. € in 2019) and ranks 33rd in terms of GDP per capita (26,420 € in 2019).

1.2. Description of Spain building stock

The *"Report on the calculation of the cost-optimal levels of the minimum energy performance requirements for buildings in the new Spanish regulations and their comparison with the current requirements"* (2018), based on the information available in the *"Long-term strategy for energy rehabilitation in the building sector in Spain"* (2014) and the *"Construction statistics. Works management visas up to 2012"* (2016) of the Ministry of Public Works, shows the number of Spanish buildings and surface area constructed by use types in the following table:

	Buildings [No]	Surface area [m^2]	Surface area by group [%]	Surface area Average [m^2]
RESIDENTIAL	**23142267**	**3283305198**	**100 %**	**142**
V1a – Detached or semi-detached single-family	2314227	476592857	14.52 %	206
V1b – Terraced or row single-family	4535884	832117251	25.34 %	183
V2a – Multi-family building, detached block	5577286	675962240	20.59 %	121
V2b – Multi-family building occupying a whole block	10714870	1298632850	39.55 %	121
TERTIARY, SERVICES AND EQUIPMENT	**1967237**	**825585829**	**100 %**	**420**
O – Offices	283352	111291436	13 %	393
E – Cultural	47582	97067969	12 %	2040
Y - Healthcare and welfare	37382	48131972	6 %	1288
G – Leisure and hospitality	196868	107481444	13 %	546
K – Sports	57926	201004443	24 %	3470
C – Commercial	1295359	223541711	27 %	173
T – Performances	5303	8085756	1 %	1525
R – Religious	43465	28981098	4 %	667
INDUSTRIAL	**1703522**	**704912001**	**100 %**	**414**
STORAGE - PARKING	**7984295**	**345084908**	**100 %**	**43**
OTHERS	**239581**	**117332565**	**100 %**	**490**
POPULATION (%)	**35036902**	**5276220501**		**151**

* For the distribution of the number of buildings in residential use, the average size was assumed to be equal within the subtypes of single-family residences and residences in detached blocks, and a built surface area for single-family residence equal to the average size of the residence;

** For the distribution by built surface area in residential use, the average size of the single-family residences was considered to be 1.5 times that of the residences in detached blocks, according to the data from the Ministry of Public Works (EE16), along with the distribution (ELP14) of the number of residences by type (V1: 10 \%, V2:19.6\%, V3:24.1\% and V4: 46.3\%);

*** Uses for which the Delegated Regulation for Directive 2010/31/EU requires the definition of a reference building (one for new buildings and one for existing buildings)

Figure 1: Characterization of the Spanish building stock by use.

The *“Long-term strategy for energy renovation in the building sector in Spain pursuant to Article 4 of Directive 2012/27/UE”* (2014) breaks down the above data by decade of construction:

Figure 2: Number of properties by uses and decades of construction according to the land register.

NO OF PROPERTIES BY USES AND DECADE OF CONSTRUCTION													
	Before 1900	1900–1920	1921–1940	1941–1950	1951–1960	1961–1970	1971–1980	1981–1990	1991–2001	2002–2011	Since 2012 (*)	Other (**)	TOTAL
RESIDENTIAL													***23 142 267***
V - Residential	437 912	1 237 387	944 525	661 857	1 278 305	3 123 052	4 185 544	2 938 095	3 728 153	4 419 507	76 738	111 192	23 142 267
NON-RESIDENTIAL													***11 894 635***
TERTIARY, SERVICES AND PUBLIC FACILITIES													***1 967 237***
O - Offices	1 999	5 898	5 981	5 590	10 328	36 178	51 190	36 706	56 613	71 932	593	344	283 352
C - Commercial	13 401	36 134	35 686	25 735	59 062	211 028	280 036	213 446	235 776	181 623	2 356	1 076	1 295 359
K - Sports	177	704	597	823	1 779	5 872	12 874	13 846	11 620	8 777	240	617	57 926
T - Entertainment	147	433	380	303	425	666	904	765	707	380	10	183	5 303
G - Leisure and Hospitality	1 598	4 340	3 019	2 076	4 418	17 556	45 028	64 020	28 005	24 475	172	2 161	196 868
Y - Health and Charitable	424	1 147	1 137	958	1 506	3 993	8 346	7 886	6 483	5 133	117	252	37 382
E - Cultural	1 151	2 853	3 131	2 820	4 965	8 269	9 315	5 843	4 305	4 139	96	695	47 582
R - Religious	11 605	14 788	2 958	2 025	1 848	2 392	2 561	1 464	1 166	974	86	1 598	43 465
INDUSTRIAL													***1 703 522***
I - Industrial	106 613	272 072	120 087	80 468	90 744	152 938	231 222	202 719	207 094	155 928	2 149	81 488	1 703 522
WAREHOUSE - PARKING													***7 984 295***
A - Warehouse - Parking	24 156	74 466	46 550	33 266	61 810	263 439	1 005 188	1 166 184	2 159 091	3 092 778	49 344	8 023	7 984 295
OTHER													***239 581***
M - Urban design and gardening	3 205	9 213	3 349	2 037	2 004	3 878	35 541	6 130	10 975	30 064	922	39 771	147 089
P - Singular building	1 216	2 535	1 642	1 313	1 430	1 775	3 319	2 443	6 978	2 086	46	483	25 266
B - Agricultural warehouse	281	863	593	458	735	949	1 884	1 176	717	969	5	170	8 800
J - Agricultural Industrial	2 273	7 840	4 906	3 939	4 101	5 731	12 753	8 043	5 031	2 316	12	1 481	58 426
Z - Agricultural													

(*) Includes properties whose year of construction is 2012 or 2013.

(**) Any properties whose year of construction is zero, or after 2013.

NB: The data refer to the month of September 2013 and are those provided by the Ministry of Finance and Public Administrations (Directorate General of the Land Registry) for all national territory, except the autonomous communities of the Basque Country and Navarre.

Source: Prepared by the Ministry of Development, based on the Directorate General of the Land Registry.

TOTAL AREA OF PROPERTIES BY USES AND DECADE OF CONSTRUCTION													
	Before 1900	1900–1920	1921–1940	1941–1950	1951–1960	1961–1970	1971–1980	1981–1990	1991–2001	2002–2011	Since 2012 (*)	Other (**)	TOTAL
RESIDENTIAL													***3 283 305 198***
V - Residential	95 641 467	232 368 161	162 768 092	112 633 414	171 118 502	351 283 958	519 393 590	416 779 847	552 369 707	636 420 425	13 115 736	19 412 259	3 283 305 198
NON-RESIDENTIAL													***1 992 915 303***
TERTIARY, SERVICES AND PUBLIC FACILITIES													***825 585 829***
O - Offices	933 429	2 396 443	2 255 814	2 261 444	3 311 727	9 398 951	16 948 099	12 095 266	25 661 331	35 350 391	761 313	117 228	111 291 436
C - Commercial	1 731 072	4 900 501	4 839 248	3 605 743	7 371 186	25 391 430	37 034 399	80 293 606	48 285 915	57 588 864	2 224 986	274 761	223 541 711
K - Sports	645 624	2 154 175	1 381 860	2 208 430	9 681 970	16 739 944	25 746 395	31 954 726	57 436 525	49 575 087	3 064 330	415 177	201 004 443
T - Entertainment	140 476	405 788	360 694	249 001	360 117	551 356	828 267	663 479	2 512 020	1 694 595	61 535	278 386	8 085 756
G - Leisure and Hospitality	1 052 336	2 257 499	1 843 506	1 235 534	3 830 906	13 879 749	16 973 923	19 425 949	22 701 321	21 667 250	1 375 757	1 237 116	107 481 444
Y - Health and Charitable	661 849	1 538 747	1 707 308	1 926 984	2 931 571	4 080 888	7 987 640	5 358 000	7 730 524	13 775 331	228 533	204 597	48 131 972
E - Cultural	2 387 605	3 976 671	4 369 558	3 718 098	7 936 223	15 420 511	20 147 724	13 494 276	12 263 870	11 589 485	349 396	414 552	97 067 969
R - Religious	8 132 005	8 631 230	3 100 559	1 724 544	1 545 580	1 676 250	1 613 448	1 057 482	2 049 203	900 559	48 560	504 117	28 981 098
INDUSTRIAL													***704 912 001***
I - Industrial	17 321 488	37 950 600	23 518 986	21 194 673	36 054 056	81 031 926	127 376 064	84 414 671	128 095 848	138 366 561	2 691 221	6 933 805	704 912 001
WAREHOUSE-PARKING													***345 084 908***
A - Warehouse - Parking	2 132 540	6 830 004	4 449 097	3 245 855	5 538 600	18 461 615	47 154 722	49 514 779	92 677 169	112 642 473	1 808 729	609 725	345 084 908
OTHER													***117 332 565***
M - Urban design and gardening works.	1 025 091	2 094 942	1 086 389	584 783	1 697 876	4 139 426	4 201 986	2 402 618	7 509 297	7 484 575	305 896	2 399 792	34 931 671
P - Singular building	1 723 968	3 717 351	2 893 505	2 916 047	2 551 457	2 187 536	4 273 021	4 112 510	5 761 938	4 646 045	331 635	240 707	35 344 920
B - Agricultural warehouse	29 242	113 833	60 776	56 951	363 509	191 158	429 612	879 909	513 579	1 617 316	735	68 623	4 325 437
J - Agricultural Industrial	275 649	1 124 101	1 295 398	860 469	1 584 219	4 461 986	9 861 286	6 122 215	8 756 442	6 122 313	11 642	2 254 776	42 730 537
Z - Agricultural													0

(*) Includes properties whose year of construction is 2012 or 2013.

(**) Any properties whose year of construction is zero, or after 2013.

NB: The data refer to the month of September 2013 and are those provided by the Directorate General of the Land Registry of the Ministry of Finance and Public Administrations for all national territory, except the autonomous communities of the Basque Country and Navarre.

Source: Prepared by the Ministry of Development, based on the Directorate General of the Land Registry.

Figure 3: Total area of properties by uses and decades of construction according to the land register.

From reading the tables, it follows that, after discounting the residential use, the most significant uses of the non-residential building stock by surface area are industrial, warehouse/parking, commercial, sports, office, leisure and hospitality and cultural uses.

On the other hand, and with regard to the decades of construction of the buildings, it is important to take into account that it is not until 1980 that the first regulation introducing minimum energy efficiency criteria in Spain began to be applied (the basic building standard NBE-CT-79 on thermal conditions of buildings).

Despite having fewer buildings than the residential sector (with less area), the tertiary sector accounts for 35% of the country's energy consumption that includes buildings. Taking into account some of the non-residential uses of the stock (commercial, sports, offices, hospitality, cultural and educational, and health, which cover 91% of the area and 96% of the buildings), excluding industrial buildings, warehouses and parking, their energy consumption is broken down as follows:

USES ACCORDING TO LAND REGISTER		Final energy ktoe
A - Warehouse - Parking		
V -Residential		
I - Industrial		
O - Offices		2 000
C - Commercial	small businesses	4 800
	shopping centres	1 000
K - Sports		200
T - Entertainment		
G - Leisure and Hospitality		1 000
Y - Health and Charitable		500
E - Cultural		400
R - Religious		
M - Urban design and gardening works, unbuilt land		
P - Singular building		
B - Agricultural warehouse		
J - Agricultural Industrial		
Z - Agricultural		
	TOTAL	10 000

Source: Prepared by GTR for the Ministry of Development.

Figure 4: Final energy consumption in the non-residential sector according to the segmentation by uses carried out based on the land register.

As a supplement to this consumption, the *"Long-term strategy for energy renovation in the building sector in Spain pursuant to Article 4 of Directive 2012/27/UE"* (2014) also shows the following disaggregation of consumption into different energy uses:

USES		DISTRIBUTION OF CONSUMPTION (in %)				
		Climate	Cooling*	Lighting	DHW	Equipment and other
Offices (private)		55	25	20	5	20
Commercial	Small businesses	40	20	20	5	15
	Shopping centres	40		45		15
Hotels		45		15	23	17
Sports centres		36	10	19	6	39
Hospitals		40		35	20	5
Public administration		55	25	20	5	20
Public primary/secondary schools		75		20		5
State secondary schools		70		20		10
Universities		40	10	30		30

*Cooling is a separate quantity of Climate and should not be considered in the sum of percentages

Source: Prepared by GTR for the Ministry of Development.

Figure 5: Distribution in % of consumption in the non-residential sector according to the segmentation by uses carried out based on the land register.

It would also be possible to locate the properties and areas through the cadastral data in the different provinces, which in turn would make it possible to determine, with some approximation, the climatic demands to be faced.

Regarding the number of heritage buildings in Spain, in 2016 there were more than 15,000 properties of cultural interest (13,681 monuments, 970 historical ensembles and 479 historical sites) according to official data:

	TOTAL					DISTRIBUCIÓN PORCENTUAL				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
TOTAL	16.559	16.795	17.107	17.302	17.450	100	100	100	100	100
Monumento	13.093	13.160	13.405	13.558	13.681	79,1	78,4	78,4	78,4	78,4
Jardín Histórico	90	91	91	91	91	0,5	0,5	0,5	0,5	0,5
Conjunto Histórico	954	955	966	970	970	5,8	5,7	5,6	5,6	5,6
Sitio Histórico	338	391	427	457	479	2,0	2,3	2,5	2,6	2,7
Zona Arqueológica	2.084	2.198	2.218	2.226	2.229	12,6	13,1	13,0	12,9	12,8

Fuente: MECD. Subdirección General de Protección del Patrimonio Histórico

*Figure 6: Properties registered as Properties of Cultural Interest (*Bienes de Interés Cultural) *by category.*

These properties are among the elements catalogued as *BIC - Bienes de Interés Cultural*, which are different types of assets that the Spanish state or the Autonomous Communities have decided to protect due to their cultural interest. Law 16/1985 on Spanish Historical Heritage created the register of these properties.

1.3. Description of Spain construction industry

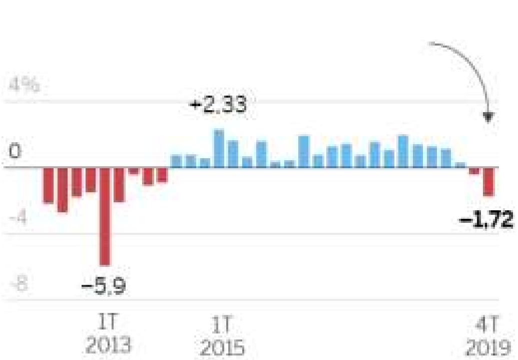
At the beginning of 2019, the construction sector was chaining a five-year period of growth in Spain and leading the economic recovery of the country after the crisis:

Economic activity indicators	Average 2000-2007	Average 2008-2014	Average 2015-2017	Data 2018
Total GDP	3.4	-1.3	3.0	2.4
GVA construction	3.1	-9.8	4.4	5.7
Investment in construction	5.4	-9.4	3.7	6.6
Investment in housing	5.4	-8.5	10.2	7.7
Investment in rest of construction	3.1	-9.8	4.4	5.7
New building permits (thousands)	642	94	65	101
New building permits	2.8	-28.7	27.5	24.7
Certificates of final completion (thousands)	482	230	47	64
Certificates of final completion	8.3	-34.9	10.0	17.8
Synthetic indicator for construction[5]	3.1	-7.9	5.2	7.6
Confidence in the construction sector (level)[5]	13.1	-41.8	-30.6	-4.6

Figure 7: Economic activity indicators and forecasts (annual change [%] unless otherwise specified).

However, the situation has changed in the last year and, according to data from INE (National Institute of Statistics in Spain), the construction sector is already in negative territory for two consecutive quarters at the end of 2019:

Quarterly variation in the supply



Quarterly change in investment

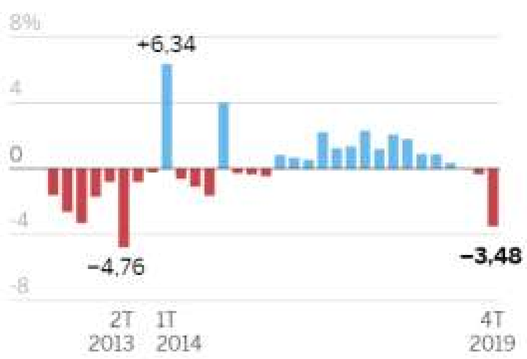


Figure 8: Quarterly variations in the building sector (Source: El País, 10.02.2020).

Issues and barriers in the construction sector

Between October and December 2019, construction suffered a quarterly drop of 1.7% in GDP, which added to the 0.3% drop recorded in the previous quarter. On the other hand, investment in construction has risen from an annual growth rate of 7% to 3.5% by the end of 2019.

Housing construction grew by nearly 12% a year ago, and it only amounts to 3% now. The non-residential sector is sinking by 12%. This category includes private buildings such as industrial warehouses, shopping centres or offices, which could have been affected by fears of a slowdown. But it also includes public works. Two factors seem to have weighed on them: the halt in the electoral cycle and the government's attempts to control the deficit by freezing investment in the latter part of the year.

On the other hand, employment in the construction sector is experiencing a sharp slowdown after it accounted for one in four jobs created in 2018. In the Labour Force Survey, employment grew by 12% by the end of 2018 and it has ended 2019 with a meagre 0.3% increase.

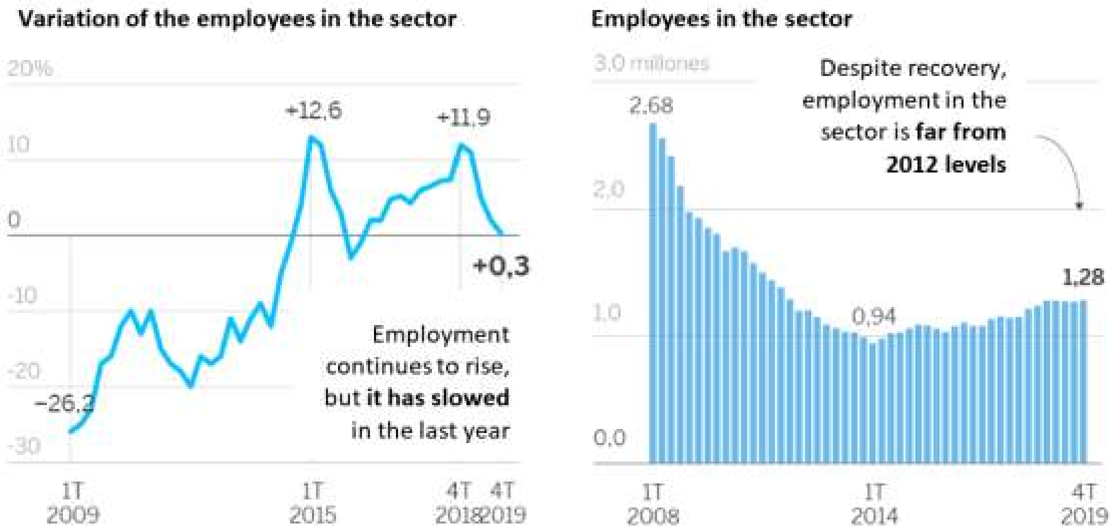


Figure 9: Employees in the building sector (Source: El País, 10.02.2020).

Confidence surveys in the construction sector worsened in the last quarter. New construction visas have lost strength over the twelve-month cumulative period and there has been a cooling off in home sales, which are dragging four consecutive months of year-on-year declines and may close the year with the first setback since the recovery began in 2013. Still, 2019 will be the second year with more houses sold (after 2018) since the bursting of the housing bubble.

Ratio between new construction and interventions on existing buildings

YEAR	NEW BUILDINGS						BUILDINGS TO BE REFURBISHED	BUILDINGS TO BE DEMOLISHED
	TOTAL	RESIDENTIAL BUILDINGS				NON-RESIDENTIAL BUILDINGS		
		TOTAL	FAMILY HOMES	PERMANENT COLLECTIVE RESIDENCE	TEMPORARY COLLECTIVE RESIDENCE			
2018	35.473	27.677	27.389	28	260	7.796	27.736	6.507
2017	33.095	24.946	24.778	19	149	8.149	28.581	6.989
2016	29.959	22.105	21.967	29	109	7.854	28.156	6.448
2015	24.823	17.077	16.971	25	81	7.746	25.825	5.100
2014	22.594	15.009	14.901	19	89	7.585	26.136	5.279
2013	24.052	16.267	16.012	55	200	7.785	25.227	5.725
2012	28.956	21.038	20.923	29	86	7.918	29.154	6.941
2011	38.973	30.194	30.052	46	96	8.779	30.237	7.295
2010	44.781	35.110	34.317	183	610	9.671	31.910	8.084
2009	51.744	39.564	39.349	102	113	12.180	33.267	7.984
2008	93.678	79.752	79.467	126	159	13.926	34.807	14.573
2007	187.147	166.322	165.833	197	292	20.825	33.359	26.141
2006	230.044	208.631	208.016	306	309	21.413	35.856	28.480
2005	203.377	184.218	183.566	190	462	19.159	33.086	20.997
2004	184.278	166.180	165.584	247	349	18.098	32.229	18.165
2003	167.138	150.064	149.456	201	407	17.074	28.392	14.420
2002	145.048	129.279	128.819	166	294	15.769	27.336	12.718
2001	144.576	128.874	128.178	220	476	15.702	25.818	11.799
2000	158.008	142.035	141.287	151	597	15.973	25.727	11.838

Figure 10: New buildings. Number of buildings by type of works (Source: Licenses. National historic information).

YEAR	TOTAL		ENLARGEMENT		EMPTYING		BUILDING FOUNDATIONS	BUILDING DECKS	BUILDING FACADES	Nº OF REFURBISHED OR CONDITIONED PREMISES
	Nº BUILDINGS	AREA (mil. m²)	Nº BUILDINGS	AREA (mil. m²)	Nº BUILDINGS	AREA (mil. m²)				
2018	27.736	1.686	6.430	1.106	1.467	582	4.004	9.067	9.760	3.516
2017	28.581	1.817	6.523	1.027	1.765	792	4.352	9.641	9.770	3.728
2016	28.156	1.358	6.851	1.024	1.412	333	4.299	9.673	9.182	4.185
2015	25.825	1.222	5.970	783	1.569	440	4.195	9.527	9.318	4.804
2014	26.136	1.183	6.029	927	1.367	255	4.167	9.955	8.797	5.143
2013	25.227	1.190	6.241	834	1.485	357	3.517	9.067	8.207	4.852
2012	29.154	1.522	7.358	1.059	1.834	462	4.499	10.285	9.543	5.739
2011	30.237	1.740	7.316	1.172	2.208	570	5.228	11.977	10.106	6.374
2010	31.910	2.761	8.826	2.203	1.936	557	5.111	12.460	10.982	6.043
2009	33.267	2.495	9.217	2.013	1.825	480	4.457	12.645	11.282	6.242
2008	34.807	3.582	11.423	2.887	2.345	896	4.858	11.223	11.650	7.371
2007	33.359	3.408	12.166	2.755	2.187	654	4.844	10.100	11.354	6.902
2006	35.856	3.282	13.727	2.478	2.912	806	4.966	10.834	12.212	7.162
2005	33.086	2.684	13.115	2.141	2.111	544	5.138	10.191	12.016	6.886
2004	32.229	2.962	12.932	2.298	2.437	685	4.572	9.461	10.642	6.020
2003	28.392	2.970	11.668	2.444	1.640	525	4.274	8.326	9.638	5.749
2002	27.336	2.556	11.985	2.072	1.608	485	4.022	8.061	8.991	5.659
2001	25.818	2.701	11.939	2.180	1.585	521	3.932	7.732	8.629	5.421
2000	25.727	2.837	12.052	2.254	1.583	585	3.847	7.487	8.757	5.272

Figure 11: Refurbishment works. Number of buildings and area by type of works (Source: Licenses. National historic information)

Innovation in the construction industry

According to the latest annual report of the Cotec Foundation, Spain's total investment in R&D in 2017 was 14,052 million euros, 792 million more than a year before, which represents a 6% increase and three consecutive years of growth, according to provisional data published in November 2018 by the National Statistics Institute (INE).

This rate of progress was higher than the nominal GDP growth of 4.3% in 2017. This means that R&D gained weight in the overall Spanish production structure for the first time in seven years, standing at 1.20% of GDP, compared to 1.19% in 2016.

However, according to the report on the construction sector by the *Observatorio Industrial de la Construcción (Fundación Laboral de la Construcción)* in relation to the distribution of domestic R&D expenditure by branch of activity, companies in the Services sector accounted for 49.0% of domestic business R&D expenditure in the year 2017, whereas those in Industry accounted for 48.5%.

The figures for companies in the construction sector reveal that they accounted for only 1.4% of total expenditure. In the breakdown of the statistics by branch of activity, within the Industry Total including the companies of 21 industrial activities corresponding to 39 CNAE *(*National Classification of Economic Activities*, Clasificación Nacional de Actividades Económicas),* the activities referred to construction companies were below the average expenditure by category, which does not correspond to the relevance of the sector to the national economy and its contribution to GDP.

<u>Spain regulatory framework and policies</u>

In Spain, the Law on Building Management (Law 38/1999 of 5 November, *Ley de Ordenación de la Edificación,* also known by its acronym *LOE*), is the legislation in force on construction since 1999. It was created to define basic requirements in buildings, which were later developed by the Technical Building Code (*Código Técnico de la Edificacion – CTE)*.

This Law also updates and completes the legal configuration of the agents that intervene in the building process, sets their obligations and establishes the responsibilities and guarantees of protection for users.

<u>Outlook (strength and weaknesses)</u>

According to the conclusions of the Institut de Tecnologia de la Construcció de Catalunya (ITeC) on the latest Euroconstruct report for the construction sector in Spain, the forecast is that the slowdown in the construction sector will continue in 2021 (2.0%) and 2022 (0.7%), unlike GDP, which, according to most analysts, will tend to grow from 2020 onwards (3.1% in 2020).

2. ENERGY RETROFIT OF EXISTING BUILDINGS

2.1. Implementation level of energy efficiency of the construction sector

The deadline for the transposition of EU Directive 2018/844 on the energy performance of buildings into Spanish national law is 10 March 2020.

In 2019, an update of the "Energy Saving Basic Document" (Documento Básico de Ahorro de Energía, DB-HE) of the "Technical Building Code" (Código Técnico de la Edificación, CTE) was approved, with new requirements to comply with Directive 2010/31/EU (EPBD), which establishes that the minimum energy efficiency requirements must be reviewed periodically at intervals of no more than five years.

2.2. Regulation and approaches in the energy efficiency of the building stock

As previously mentioned, the "Technical Building Code" (*Código Técnico de la Edificación,* CTE, first created by the Royal Decree 314/2006) was updated in 2019 (through **Royal Decree 732/2019**). It includes the energy performance requirements for both new buildings and existing ones.

This document is structured in two parts, the second of which consists of the "Basic Documents" (Documentos Básicos, DB). One of them is the "Energy Saving Basic Document" (Documento Básico de Ahorro de Energía, DB-HE), whose scope is specified in every section:

- Section HE0. "Limitation of energy consumption" (*Sección HE0. Limitación del consumo energético*).
- Section HE1. "Conditions for the control of energy demand" (*Sección HE1. Condiciones para la limitación de la demanda energética*).
- Section HE2. "Performance of thermal installations" (*Sección HE2. Rendimiento de las instalaciones térmicas*). This requirement is developed in the "Regulation of Thermal Installations in Buildings (*Reglamento de Instalaciones Térmicas en Edificios*, RITE), first approved by the Royal Decree 1027/2007, having been last updated by **Royal Decree 56/2016**.
- Section HE3. "Conditions of lighting installations" (*Sección HE3. Condiciones de las instalaciones de iluminación*).
- Section HE4. "Minimum Renewable Contribution of Domestic Hot Water" (*Sección HE4. Contribución mínima de energía renovable para cubrir la demanda de Agua Caliente Sanitaria*).
- Section HE5. "Minimum Generation of Electric Energy" *(Sección HE5. Generación minima de energía eléctrica)*.

In recent years, the incorporation of thermal insulation in roofs and facades and the replacement of existing windows and frames are among the most common energy improvement actions. It is also noteworthy the improvement or replacement of heating, cooling and DHW systems, as well as the replacement of existing lighting and other domestic appliances with more efficient ones.

The role of financial aid and funding (both at national and regional level) as a key element in providing incentives for energy retrofitting should be highlighted. According to data provided by the Institute for Energy Diversification and Saving (*Instituto para la Diversificación y Ahorro de la Energía, IDAE)*, which belongs to the Ministry for Ecological Transition and Demographic Challenge, there is a significant demand for aid applications for the energy retrofitting of buildings. In one specific case, the Pareer Crece Programme -a programme for granting financial aid at national level for the energy renovation of existing buildings intended for any use- the budget allocated has been insufficient, since the EUR 200 million provided have not served to satisfy all the demands and many citizens have been left out, waiting for future calls.

2.3. Tools currently used for energy efficiency design and interventions

The most common programs for building energy certification in Spain are:

- Unified LIDER/CALENER Tool (HULC): to both verify the compliance with current mandatory energy regulations (CTE DB-HE 2019, explained in 2.1) and issue the energy efficiency rating report.
- CERMA: for the energy efficiency rating of residential buildings.
- CE3 / CE3X: for the energy efficiency rating of residential and tertiary buildings.
- CYPETHERM HE Plus: for the energy efficiency rating of residential and tertiary buildings (private initiative software).
- SG SAVE: for the energy efficiency rating of residential and tertiary buildings (private initiative software).

And for building energy simulation:

- OpenStudio: to support building energy modelling using EnergyPlus.
- DesignBuilder: for building simulation (energy, natural lighting and ventilation…). It is supported by the EnergyPlus engine.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

The last update of the “Energy Saving Basic Document” (*Documento Básico de Ahorro de Energía*, DB-HE) of the “Technical Building Code” (*Código Técnico de la Edificación,* CTE) in 2019 leave heritage buildings out of the application of the energy performance restrictions when the application of the building regulation “could unacceptably affect its character or appearance, being the authority dictating the official protection who determines the unalterable elements”.

Considering each of the sections of the document mentioned above:

- Section HE0. “Limitation of energy consumption” (*Sección HE0. Limitación del consumo energético*). Since there is no limitation on their scope, heritage buildings could be considered as existing buildings and should therefore be required to comply with the standards of this section. However, heritage buildings are exempted from the application of this section when so decided by the competent body on historical-artistic protection.
- Section HE1. “Conditions for the control of energy demand” (*Sección HE1. Condiciones para la limitación de la demanda energética*). Same consideration as for the HE0.

- Section HE2. "Performance of thermal installations" (*Sección HE2. Rendimiento de las instalaciones térmicas*). This requirement is developed in the "Regulation of Thermal Installations in Buildings (*Reglamento de Instalaciones Térmicas en Edificios*, RITE). See **Royal Decree 56/2016** in the following point.
- Section HE3. "Conditions of lighting installations" (*Sección HE3. Condiciones de las instalaciones de iluminación*). Same consideration as for the HE0.
- Section HE4. "Minimum Renewable Contribution of Domestic Hot Water" (*Sección HE4. Contribución mínima de energía renovable para cubrir la demanda de Agua Caliente Sanitaria*). Since it is not specified that heritage buildings are outside its scope, those having DHW and demand for it must comply with these requirements at the time of their extension/renovation.
- Section HE5. "Minimum Generation of Electric Energy" *(Sección HE5. Generación minima de energía eléctrica)*. For heritage buildings not able to comply with the requirements for existing buildings, according to the judgement of the competent body on historical-artistic protection, there will be a justification of such impossibility. Moreover, different alternatives should be studied, implementing the solution which comes closer to the situation of maximum production.

Royal Decree 56/2016 updated the "Regulation of Thermal Installations in Buildings" (Reglamento de Instalaciones Térmicas en Edificios, RITE, first created by the Royal Decree 1027/2007). No special mention is made of heritage buildings, but these standards must be considered for the proper functioning of their thermal installations - not only in their renovations (they can be reasonably modified without altering the protection of the building) but also in their maintenance, use and inspection.

On the other hand, in 2009, the Minister of Housing and the President of the CSCAE (Higher Council of the Colleges of Architects of Spain, *Consejo Superior de los Colegios de Arquitectos de España*) signed the "Specific Collaboration Agreement to carry out a study on the application of the CTE to architectural intervention and restoration works in protected buildings" (*Convenio Específico de Colaboración para la realización de un estudio relativo a la aplicación del CTE a las obras de intervención y restauración arquitectónica en los edificios protegidos*). This agreement established the basis of the "CTE Application Guide to protected buildings" (*Guía de aplicación del CTE a edificios protegidos, GACTEP*). The last version available is from September 2009. Since April 2010, it is under review by the Ministry of Housing. It is not the definitive document, as some parts are expected to be completed and adequate. This guide does not deal with energy efficiency issues in any of its sections.

In other relevant related documents such as, for example, the Spanish National Energy Plan 2014-2020, although it is recognized that protected buildings need specific programs to improve their energy efficiency, it is not specified which ones. This limitation has long been identified, hence the Spanish participation in related European projects and the existence of groups and workshops on the subject.

3.1. Case studies of energy improvement intervention on historical buildings

There are several EU projects on the energy renovation of heritage buildings with Spanish partners, in the framework of which work with Spanish pilot buildings has been done:

- **RENERPATH** Project - Methodology for Energy Retrofitting on Heritage Buildings (POCTEC Spain-Portugal Cross-Border Cooperation Operational Programme 2007-2013).
    - Objective: to establish a methodology for energy retrofitting, applicable to heritage buildings for public or private use in the community of Castilla y León (Spain) and the central area of Portugal.
    - Interesting outcome: *"Application Guide for Energy Retrofitting of Heritage Buildings"* (novel and non-intrusive techniques in the characterization of the building envelope, energy solutions applicable to heritage buildings relating to their envelope, air-conditioning and lighting).
    - **Pilot case:** Cathedral of Ciudad Rodrigo (Salamanca).
- **RENERPATH2** Project - Continuation of the previous project (POCTEC 2014-2020).
    - Objective: to establish a European pre-normative for the energy retrofitting of heritage buildings for public or private use, by using the methodology obtained with the POCTEP RENERPATH Project.
    - Interesting: it will be implemented first in singular buildings in the region of Castilla y León and the central zone of Portugal.
    - **Pilot cases:** Mota Castle in Medina del Campo (Valladolid), Casa de la Cultura in Ciudad Rodrigo (Salamanca), Episcopal Palace in Astorga (León) and Collegiate Church of San Luis in Villagarcía de Campos (Valladolid).
- **3ENCULT** Project – European Commission DG Environment - Seventh Framework Programme (end of the project: March 2014).
    - Objective: to develop passive and active solutions for conservation and energy efficient retrofitting.
    - Interesting: eight case studies to demonstrate and verify solutions applicable to most of the European built heritage in urban areas. Building owners and local historic preservation agencies integrated in local case study teams. Documentation can be download here.
    - **Pilot case:** Industrial Engineering School in Béjar (Salamanca).
- **VIOLET** Project – preserVe tradItiOnal buiLdings through Energy reducTion (Interreg Europe).
    - Objective: to improve regional public policy to enhance energy efficiency in traditional buildings, by addressing both low carbon and cultural preservation actions.
    - Interesting:
        - Each region contributes to the main output of the project: an action plan describing the policy actions required to improve energy efficiency in traditional buildings.
        - The project addresses the following policy instruments:
            - *Regional Operational Programme 2014 – 2020: Priority Axis 5.1 "Preserving, protecting, promoting and*

    developing natural and cultural heritage". The instrument needs to be improved to include energy efficiency criteria and to target traditional buildings with specific solutions and monitoring tools.
  - *Operational Programme "Competitiveness and Sustainable Development 2014-2020" (Axis 3: Reduction of Carbon Dioxide Emissions and Adaptation to Climate Change)*. Improvements are needed to include energy efficiency standards and prove that energy refurbishment of traditional buildings results in significant energy savings, economic opportunities and cultural value.

- **EFFESUS** Project – Energy Efficiency for EU Historic Districts' Sustainability - Seventh Framework Programme (end of the project: August 2016).
  - Objective: to develop and demonstrate, through seven case studies, a methodology and criteria for selecting and prioritising energy efficiency interventions in the retrofitting of historic districts.
  - Interesting:
    - The main output of the project was supposed to be a Decision Support System (DSS, software) including all the parameters needed to select suitable energy efficiency interventions for historic districts.
    - Public deliverables.

- **INCEPTION** Project – Inclusive Cultural Heritage in Europe through 3D semantic modelling (H2020).
  - Objective: to realise innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, buildings, sites and social environments.
  - Interesting: Demonstration cases in Croatia, Cyprus, Greece, Italy, Netherlands and Spain.

4. BIM ADOPTION IN SPAIN

buildingSMART Spanish Chapter is a private non-profit association, which forms part of buildingSMART International, whose main objective is to promote the integration of all processes in all the phases in the building industry through the coordinated management, use and exchange of all associated information to improve efficiency, productivity and product quality in the construction. Based on this objective, they decided to create an Observatory of Projects and Works having used the BIM methodology in Spain, allowing to know the degree of implementation of BIM periodically[1].

In May 2017, a review of the status and participation in the Observatory ended with the following results:

- Minimum participation: only 38 projects were published.
- Low participation of both buildingSMART Spanish chapter members and user groups.

On the other hand, es.BIM is a group whose main mission is the implementation of BIM in Spain. They have decided to set up a BIM tender observatory with a dual function: to verify the progress of the inclusion of BIM requirements in public tenders (through a monthly monitoring of the number of public tenders by categories) and to analyse how BIM is included in these tenders.

The 7th observatory report includes the analysed results of 517 public tenders including some BIM requirement and having been published from the beginning of 2017 to the first half of 2019, representing a total accumulated investment of 1,532.7 million €:

	2017	2018	2019*	total
número	106	216	195	517
inversión	264,5 mill.	424,8 mill.	843,3 mill.	1.532,7 mill.

Figure 12: Annual breakdown of the number of and investment in public tenders with BIM requirements

The building sector has gradually increased the number of tenders published since the beginning of 2017. In relation to infrastructure and the cumulative total, the building sector accounts for 72% (372 tenders) compared to 28 for infrastructure. However, in terms of investment, they represent only 44% of the value (672.9 million € invested).

In overall terms, renovation projects (*rehabilitación,* turquoise colour) slightly predominate over new construction ones (*obra nueva,* dark green) in the case of building projects, both in number and in investment. However, it can be seen when studying the annual evolution since 2017 that the values have been reversed:

[1] https://www.buildingsmart.es/observatorio-bim/casos-de-%C3%A9xito/

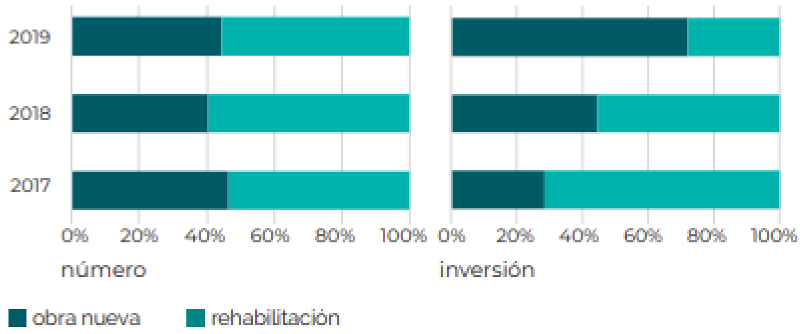


Figure 13: Breakdown of the % of the number of and investment in public with BIM requirements in the building sector by year

As for the use of the projects under tender were destined, buildings intended for health or educational purposes had, overall, the highest number of tenders (21% and 26%) and investment (27% and 24%). However, in the second quarter of 2019, housing and transport were the uses with the most investment (42% and 21%) and in the first quarter of 2019 there was an investment of 27% in sports use.

4.1. Spanish regulations on digitalization of the construction industry and BIM

In 2015, in response to the European Directives on public procurement 2014/23/EU and 2014/24/EU, the Ministry of Development set up the Commission for the implementation of the BIM methodology in Spain. The Spanish National BIM Strategy is also proposed this year.

In March 2018, a few months after the publication of the Handbook for the introduction of BIM by the European Public Sector (November 2017), the Spanish Public Sector Contracts Law 9/2017 came into force, transposing the Directives of the European Parliament. This law establishes the possibility of requiring projects submitted to public tenders to be made with BIM or a similar methodology.

This is reflected in point 6 of the fifteenth additional provision on the use of BIM: "For public works contracts, public contracts for works concessions, public service contracts and design contests, and in mixed contracts to combine elements thereof, contracting authorities may require the use of specific electronic tools such as digital building information modelling (BIM) or similar tools”.

The same year, in June 2018, the BIM White Paper for Public Administrations was proposed and by the end of the year (on 17 December 2018) the BIM methodology was made compulsory for all publicly funded building projects of more than two million €.

On 26 July 2019, this obligation was also extended to all publicly financed construction projects for infrastructure.

In 2020, it is expected:

- The extension of this obligation to all public facilities and infrastructures in all phases: design - construction - maintenance.
- Include in this objective all new construction and renovation projects.

4.2. Average user's (enterprises, design firm) year of experience using BIM

In the survey carried out by the CSCAE (Higher Council of the Colleges of Architects of Spain, *Consejo Superior de los Colegios de Arquitectos de España*) between February and May 2016, in which 3,788 architects responded on the level of implementation of BIM in their professional practice, the following conclusions were drawn:

- The degree of implementation is still low among architectural firms, especially in small offices (it is only used in 40% of the firms having participated in the survey).
- The level of satisfaction of the architects having implemented these systems is high, so it can be deduced that their percentage of projects with BIM will increase.
- Collaboration through BIM systems with other professionals involved in the architectural process is still low (barely 24%), so implementation in the building sector as a whole is slow. This is also reflected in the fact that the use of BIM is mainly carried out in the phases of the project that are most closely linked to architectural conception and design (project drafting and 3D modelling) and to a lesser extent in other phases of the project in which collaboration with other professionals is usually involved (structures and facilities, for example).
- The implementation rate is expected to increase in the short and medium term, as 64% of respondents plan to receive training, mainly in BIM tools.
- 60% of those who do not initially wish to receive training would attend technical BIM seminars if they were free.

The CSCAE considers that, in the medium term, most Spanish architects will carry out their work with BIM systems and that the adaptation process should be carried out taking into account the current business structure in the architectural services sector, with measures that facilitate access to training, equipment and computer applications, with affordable costs and deadlines.

4.3. Perceived benefits and issues on BIM

Another survey was carried out by the information and communication technology services company Ibermática. Based on 131 responses from companies in the medium-sized construction sector, located in national territory, with activity in public, private and civil works, the following results were published in 2018 regarding opinions on the advantages of BIM:

- 35% of entities declared to have increased the quality of their projects and reduced errors and uncertainties.
- 20% considered that it improves cost management and increases the company's efficiency.
- 21% noted that there is greater transparency and fluidity of information, not only within the company, but also between architects, suppliers and clients.
- Surprisingly, only 20% indicated that management is improved with a reduction in post-construction costs.
- 37% found that the main advantage of the integration of BIM and ERP is the integrated view of the work.

- 23% considered that it allows them to make decisions based on data.

In the same survey, with regard to the obstacles to the implementation of BIM, the existence of factors preventing its widespread adoption was noted. Not only a change in the technology used, but also in the approach of the design and construction teams, adapting the organization and business processes, is required. Thus, 24% of companies surveyed felt that involvement of all departments is lacking.

On the other hand, 20% considered the cost of licenses as one of the main barriers, 18% found that their partner companies in projects or works do not use it, and 12% did not have enough trained personnel.

4.4. HBIM adoption in Spain

In Spain, progress towards the implementation of BIM in historical/listed buildings seems to have been linked, in most cases, to publicly funded research projects.

For example, the R&D project financed by the Spanish Ministry of Economy and Competitiveness entitled: *"Design of a Database, Management Model for the Information and Knowledge of Architectural Heritage (HAR2013-41614-R)"*, gave as a result the connection between historical databases and BIM databases for the first time (García Valldecabres et al., 2016). Also, HBIM templates were created containing HBIM families, historical phases, and heritage materials to support future heritage groups interested in using this platform.

An HBIM protocol to improve the workflow in heritage interdisciplinary projects has also been developed (the on-line platform BIMlegacy) and applied in a real case study. BIMlegacy also proposes specific training for heritage stakeholders and aims to help them in medium size building interventions. It focuses on buildings owned by private institutions and underlines the possible benefits and issues of HBIM.

Some Spanish HBIM case studies are:

- The Pavillion of Charles V, in the Alcazar of Sevilla.
- Church of San Juan del Hospital in Valencia.
- Chapel of the Sacred Heart of the Cathedral of Palma de Mallorca.
- Sagrada Familia Temple of Barcelona.
- Cathedral of Santa María of Vitoria-Gasteiz.

4.5. HBIM AND INTEROPERABILITY

4.6. BIM and energy efficiency

At present, there is not much information addressing the issue of integrating BIM methodology for energy efficiency interventions in Spain.

Interoperability through the IFC standard format seems to be one of the most complex aspects in the case of the integration of BIM for energy certification in Spain. Thus, although there are programs allowing to get very close to the results provided by official energy certification tools, there are other programs that are far from them, and do not even take into account indispensable aspects, such as thermal bridges.

However, as it is necessary to obtain energy certification through an official recognised tool, interoperability must be used to transfer data to a recognised tool. The most direct case would be the import of the IFC obtained through the modeling programs into the official tool Cypetherm HE Plus.

On the other hand, none of the major power simulation engines such as EnergyPlus and DOE-2 are capable of directly importing BIM files such as gbXML and IFC directly from CAD tools currently.

However, there are graphical energy simulation interfaces able to use BIM files such as OpenStudio, IES-VE, EGB, ICE AIF, RIUSKA and Ecotect.

4.7. HBIM and energy improvement

Any case study found. This case is more complex, due to the fact that in most cases Spanish heritage buildings are not subject to energy efficiency certification standards.

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ANNEX 3 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF CYPRUS

Country:	Cyprus (CY)
Date:	31/01/2020
Prepared by:	PP3 CI-EEWRC
Status:	Finished
Version:	v1
Authors:	Stavroula Thravalou, Kristis Alexandrou, Georgios Artopoulos

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Index

1. GENERAL INFORMATION

1.1. General Cyprus data (population, official language, capital, area, GDP total/per capita, currency)

The Republic of Cyprus is an EU member and is located at the southwest Mediterranean Region. Cyprus has a total population of 840,407 (2011) and an area of 5,896 Km^2 under its administration. The official languages are Greek and Turkish, and the currency is Euro (€). Cyprus total GDP /per capita is approximately 22,981 €.

1.2. Description of Cyprus building stock

In 2013, there were 300 thousand permanently occupied dwellings: approximately 120 thousand single family houses, 65 thousand semidetached and row houses, 110 thousand apartments, and 8 thousand other building types (mainly back-yard houses). The majority of the Cypriot dwelling stock (67%) was owner-occupied, with the largest part (78%) located in the coastal and low land areas. Approximately 40% of the stock was built before 1981 and 54% between 1981 and 2006, before the first normative energy requirements. Details about the residential building types are as follows:

36,5%	Apartment Buildings
26,8%	Single Houses
16,7%	Semi-Detached Houses
11,2%	Residences in mix-use buildings
6,3%	Houses (in continuous land construction)
2,5%	Auxiliary Homes

The age of Residential buildings according to construction date 2014 is:

8,43%	>2010
28,60%	2000-2010
16,77%	1990-1999
19,44%	1980-1989
13,32%	1970-1979
10,09%	1945-1969
3%	<1945

In 2013, the permanently occupied non-residential building stock consisted of about 30 thousand buildings with a total floor area greater than 9 Million m^2. Office buildings (public and private) represented 39% of the total stock, while the hospitality sector (accommodation, restaurants, and taverns) accounted for 25%. The largest part (83%) was built before the first normative energy requirements. Details about the non-residential building types are as follows (Table 1):

	Total Floor Area $[m^2]$[1]	Number of establishments[1]	Average floor area $[m^2]$[1]	Specific final energy consumption $[kWh/m^2]$[1]
Hotels	2,094,134	766	2,734	239.17
Secondary schools	613,546	144	4,261	70.72
Primary schools	453,755	325	1,396	64.91
Nurseries	96,376	419	230	77.24
Tertiary education	222,404			304.33
Public buildings	1,886,370	1,087	1,735	74.84
Airports	119,600	2	59,800	283.70
Supermarket and malls	280,396	67	4,185	319.06
Healthcare institutions	485,898	83	5,854	386.30
Restaurants	179,360	2,242	80	1,300.00
Private offices	1,665,000	11,100	150	223.04
Retail shops	1,080,000	18,000	60	226.47

[1] Data from JRC Petten report

Table 1: Number of non-residential building types in Cyprus.

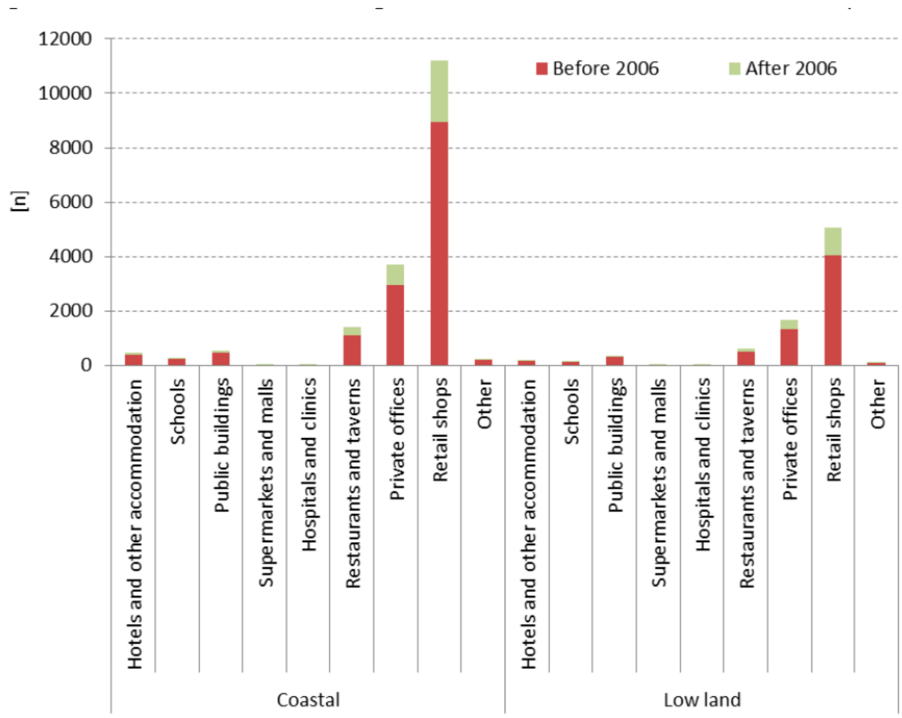

Figure 1: Number of buildings in coastal and low land climates per building type.

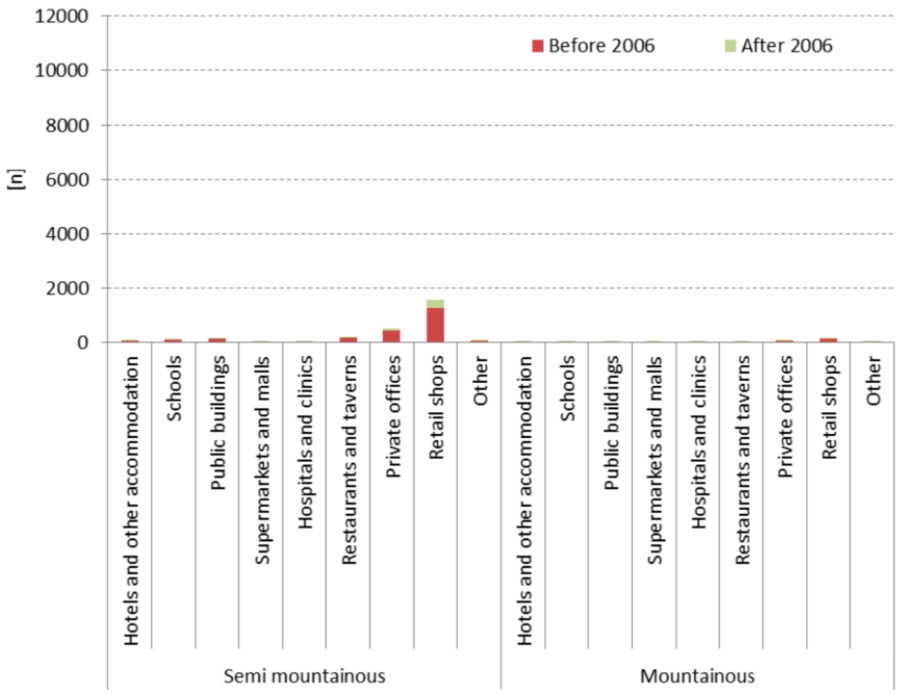

Figure 2: Number of buildings in semi-mountainous and mountainous climates per building type.

According to the department of Lands and Surveys, there are approximately 6.500 Heritage buildings in Cyprus and their number is growing. The majority of heritage buildings are of residential use. One of government's future plan is to roof public services in heritage buildings. Cyprus adopted and signed numerous international agreements in regard to heritage building protection such as The Venice Charter (1964), the declaration of Amsterdam (1975), The Granada convention (1985), the charter for the conservation of historic towns and urban areas (1987), and many more.

1.3. Description of Cyprus construction industry:

The construction sector in Cyprus is showing signs of recovery after a severe economic and financial crisis coupled with a housing crisis. Notably, production in construction dropped overall by 47% from 2010 to 2016. Nevertheless, since 2014, it has picked up by 13.2%. Similarly, even though the drop-in employment in the construction sector over the period 2010-2016 stands at 39.0%, there is an upward trend since 2014. Yet, the gross operating surplus of the broad construction sector amounted to EUR 247 million in 2014, 73.5% below the 2010 level.

The number of enterprises in the broad construction sector in Cyprus totalled 11,994 in 2016, with the construction sub-sector (NACE F) accounting for 66.4% of the total firms. Overall, the number of enterprises in the broad construction sector decreased by 12.3% from 2010 to 2016. Company growth has been positive in two of the four sub-sectors from 2010 to 2016, namely in engineering activities and related technical consultancy as well as in real estate activities which grew respectively by 11.6% and 16.5%. On the other hand, the construction and manufacturing sub-sector saw a decrease by respectively 17.1% and 11.3%. Despite the overall decrease, both sectors have been following an upward path in recent years. In line with the drop in the number of companies, production has decreased dramatically from 2010 to 2016, by 47%. However, since 2014, production has picked up again.

Productivity

Labour productivity in the broad construction sector experienced a sharp decrease from 2010 to 2014, dropping from EUR 51,628 to EUR 26,149, representing a 34.7% decrease (Figure 7). This decrease has placed Cyprus below the EU-28 average, which stood at EUR 50,200 in 2014. Real estate activities fare the best, decreasing by 29.1% over the 2010-201615 period, while architectural and engineering activities experienced the largest decrease, with a 38.4% drop. The productivity in the manufacturing and construction sub-sectors declined, respectively, by 31.7% and 38.0% over the same period.

According to the Productivity Centre in Cyprus, labour productivity in the construction sector is equal to 64.1% of the general economy's productivity, while this number amounts to 62.8% for the manufacturing sector. This is to be contrasted with gross value added in real estate activities, which is about 20 times higher than average productivity in the economy. This is inherent to the sector, given the high value of housing and the relatively low number of individuals working in this sector16.

Employment

In 2016, the broad construction sector employed 30,455 people. The number of persons employed in the broad construction sector declined by 39.0% between 2010 and 2016. The construction sub-sector employed the majority (68.4%) of the total construction workforce in 2016, followed by manufacturing (18.2%), architectural and engineering activities (7.6%), and real estate activities (5.8%). The narrow construction sub-sector experienced a 41.8% decrease in its workforce from 2010 to 2016, the highest among the four sub-sectors. The manufacturing sub-sector also experienced a large decrease, over the same period, losing 38.7% of its employees. On the other hand, employees in the real estate activities have stayed relatively constant, decreasing only by 2.0%.

The number of self-employed workers in the construction sub-sector has declined substantially over 2010-2016, reaching 6,100 people in 2016, 36.5% below the 2010, when 9,600 self-employed were working. Since 2015, the number of self-employed has however started to pick up. In parallel, full-time employment in the construction sub-sector decreased by 43.1% between 2010 and 2016, while the number of part- time workers more than doubled. Finally, SMEs employed 88.0% of the entire workforce of the broad construction sector in 2012.

The number of authorised building permits in Cyprus in 2018 is 6,408. There is no information regarding the amount of building renovations.

Innovation in the construction industry

Cyprus has moved down the ranking in the European Innovation Scoreboard in 2017, being classified as a moderate innovator. It is the country, after Romania, that has seen its rank decrease the most between 2010 and 2016. The performance relative to the

EU peaked in 2011 (95%), but has declined to 74.8% in 2016. Its relative strengths lie in Attractive research systems, Human resources, and Intellectual assets while its relative weaknesses are in Linkages, Finance and support and Firm investments.

In addition, the National Reform Programme sets a very modest R&D intensity target of 0.5% for 2020, the lowest R&D intensity target in the EU, and similar to 2010 levels. According to the European Commission's Researchers Report, 70.6% of total R&D expenditure was financed by government in 2011, the highest percentage in the EU and significantly above the EU average of 34.9%, highlighting the lack of private funding in innovation. According to the European Semester Country Report on Cyprus, investment in R&D carried out by the private sector amounted to only 0.08% of GDP, the lowest of all Member States. The report stresses that this can notably be explained by structural limitations in Cyprus, due to its small market size, remote location and service-oriented economy.

In addition, business enterprise R&D expenditure (BERD) in the broad construction sector has shown a generally decreasing trend since 2010. Indeed, BERD in the professional, scientific and technical activities sub-sector experienced a 43.9% decrease over 2010-2014, from EUR 2.1 million to EUR 1.2 million, remaining the highest among the sub-sectors. Conversely, BERD in the construction sub-sector has increased by 68.2%, from EUR 66,000 in 2010 to EUR 111,000 in 2013. In 2014, however, BERD in the construction sub-sector dropped significantly to EUR 33,000, representing a 50.0% decrease since 2010. No values have been registered regarding BERD in real estate activities during that period.

In parallel, the total R&D personnel (full-time equivalents – FTE) in the broad construction sector reflected the trend in BERD. Indeed, total FTE in the professional, scientific and technical sub-sector experienced a 39.6% decrease over 2010-2014, from 48 to 29, the highest among the sub-sectors. The total FTE in the construction sub-sector registered a minimal decrease, from 1 to 0 FTE during the same period of time, and no data have been registered regarding BERD in real estate activities during this period. At the same time, no construction-related patent applications have been registered since 2007 (1 patent), due to the market size.

Eco-innovation and digitalisation

In order to boost innovation in the construction sector and bring about the scaling-up of innovations from the company level to the market, several initiatives have been launched. For instance, the Smart Specialisation Strategy for Research and Innovation (S3CY) has been approved by the Council of Ministers in March 2015. The main objective of this Strategy is to maximise the knowledge-based development potential of the Cyprus economy by supporting targeted sectors in which Cyprus has a competitive advantage. In addition, this Strategy includes an extensive analysis of the national R&I priorities, as well as an Action Plan, to be implemented over the period 2016 – 2020, with measures amounting to EUR 139.5 million combining European Structural and Investment Funds (ESIF) and National funds. This Strategy is expected to foster the inclusion of SMEs in RDI activities and the attraction of private investments.

Moreover, the National Energy Efficiency Action plan of 2014 includes a list of measures to be implemented to foster the innovation, particularly for SMEs. The Ministry of Energy, Commerce, Industry and Tourism (MECIT) organises seminars and workshops especially directed to professionals in the construction sector on the benefits of improving energy efficiency. For the period 2014-2020, MECIT announced a new improved scheme with a total amount of EUR 10 million to encourage new enterprises and start-ups to turn to innovation. This scheme is also intended to encourage cooperation between construction companies and research centres and universities.

In 2016, a new multi-annual program, namely "RESTART 2016-2020" was launched in order to further promote research and innovation focusing, inter alia, on the construction sector. Endowed with a budget of EUR 100 million, the program aims to foster smart development, ensure the sustainability and potential of the Research, Techno- logical Development and Innovation (RTDI) system, as well as support the operational framework of the RTDI system.

Lastly, the introduction of Building Information Modelling (BIM) technology is slowly picking up in Cyprus with new research papers being published and construction companies introducing the practice in Cyprus.

Cyprus regulatory framework and policies

Policy schemes

Housing policy in Cyprus is under the responsibility of the Ministry of Interior, together with other associated government organisations, which offer several housing support schemes targeting both low- and middle-income households. One such organisation is the Special Service for the Care and Rehabilitation of Displaced Persons (SCRDP).

The Scheme for the Purchase of a House/Apartment provides financial assistance to beneficiaries wishing to purchase a dwelling, depending both on the size of the property, the income and the composition of the household.

Finally, the SCRDP offers a Rent Subsidy Plan, which provides rent allowances to beneficiaries.

The Cyprus Land Development Corporation (KOAG) is also a key actor in terms of the provision of social housing. The organisation aims to satisfy the housing needs of low- and medium-income families, offering dwellings and building sites at affordable prices and attractive terms of sale.

To do so, it acquires land throughout the country and divides it into building sites or develops it into housing estates and apartment buildings.

Thus, the KOAG offers several schemes, such as a Medium-Income Housing Scheme, which is available to beneficiaries whose annual income ranges between EUR 22,000 and EUR 72,000, depending on the number of children. The Low-Income Housing Scheme which provided financial support to low-income families for the purchase of their own dwelling has been discontinued

Furthermore, the KOAG launched a new 4-year programme in September 2016, known as the Primary Residence Protection Plan. The programme is following a commitment of the Cypriot government to reduce the size of the housing schemes by streamlining and consolidating them in exchange of the EU financial assistance.

Another state institution offers financial aid for housing, namely the Home Financing Organisation of Cyprus. The new loan scheme is open to applicants from April 2017 to

March 2018 and provides loans with favourable conditions in order to purchase or build a property as well as for renovations or energy upgrades.

Building regulations

The main pieces of legislation which regulate the construction of all buildings and civil engineering works, thus defining the development and building control system in Cyprus, are the Streets and Buildings Regulation Law (first issued in 1959) and the Town and Country Planning Law (approved in 1972, but enforced in 1990).

Based on this Law, several regulations have been issued, namely the Streets and Building Regulations (Energy efficiency of Buildings) and the Streets and Building Regulations (Electrical and Mechanical Installations). The former regulate the requirements and procedures for the issue of building permits with respect to the provisions of Directive 2002/91/EC on the energy efficiency of buildings, whereas the latter regulate the certification of electrical and mechanical installations and aspects related to the qualification of the responsible engineers.

Foreign experts have recently reviewed the construction development legislation framework in Cyprus and have recommended the creation of a new legislative framework and several radical changes, including to the building licensing system and procedures91. Other recommendations included the introduction of a comprehensive license covering both town planning permission and building permit, and the creation of a one-stop shop.

Outlook (strength and weaknesses)

Following a 10.0% continuous decline in its GDP between 2010 and 2014, the year 2015 marked the start of a reversal of the trend in Cyprus, with GDP increasing by 1.7% and by 2.8% in 2016.

Despite the first signs of stabilisation in the construction sector, challenges still remain, particularly in relation to the banking sector, with liquidity and high levels of non-performing loans still being restrictive factors that may hamper the financing of new projects.

2. ENERGY EFFICIENCY OF EXISTING BUILDINGS

2.1. Implementation level of energy efficiency of the construction sector

The first mandatory energy performance requirements in building codes in Cyprus were introduced with the adoption of the 2007 Decree on the Minimum Energy Performance Requirements for Buildings (Decree 568/2007). The 2007 Decree, which was adopted as a result of the implementation of the EU's Energy Performance of Buildings Directive (EPBD), introduced prescriptive requirements expressed as minimum heat transfer coefficients for the building envelope for all new buildings. The same prescriptive requirements also applied to buildings over 1000 m^2 undergoing major renovation. Major renovation was defined as renovation, addition or modification works undertaken in a building whereby the total cost of the works on the building shell and/or technical systems for heating, hot water, air conditioning, ventilation and lighting is higher than 25% of the value of the building – excluding the value of the land – or in cases where the works cover more than 25% of the building envelope (Decree 429/2006). The minimum requirements were revised in 2009 and performance-based requirements in the form of minimum energy class B under the Cypriot EPC system were introduced for new buildings and buildings over 1000 m^2 undergoing major renovation. Energy class B is achieved if the primary energy consumption for heating, cooling, DHW, lighting of the building in question is the range of 50-100% of the equivalent consumption of a reference building. Prescriptive requirements for the building envelope still applied for all buildings and the requirement for solar thermal system for domestic hot water in new residential buildings was introduced. Following a revision in 2013, a new Decree came into force with more stringent heat transfer coefficients (U values were reduced by 15%) as well as additional requirements. For example, a requirement for external shading for existing buildings, regardless of their side, was put in place as well as requirements on building elements replaced or retrofitted.

Energy efficiency of the construction industry and energy retrofit intervention

Over the last decade, financial support for investments in energy efficiency and renewable energy technologies has been made available to Cypriot households, commercial companies and public sector through the following government-supported schemes:

1. Grant Scheme for the promotion of renewable energy and energy conservation (2004-2013)
2. Grant Scheme "I save – I upgrade" (2014-2020)

These schemes are considered an important pillar of the energy efficiency policy in Cyprus, and have generated and expected to generate important energy savings that contribute to both ESD and EED energy efficiency targets in Cyprus. According to calculations presented to the European Commission by the Cypriot authorities, these schemes are expected to significantly contribute to the Article 7 target under the Energy Efficiency Directive, whereby collectively they are estimated to reach 48% of the cumulative final energy savings target of Cyprus. Important design and implementation differences are noted between the two schemes, which are discussed in more detail below.

	Residential	Tertiary	Public
Grant Scheme for the promotion of renewable energy and energy conservation (2004-2013)			
Renewable energy technologies (Part 1 out of 2)			
2012 (achieved)	13443.1	1 177.4	110
2016 (expected)	13628	1 177.4	110
2020 (expected)	1011.1	84.7	0
Energy conservation measures (Part 2 out of 2)			
2012 (achieved)	10523.8	10 331.6	
2016 (expected)	11089.2	10 293.45	
2020 (expected)	1137.2	768	
Grant Scheme for installing photovoltaic systems using the NET-METERING method (2013-2016)			
2012 (achieved)	0		
2016 (expected)	47.62		
2020 (expected)	47.62		

(Source: Cyprus NEEAP 2014)

Table 2: Energy saving (TOE per year) of financial incentive schemes in Cyprus.

2.2. Mostly used approaches in the energy efficiency of the building stock

The mostly used approaches in the energy improvement of existing buildings comprise:

1. Building envelope insulation;
2. Window replacement;
3. Energy efficiency boilers for space heating/DHW;
4. Geothermal heat pumps;
5. Solar thermal systems;
6. Biomass boilers;
7. Efficient light bulbs;
8. waste energy recovery systems;
9. CHP systems;
10. Smart meters;
11. External removable or fixed shading;
12. Energy efficient air conditioning systems (split units).

2.3. Tools currently used for energy efficiency design and interventions

The most used software is ISBEM CY.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

The Republic of Cyprus has not formulated or adopted any energy improvement regulations at this stage. Currently the Government is providing funding schemes for heritage buildings conservation only.

- Describe and discuss, if any, case studies of energy improvement intervention on historical buildings

Case studies of energy improvement intervention on historical buildings

One of the major case studies on energy improvement intervention on historical buildings the Public Library in Strovolos, Nicosia.

The building was constructed in 1915 and it has been declared as a heritage structure. Since its construction, the building has been used as a public school, butchery and finally as the town hall of Strovolos municipality. In 1993 the building was abandoned. During 2011-2012 the building was renovated with energy saving measurements. Precisely, the following measurements have been applied:

5 cm of roof thermal insulation; internal thermal insulation on building walls; single glazing windows of the north and east side of the building have been replaced with double glazing panels; sunscreen panels protection for the west facing glazing; geothermal heat pump for heating and cooling; electronic energy management system.

The total cost of the renovation reached €290.000 and the depreciation time is estimated to be 4 years.

4. BIM ADOPTION IN CYPRUS

Currently there is no valid source to indicate the level BIM adoption or the number of projects developed following this new technology in the AEC industry. A negligible amount of architecture offices and land developers are using BIM mainly by utilizing the level 1 benefits provided by the BIM software; that of automated CAD design.

The Cyprus Government has not formulated or adopted any BIM regulation at this stage. A recent report from the ministry of Interior dated in 2017 and titled: 'TECHNICAL ASSISTANCE FOR REFORMING THE CONSTRUCTION DEVELOPMENT LEGISLATION FRAMEWORK IN CYPRUS' states that BIM should be part of future reform along with e-government and e-permitting.

BIM is currently used by architectural practices mostly in small scale construction sites, and my international firms building in Cyprus, such as:

1. Eleftherias Square, Nicosia (Zaha Hadid Architects), 2020 (LOIS Builders)
2. EDEN Roc Residence, Limassol, Prime Property Group, Architects: UHA London. Building Type: Residential Development; Site: 18,000 sq m; Area: Approx 12,200 sq m; Height: 32m[1].

[1] 1. (https://www.prime-property.com/en/Development/Eden_Roc_Residence/)

4.1. 2.2 HBIM adoption in Cyprus

There is no adoption of HBIM IN Cyprus yet, as there is lack of expertise in the architects who are active in the conservation and renovation field. HBIM was recently included in the areas of research in academia, only used by researchers for the documentation and safeguarding of monuments, such as the Byzantine churches of Troodos.

Main obstacles and issues for the lack of penetration of the methodology in the professional market can be:

1. Lack of standards and policies by the relevant authorities (Department of Antiquities and the Town Planning & Housing Department of the Ministry of Interiors);
2. Lack of expertise among officers and practitioners (engineers), training needed;
3. Lack of resources to justify the additional cost/labour in the practice.
4.

4.2. HBIM and interoperability

Interoperability in the construction industry in Cyprus is poor. Design process, Construction schedule, project data, procurements, tenders and general project management are mostly performed with traditions means of communications and data exchange i.e. emails, data sharing platforms, data clouds, online chatting platforms, telecopying (FAX) and phone calls.

<u>BIM and energy efficiency</u>

Government's slow adoption to new technology. There is a lack of training and guidelines for working groups i.e timber workshops, metal workshops, plumbers etc.

<u>HBIM and energy improvement</u>

CI-EEWRC is not aware of any case study in Cyprus where HBIM approach and energy simulation have been coupled on an historical building

Barriers are identified both with regards to the integration of BIM in the renovation practice of professionals and authorities officers (lack of skills and resources), and the lack of knowledge regarding the interoperation/combination of EE retrofit policies with energy performance simulation and BIM standards.

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ANNEX 4 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF JORDAN

Country:	Jordan
Date:	13/2/2020
Prepared by:	PP4 RSS-NERC
Status:	Finished
Version:	V1
Authors:	Eman Al Shbail, Muhieddin Tawalbeh

This project is funded by the EU under the ENI CBC Med Programme

Index

GENERAL INFORMATION

1.1. General country data (population, official language, capital, area, GDP total/per capita, currency):

The total Number of Jordan Population is around 10 million. The official language is Arabic and English is the second. Amman is the capital of Jordan. Total area is 89,320 km^2. The GDP of Jordan is around 43 billion USD. Jordan currency is Dinar

1.2. Description of Jordan building stock

Total number of Licensed Dwellings (Department of Statistics, 2018): 20, 628

Number of Private Buildings (Department of Statistics, 2018): 10, 041

Number of Public Buildings (Department of Statistics, 2018): 2959

Type of Building, Urban/ Rural & Governorate	Year of Laying Fundaments																سنة المباشرة بوضع الأساس
	غير مبين Unspecified	قبل 1950 Before 1950	1950-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009	2010	2011	2012	2013	2014	2015	المجموع Total
Jordan																		
Amarah	56119	1855	3979	11839	28391	30372	20070	28320	21425	25425	18377	6788	2752	3741	6858	9614	12566	**288491**
Dar	89121	1840	4151	12136	34853	36897	29808	40114	35718	48170	47903	17736	7640	9681	17515	25207	30874	**489364**
Villa	2902	14	44	71	443	665	777	1296	1178	2014	2642	792	393	603	791	980	1489	**17094**
Total	**148142**	**3709**	**8174**	**24046**	**63687**	**67934**	**50655**	**69730**	**58321**	**75609**	**68922**	**25316**	**10785**	**14025**	**25164**	**35801**	**44929**	**794949**

Table 1: Number of Dwellings with age of construction.

Stock by age – all types of buildings Year of data: 2015	**%**
<1945	3709
1945-1979	95907
1980-1999	246640
2000-2010	169847
>2010	130704
Sources: Department of statics	

Building types Year of data: 2015	Value:
Residential buildings	
Total number of buildings	684718
Total number of dwellings/units	2,350, ,490
Total area of construction	387830850[1] m^2
Sources:	**Department of statics**
Non-residential	
Total number of buildings	157021
Total area of construction	NA
Sources: Department of statics	

Table 2 and 3: show the stock by age, number of buildings (according to Department of Statistics (DOS)/2015) consequently.

1.3. Description of Jordan construction industry:

[1] Based on average 155 m2/dwelling – Residential Survey – MEMR 2013

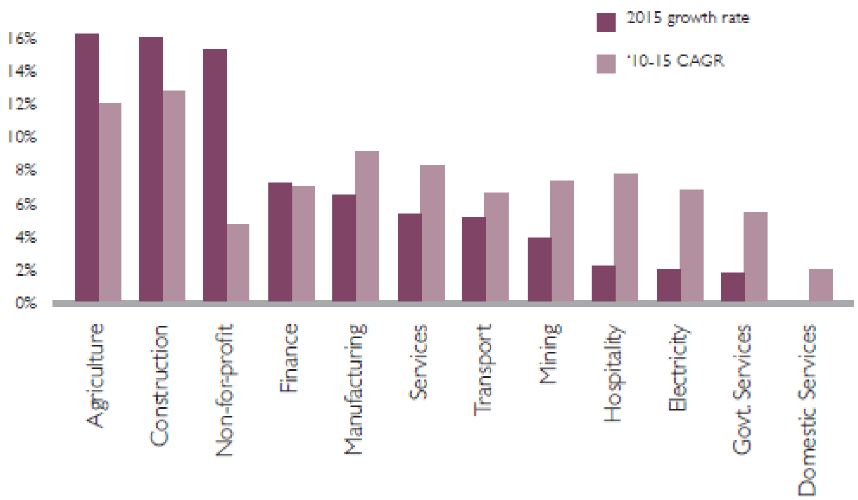

Figure 1: Growth Rate of Construction Sector among other sectors (Source: DOS, 2015).

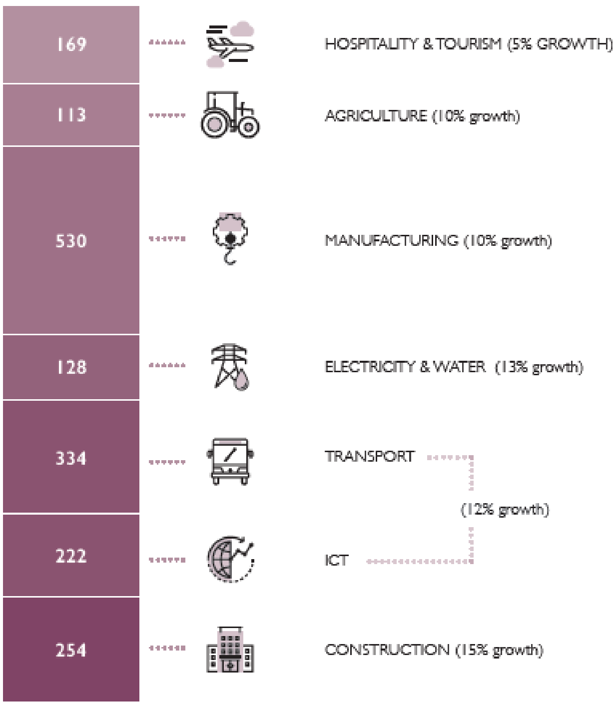

Figure 2: Growth needed by each sector to achieve 5% GDP growth throughout 2018 - 2022.

Figure 2: shows how much each sector must grow by to achieve 5% GDP growth throughout 2018 - 2022. (EPC analysis, Jordan Economic Growth Plan 2018 - 2022).

Innovation in the construction industry

The most relevant innovation factors in Jordan construction industry are summarized below:

1. Update and develop procedures for assessing and submitting tenders;
2. Put in place legislative frameworks that provide appropriate protection to investors and beneficiaries;

3. Open new export horizons;
4. Improve engineer education and training;
5. Employ new international best practices (Jordan Economic Growth Plan 2018 - 2022)

Jordan regulatory framework and policies:

The main regulations on the construction sectors are:

1. The Jordanian National Construction Law No. (7) for 1993 and Building and Planning Regulation in the City of Amman and its Amendments No. (67) for 1979;
2. Amman Building and Urban Planning Regulation of 2011.

Outlook (strength and weaknesses)

Jordan needs to substantially increase its infrastructure to accommodate the expected surge in its population. School infrastructure, hospital facilities and increased housing are all required. These projects have the benefit of job creation.

The low contribution of the main contractors of the construction sector may lead to weak linkage, weak organization and weak execution, then to more problems with quality, cost and time, which are generally known as the main criteria of the successful execution of construction projects.

2. ENERGY EFFICIENCY OF EXISTING BUILDINGS

2.1. Implementation level of energy efficiency of the construction sector

The renewable energy sources and its devices and equipment and also the Energy Efficiency Equipment exempted from the customs duties and subjecting to general sales tax in percentage or amount of (zero).

The commodities and services locally manufactured or imported, which are deemed as inputs for producing and manufacturing renewable energy sources and its devices and equipment and also the Energy Efficiency Equipment from the customs fees and subjecting to general sales tax in percentage or amount of (zero).

The Second National Energy Efficiency Action Plan (NEEAP), NEEAP 2017-2020 is developed according to the format used by the Arab EE Guideline. Accordingly, the NEEAP starts by the national baseline to be used as reference against which actual savings are to be measured. The document also presents the national objectives to be reached by 2020. The importance of this document is that it sets the path towards the development of energy efficiency for years to come. The second NEEAP also includes all the major players involved in the application of the different measures, including a budget estimate for the application of these measures.

Jordan adopted the first NEEAP in 2011.

2.2. Regulation and approaches in the energy efficiency of the building stock

The main regulations on energy efficiency of the building stock are listed below:

1. Updated Renewable Energy and Energy Efficiency Law No. 33, 2014

2. Bylaw No. (73) For year 2012: The Bylaw on Regulating Procedures and Means of Conserving Energy and Improving Its Efficiency[2]
3. Bylaw No. (50) For Year 2018: By-law of Provisions and Conditions of Exempting Systems of Renewable Energy Sources and its Devices and Equipment[3].
4. Bylaw No. (49) for Year 2015: Jordan Renewable Energy and Energy Efficiency Fund (JREEEF)[4]
5. The Second National Energy Efficiency Action Plan (NEEAP) for the Hashemite Kingdom of Jordan for years 2017-2020- 30 March 2017[5]

2.3. Tools currently used for energy efficiency design and interventions

The most used software is HAP, RetScreen, TRANSYS.

The most used instruments are: Flow meter, lux meter, power analyser.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

Due to lack of government support, BIM unawareness, the absence of BIM training centres and specialists, the application of BIM is still widely unused in Jordan.

There is no clear example for a case study intervention on energy efficiency for historical buildings in Jordan.

4. BIM ADOPTION IN THE COUNTRY

RSS-NERC is aware of no more of 15-20 projects developed in BIM in Jordan. Active organizations in the field are BIM LAB, Sterling BIM.

The best strategy to adopt BIM among construction companies in Jordan is still unclear, so many barriers and challenges are facing BIM adoption, such as, but not limited to:

1. Lack of government support;
2. BIM unawareness;
3. Absence of BIM training centers and specialists;
4. Resistance to change;
5. Cost*(BIM Adoption Strategies – The Case of Jordan/ International Journal of Civil Engineering and Technology 10(7), 2019, pp. 343-348).*

4.1. HBIM adoption in Jordan

The adoption of HBIM in Jordan is lacking, due to similar barriers to the adoption of BIM, for instance:

1. Lack of government support;
2. BIM unawareness;

[2] http://www.memr.gov.jo/EchoBusV3.0/SystemAssets/PDFs/EN/Laws/8-1-2013conservingenergyandimprovingitsefficiency.pdf
[3] http://www.memr.gov.jo/EchoBusV3.0/SystemAssets/PDFs/AR/Regulations/last.pdf
[4] http://www.memr.gov.jo/EchoBusv3.0/SystemAssets/PDFs/AR/Regulations
[5] 2nd NEEAP Document, 2017

3. Absence of BIM training centers and specialists;
4. Resistance to change;
5. Cost.

4.2. HBIM AND INTEROPERABILITY

BIM and energy efficiency

The use coupling of BIM and energy efficiency in Jordan is lacking, due to similar barriers to the adoption of BIM, for instance:

1. Lack of government support;
2. BIM unawareness;
3. Absence of BIM training centers and specialists;
4. Resistance to change;
5. Cost.

HBIM and energy improvement

RSS_NERC is not aware of any case study in the use of HBIM and energy improvement, due to similar barriers to the adoption of BIM, for instance:

1. Lack of government support;
2. BIM unawareness;
3. Absence of BIM training centers and specialists;
4. Resistance to change;
5. Cost.

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EPC analysis, Jordan Economic Growth Plan 2018 - 2022

ANNEX 5 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF PALESTINE

Country:	Palestine (PP5)
Date:	13/02/2020
Prepared by:	PP5 CCHP
Status:	Finished
Version:	v1
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Index

1. GENERAL INFORMATION

1.1. General Palestine data (population, official language, capital, area, GDP total/per capita, currency)

The State of Palestine is located at the west Mediterranean Region. Palestine has a total population of 4.976 million (2019) and an area of 6,220 Km^2 controlled by the Palestinian Territory. The official language is Arabic, and the Currencies used in Palestine include the Jordanian Dinar and the US Dollar, but the most popular is the New Israeli Shekel (NIS) Palestine total GDP /per capita is averaged approximately 1682.25 USD.

1.2. Description of Palestine building stock:

In 2017, there were 929,221 permanently occupied dwellings: approximately 327,861 single-family houses, 9,783 villas, 571,744 apartments, and 19833 other building types (mainly independent rooms). The majority of the Palestinian dwelling stock (95%) was owner-occupied, with the largest part (64%) located in the West Bank areas. Approximately 31% of the stock was built before 1987 and 43% between 1987 and 2007, before the first normative energy requirements. Details about the residential building types are as follows:

61,5% Apartment Buildings

26,8% Single Houses

The age of Residential buildings according to construction date 2017 is:

26.2% >2008

24.7% 1998-2007

18.2% 1988-1997

12.2% 1978-1987

7.8% 1968-1977

8% 1948-1967

2.9% <1948

In 2017, the permanently occupied non-residential building stock consisted of about 70 thousand buildings with a total floor area greater than 9 Million m^2. However, this table illustrates details about the non-residential building types, which are as follow (Table 1):

Type	Number of Establishments
Hotels	112
Secondary and primary schools	3,037

Nurseries	201
Tertiary education	50
healthcare institution	750
restaurants	3,490

Table 1: Number of some non-residential building types in Palestine

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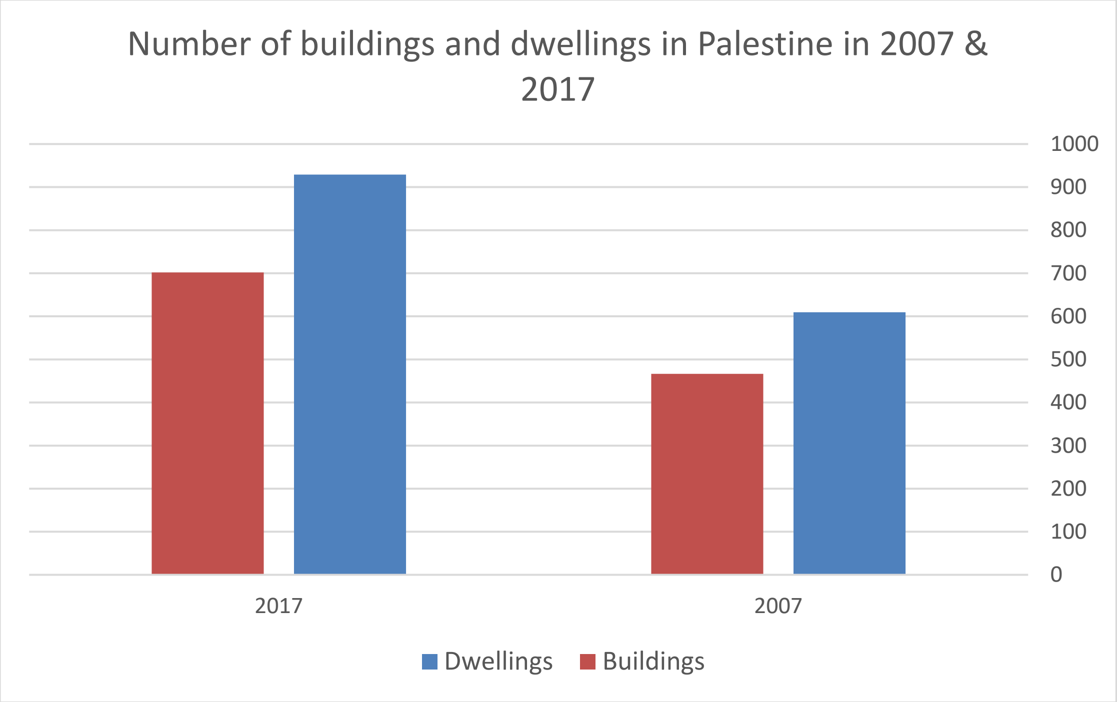


Figure 1: Number of buildings and dwellings in Palestine in 2007 & 2017

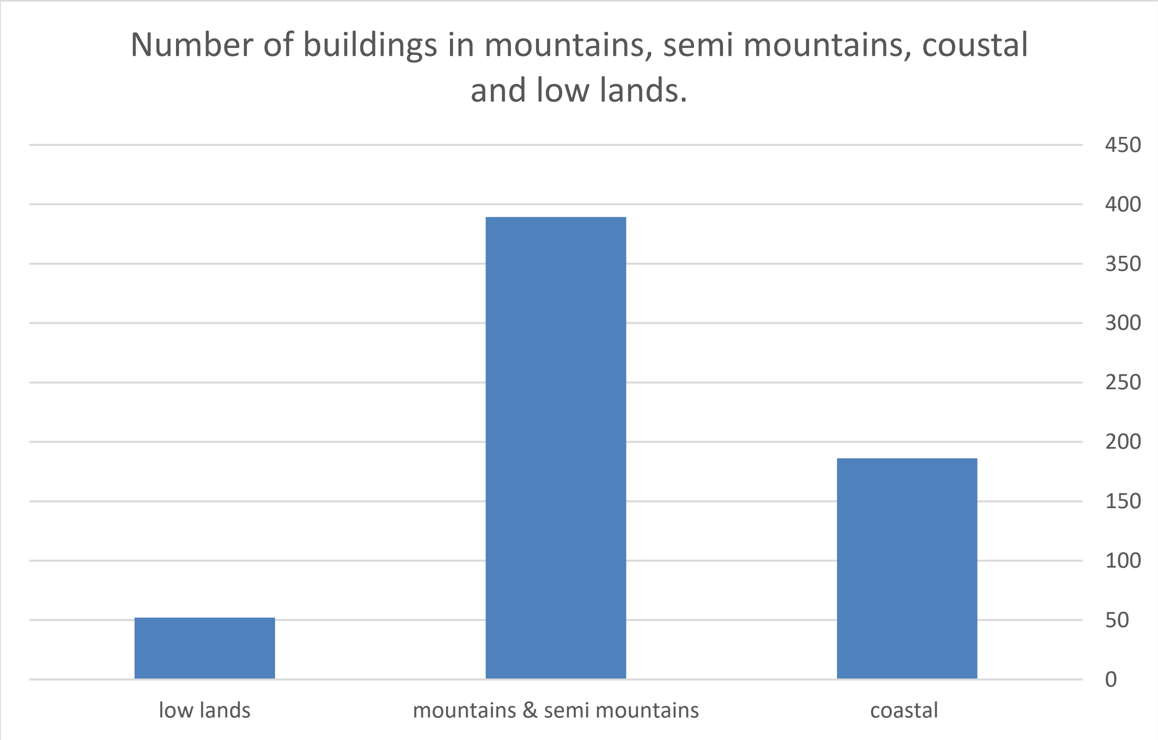


Figure 2: Number of buildings in semi-mountainous, mountainous, coastal and Jordan valleys (low lands) climates per building.

According to the department of Lands and Surveys, there are approximately 6.500 Heritage buildings in Palestine and their number is growing. The majority of heritage buildings are of residential use. One of government's future plan is to roof public services in heritage buildings.

1.3. Description of Palestine construction industry

Productivity

The construction sector in Palestine is showing signs of increment after a severe economic and financial crisis coupled with a housing crisis. Notably, as example, the production in construction increased by 61% from 2007 to 2017 compared to that in 1997. However, there is also an upward trend in employment in the construction sector since 2007. Yet, the gross operating surplus of the construction sector amounted to USD 590 million in 2014, 11% below the 2010 level. However, the GDP in Palestine in that year was 12.72 billion USD and the value of spending on ongoing maintenance of buildings is 276.6 million USD.

According to the statistics from PCSB in Palestine, labour productivity in the construction sector is equal to 10.7% of the general economy's productivity. This is to be contrasted with gross value added in real estate activities, which is higher than average productivity in the economy. This is inherent to the sector, given the high value of housing and the relatively low number of individuals working in this sector.

Employment

The results of the survey of (2018) in Palestine showed that 35.1% of workers work in services activities and other branches, compared to (21.7%) work in trading, restaurants and hotels activity, while the construction activity was one of the economic activities that have been damaged since (2000) until now, where the percentage reached 17.7% in (2018) compared to 19.4% (2000).

On the other hand, the results showed that the employees were distributed according to the workplace in 2018 by 60.1% in the West Bank and 26.6% in the Gaza Strip compared to 13.3% in Israel and the settlements (they make up 18.2% of workers in the West Bank).

Nevertheless, workers were distributed according to the practical situation, with 69.7% of wage employees, 18.9% of self-employed workers, 7.1% of employers, and 4.3% of family members without pay.

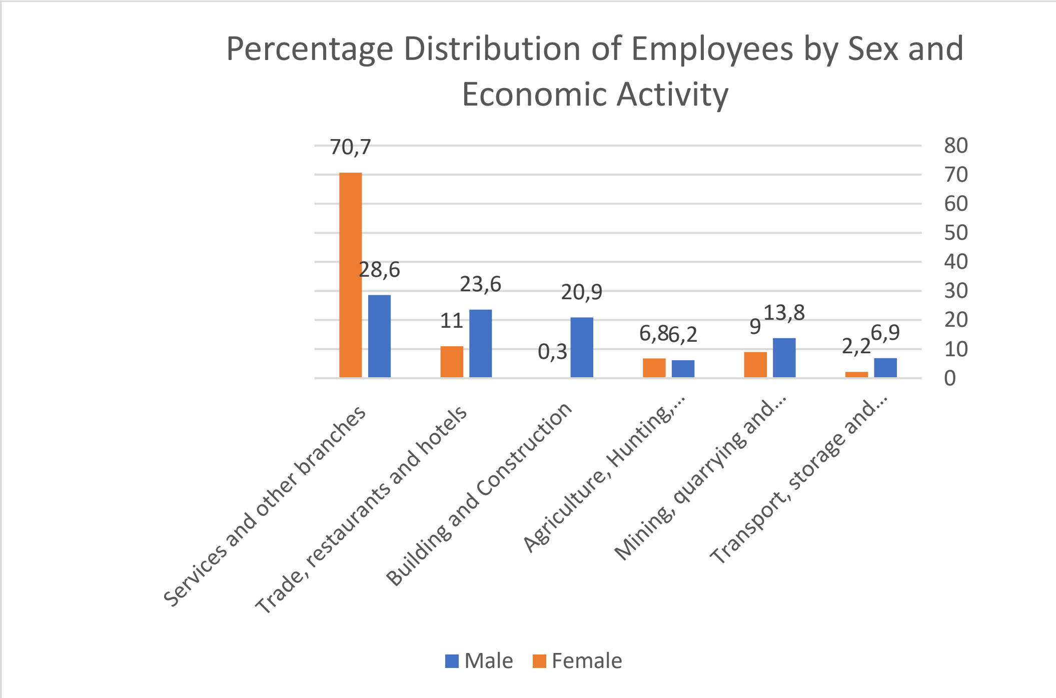


Figure 3: Percentage Distribution of Employees by Sex and Economic Activity

Ratio between new construction and interventions on existing buildings

The number of authorised building permits in Palestine in 2018 is 2,602. CCHP found no information regarding the amount of building renovations.

Innovation in the construction industry

There can be some confusion between innovation and R&D, mainly because of the high correlation between the two. R&D is an indicator and driver of innovation. Spending on R&D plays a big role in the process of innovation, through the development of knowledge and technology essential to producing new goods and services, and improving the quality of the available goods or finding new ways to produce goods and services.

Similar to other sectors and economic activities, the R&D sector is affected in one way or another by the political and economic conditions in the Palestinian territory. These conditions had adversely affected all economic activities, especially the industrial sector.

In 2013, R&D expenditure for Palestine was 0.5 %. Though Palestine R&D expenditure fluctuated substantially in recent years, it tended to increase through 2007 - 2013 period ending at 0.5 % in 2013.

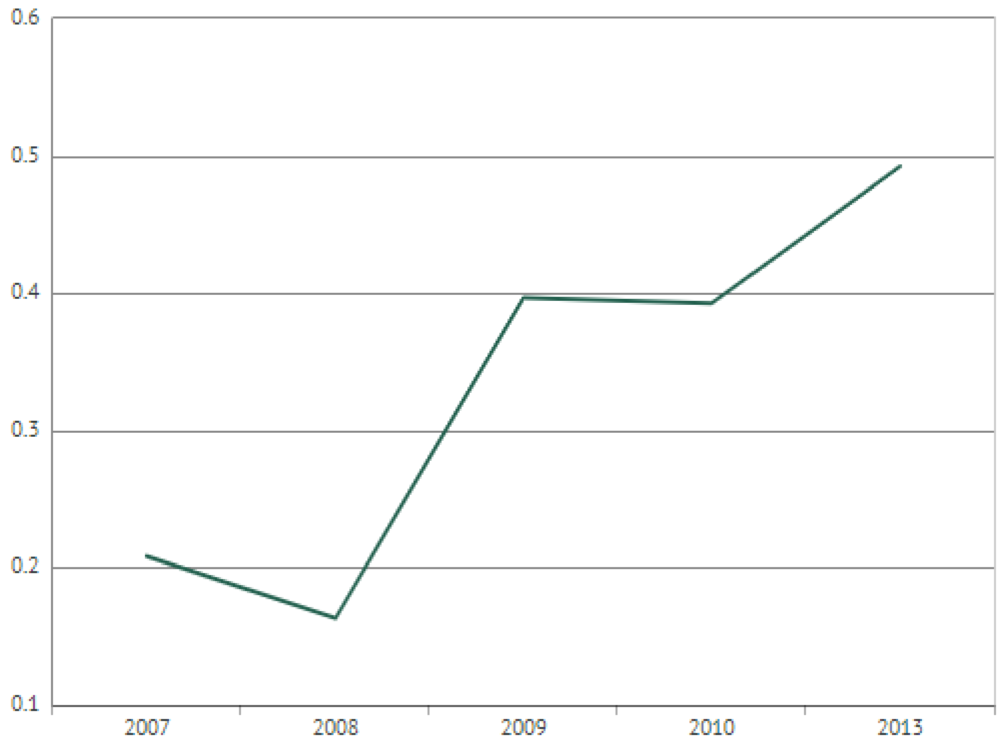


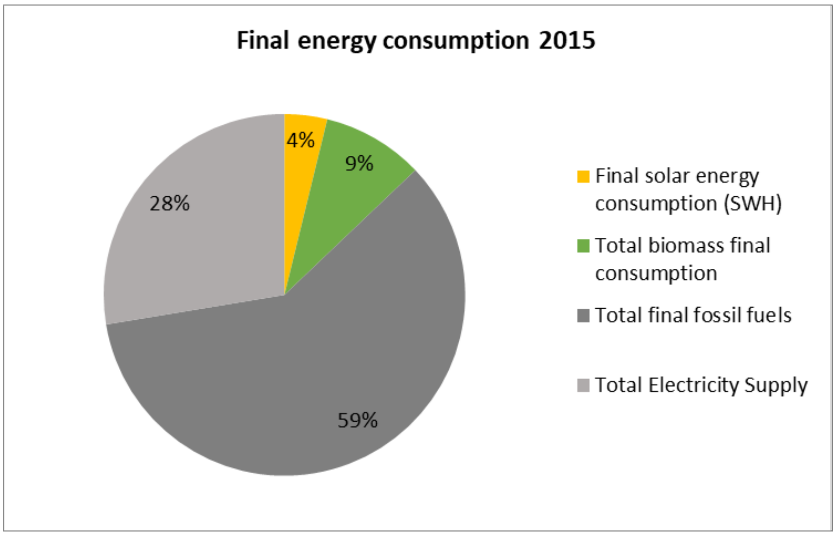
Figure 4: R&D expenditure percentage for Palestine.

Eco-innovation and digitalisation

Among the many challenges that Palestine faces, the energy challenge is one of the most imminent ones. Palestine is almost completely dependent on energy imports, not only for fuels but also for electricity. Therefore, it is crucial to foster the use of locally available renewable energy resources.

The National Renewable Energy Action Plan (NREAP) 2019 for Palestine outlines the strategy to accelerate the deployment of renewable energy technologies. It defines the targets for the different sectors and describes the measures that have been and will be put in place to reach those targets.

The renewable energy resources in Palestine are abundant, especially solar energy. Solar water heaters have been already widely deployed while solar PV energy has only started. Wind energy resources are also available but more difficult to explore.



Figur 5: Final energy consumption (2015).

It is interesting to note that the share of renewable heating within the final energy consumption including transport is about 13%.

As we can summarize the characteristics and facts about the energy sector in Palestine in a few points as follow:

1. Electrical Energy represent (31%) of total energy consumed.
2. Fully dependent on the IEC (88%).
3. 99% of population benefit from electricity.
4. Insufficient quantity.
5. No purchase agreement with the Israel Electric Company (IEC).
6. High cost of electricity generated from Gaza Power Plant and Inability to exploit the full power of the plant.
7. Most of renewable energy is thermal (18%).
8. 75% of consumption is domestic.
9. High rate of electricity consumption 7%.
10. High tariff imposed from the IEC compared with neighbor countries.
11. The absence of a unified electrical system.
12. Large number of distributors (municipalities and companies).
13. Inefficient collection system.
14. High rate of electricity losses (25%).
15. Net lending issues.

<u>Palestine regulatory framework and policies</u>

Policy schemes

Housing policy in Palestine is under the responsibility of the Ministry of Public Works and Housing. In applying this system, any legislation related to safety, public health and environmental protection shall be observed, and any person, before undertaking any construction project, must apply to the relevant committee to obtain a license.

Large hotels, hospitals, cinemas, theaters, public halls, a gas station, a gas refill or any buildings whose nature requires use of the continuity of the electric current shall install stand-by generators.

All places intended for use in the construction, including the bathrooms, should be equipped with natural lighting and ventilation with one or more openings in the outer walls. However, the provisions related to natural ventilation and lighting do not apply if the nature of the architectural design or the technical reasons require the use of ventilation and artificial lighting in the building.

The maximum height of the building should be 72 meters from the ground level, and the number of floors of the high construction must not exceed 20 floors

For the purposes of licensing the construction of additional floors above existing buildings, the applicant must submit a construction report proving that the existing building bears that. In addition, it is not permissible to authorize any building unless it has specified on its plans parking lots within the project boundaries.

In every building, there should be the following services:

1. Water well;
2. Water tanks on the roofs;
3. The deaf hole, which is constructed according to the engineering specifications determined by the competent authority.

Public buildings, commercial buildings, and multi-apartment residential buildings and office buildings must be adapted to suit people with special needs within their entrances and corridors according to the specifications determined by the committee.

Chimneys:

1. The chimney of the buildings must be constructed of solid materials lined with foldable or fire-resistant pipes.
2. The height of the building chimney should not be less than one meter from the highest point on the surface.
3. Factory chimneys shall be no less than ten meters from the road line or the plot of land.
4. The height of the factory chimneys shall not be less than three meters from the permitted limit for the height of the buildings in that area.
5. Provide factory chimneys with mechanical devices to purify the fat from harmful substances.

Residential areas are divided into several types:

1. Rural housing.
2. Agricultural housing.
3. Commercial area.
4. Industrial areas.
5. Office area.
6. Public buildings area.
7. Tourist facilities area.

Building regulations

The main building regulations of Palestine are listed below:

1. The amended Basic Law of 2003 and its amendments, especially Article (70) thereof.

2. Law regulating cities, villages and buildings No. (79) of 1966, especially Article (67) thereof.
3. Urban Co-ordination Law No. (28) by the year of 1936.
4. Recommendation of the Supreme Organizing Council at its meeting No. (2011/1) dated 13/1/2011.
5. Cabinet Resolution in Ramallah on 5/17/2011 regarding buildings.

Building regulations related to energy

The main pieces of legislation, which regulate the energy in general and in the construction of all buildings, thus defining the development and building control system in Palestine, are:

1. The law of electricity sector (2009).
2. The law of Renewable Energy (RE) and Energy Efficiency (EE) (2015).
3. Net metering regulation which is approval of an organized instructions for renewable energy projects connected to the electricity grid using the net metering system according to the decision of the Council of Ministers in (2015).
4. Net metering- additions, adding an article to the decision of the Council of Ministers on the authentication of the tariff.
5. Instructions for (PV) schools, Palestinian Energy Authority (PEA)Instructions for renewable energy projects on the roofs top of public schools connected to the electricity network using a net metering system.
6. Procedures of Applying the Palestinian Initiative for Solar Power from: “The Overall strategy for Renewable Energy in Palestine” (2012)

Outlook (strength, weaknesses and constraints) of energy in Palestine

We can summarize the constraints about the energy in Palestine in these points:

1. Israeli Occupation.
2. Lack of local production capacity to meet the needs of the local market power
3. Absence of an integrated electrical system.
4. Large number of electricity distributors, which makes it difficult to control and reorganization
5. The delay in completion of distribution companies, which must operate the system according to the specifications and appropriate standards.
6. Lack of legislation and laws regulating renewable energy
7. High price of renewable energy systems, which weaken the desire of government agencies to invest in this sector.
8. The absence of a national strategy to promote the use of renewable energy
9. Government deficit and the private sector to invest in renewable energy research
10. Lack of knowledge and training
11. Not bind the community to install solar energy systems and non-mandatory inclusion of system design and construction of the Green Building Code.

2. ENERGY EFFICIENCY OF EXISTING BUILDINGS

For the time being, Palestine does not have specific policies that prescribe a minimum required level of energy efficiency usage in new or newly refurbished buildings. There were initiatives in the past that dealt with this topic.

Solar water heating is in general widely used in Palestine; therefore, a specific support is not required. The NEEAP 2012-2020 foresees the installing of around 4000 m^2 of large solar water heating systems in the governmental buildings and industrial sectors.

It is recommended to review the current building codes and to put measures in place to require a minimum level of energy efficiency and use of RE for buildings. This regulation shall take the situation in Palestine and the specific circumstances of building locations, orientation, age, etc. into consideration. Energy efficiency measures are part of the National Energy Efficiency Action Plan (NEEAP) in Palestine.

2.1. Implementation level of energy efficiency of the construction sector

According to the calculations presented from the Palestinian Energy and Environment Research Centre, the expected annual consumption and projected savings are represented in table 2, while table 3 illustrates the quantity of available energy and electricity (GWh) in Palestine by year and source of electrical energy from 2010 to 2015.

	2012-2020 forecasts	NEEAP 2020-2030 annual consumption and projected savings (GWh)										
Synthesis for all sectors	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total for 2020-2030
Total forecasted consumption (GWh)	8 106,2	8 426,5	8 774,7	9 137,4	9 515,1	9 908,6	10 201,8	10 504,9	10 818,5	11 142,7	11 478,2	108 014
Total savings from the 2020-2030 EE action plan(GWh)	859,3	901,7	946,0	983,5	1 018,4	1 057,7	1 142,8	1 167,9	1 193,6	1 220,0	1 246,9	11 738
Total savings from the 2020-2030 EE action plan(M$)	114,7	120,3	126,2	131,2	135,9	141,1	152,5	155,8	159,3	162,8	166,4	1 566

Table 2: The expected annual consumption and projected savings (2020-2030).

Quantity of Available Energy and Electricity (GWh) in Palestine by Year and Source of Electrical Energy, 2010-2015							Conversion fact
Based on PCBS data							0.277777778
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Growth 2010 vs. 2015**
Energy:							
Total energy supply [TJ]	55,863	61,011	60,195	63,121	71,048	74,884	
Final energy consumption [TJ]	44,278	42,651	50,154	52,375	67,470	69,950	
Total energy supply [GWh]	15,517	16,947	16,721	17,534	19,735	20,801	
Final energy consumption [GWh]	12,299	11,847	13,932	14,549	18,742	19,430	
Electricity:							
Imported Electricity	4,158.85	4,621.69	4,909.26	4,734.25	4,935.30	5,413.09	130%
Purchased from Palestine Electric Company	304.99	542.44	391.97	402.61	266.05	354.97	
Self-Generation Produced Electricity*	168.34	26.89	69.15	131.49	70.53	150.40	
Total domestic production	473.32	569.33	461.11	534.10	336.59	505.37	Sum visible in e
Total Electricity Supply	**4,632.17**	**5,191.02**	**5,370.37**	**5,268.35**	**5,271.88**	**5,918.46**	128%
Supply growth (2010-15)		12%	3%	-2%	0%	12%	
Average last 3 years							
Losses	- 1,559.8	- 1,291.7	- 537.0	- 527.0	- 175.8	- 711.3	
Total Final Electricity Consumption	**3,072.4**	**3,899.5**	**4,833.4**	**4,741.3**	**5,096.1**	**5,207.3**	169%
Supply growth (2010-15)		27%	24%	-2%	7%	2%	
Average last 3 years							
% electricity supply of total energy	30%	31%	32%	30%	27%	28%	
Average last 3 years							28.4%
% final electricity consumption ove	66%	75%	90%	90%	97%	88%	
Average last 3 years							91.5%

Table 3: Quantity of available energy and electricity (GWh) in Palestine by year and source of electrical energy from 2010 to 2015.

The summary of policies and measures implemented or in the process of being implemented in Palestine to push forward the implementation of energy projects is as follow:

1. Financial support.
2. Feed in Tariff.
3. Net metering.
4. Tenders.
5. Licences.

There are two main laws about the mechanism for Implementation that are:

1. General Electricity Law from 2009.
2. Renewable Energy (RE) and Energy Efficiency (EE) law from 2015.

2.2. Regulation and approaches in the energy efficiency of the building stock

The following tables shows the electricity supply and consumption projections compared to the targets until 2020 and 2030. It also shows the assumed growth of non-renewable electricity generation capacity.

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total energy supply [GWh]	20,801															
Total Electricity Supply [GWh]	5,918															
Total Final Electricity Consumption [GWh]	5,207															
RE capacity [MW] based on 500 MW target			25	40	63	100	117	138	162	190	224	263	309	362	426	500
Growth				58.7%	58.7%	58.7%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	
PV capacity based on 500 MW target [MW]			24	39	62	89	95	110	130	152	179	210	247	290	340.54	400
Wind capacity based on 500 MW target [MW]			0.7	0.7	0.7	0.7	11	14	16	19	22	26	31	36	43	50
Biogas capacity based on 500 MW target [MW]			-	-	-	10	11	14	16	19	22	26	31	36	43	50
RE generation [GWh] based on 500 MW target																
PV generation based on 500 MW target [GWh]			39	62	100	143	152	177	207	244	286	336	395	464	545	640
Wind generation based on 500 MW target [GWh]			1.4	1	1	1	22	28	32	38	45	53	62	72	85	100
Biogas generation based on 500 MW target [GWh]			-	-	-	30	33	41	49	57	67	79	93	109	128	150
Total RE generation based on 500 MW target [GWh]			**40**	**64**	**101**	**174**	**208**	**246**	**288**	**339**	**398**	**468**	**549**	**645**	**758**	**890**
Percentage of total electricty consumption			0.7%	1.0%	1.5%	2.5%	2.8%	3.1%	3.5%	3.9%	4.3%	4.7%	5.2%	5.8%	6.4%	7.1%

Table 4: RE target capacity projections based on 2030 target strategy.

The following gives a short reasoning why certain technologies are included and others not:

1. PV: Being a modular RE technology, deployment of PV can go very fast, both for small rooftop systems as well as for large-scale ground-based plants. Palestine's RE strategy puts an emphasis on PV.
2. Onshore Wind: While there is wind potential in mountains, even in these areas the average wind speeds less than 6 m/s (see Wind Atlas for Palestine). Wind development can only take place in Area C and therefore depends on approval from Israel. Reasonable deployment is only expected after 2020.
3. Offshore Wind is currently no option for Palestine, not only because of contested sea rights but also because there is actually no offshore wind development in the Mediterranean. Resources are low in Palestine.
4. Geothermal: There are a few demonstration plants and studies, but apart from R&D projects, no specific support is planned and thus no important development is to be expected.
5. Solid biomass like wood, charcoal, olive cake: Those resources have been used and may further grow. However, no specific targets will be set.
6. Solar Water Heating: Palestine has already a great number of SWH systems deployed. Further growth is rather limited to available rooftop space; therefore, no specific targets will be set.
7. Biogas has potential to grow using waste, agricultural residues and animal waste.

2.3. Tools currently used for energy efficiency design and interventions

Green building guideline published by Engineers association - Jerusalem centre (2013), is used to deliver energy efficiency design and interventions.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

Palestine has not formulated or adopted any energy improvement regulations at this stage. Currently the Government is providing funding schemes for heritage buildings conservation only.

Until now, there is no case studies of energy improvement intervention on historical buildings.

4. BIM ADOPTION IN THE COUNTRY

Currently there is no BIM adoption or the number of projects developed following this new technology in the AEC industry.

Until now, there is no implementation in Palestine for BIM. However, Revit program has been used in some projects.

There is no regulation on digitalization of the construction industry and BIM, a few buildings have used the green building regulation (LEAD).

The Palestinian association- Jerusalem centre published the green building guideline in 2013 (version one).

There is no design firm using BIM in Palestine.

4.1. HBIM adoption in the country

There is no adoption of HBIM yet, as there is lack of expertise in the architects who are active in the conservation and renovation field. BIM was recently included in the areas of research in academia.

Main obstacles and issues for the lack of penetration of the methodology in the professional market:

1. Lack of standards and policies by the relevant authorities (Department of Antiquities and the Town Planning & Housing Department of the Ministry of Interiors);
2. Lack of expertise among officers and practitioners (engineers), training needed;
3. Lack of resources to justify the additional cost/labour in the practice.
4. Lack of awareness about the importance of BIM for all the contraction stages.

4.2. HBIM and interoperability

Interoperability in the construction industry in Palestine is poor. Design process, Construction schedule, project data, procurements, tenders and general project management are mostly performed with traditional means of communications and data exchange i.e. emails, data sharing platforms, data clouds, online chatting platforms, tele copying (FAX) and phone calls.

BIM and energy efficiency

There is no adoption in Palestine of BIM for energy efficiency.

HBIM and energy improvement

CCHP is not aware of any case in which HBIM methodology has been coupled with energy improvement strategies. Barriers are identified both with regards to the integration of BIM in the renovation practice of professionals and authorities officers (lack of skills and resources), and the lack of knowledge regarding the interoperation/combination of EE retrofit policies with energy performance simulation and BIM standards.

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ANNEX 6 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF LEBANON

Country:	Lebanon
Date:	13/02/2020
Prepared by:	PP6 LCEC
Status:	Finished
Version:	V1
Authors:	Rami Fakhouri, Sorina Mortada

This project is funded by the EU under the ENI CBC Med Programme

Index

GENERAL INFORMATION

1.1. General Lebanon data

The population of Lebanon is 6,848,925 people. Official language is Arabic. The capital is Beirut. It has an area of 10,452 km^2. GDP(total) is 56.369 Billion USD. The GDP per capita is 8,269 USD and the currency is the Lebanese pounds (LBP).

1.2. Description of Lebanon building stock

A study published by the Ministry of Environment, based on data collected between 1996-1998 by the Central Administration of Statistics (CAS), showed that in the capital Beirut, 40% of the existing buildings were constructed before 1950, whereas in the suburbs of Beirut, 30% of the buildings were constructed between 1951 and 1970 (Ministry of Energy and Water/ Lebanese Center for Energy Conservation (LCEC) 2016). The new construction shares decreased during the war between 1971 and 1990 and then peaked in the nineties where the country was being reconstructed after the war.

Diving deeper into the building sector, the total area of office buildings increased about 30% from 2004 to 2015, while the residential built area increased around 5 %, the commercial built area increased around 49%, during the same period. This increase was at its peak after the 2006 war, after which in 2008 the country witnessed a boom in real estate construction until 2013 (Lebanese Center for Energy Conservation (LCEC) 2018).

1.3. Description of Lebanon construction industry:

According to the Engineering Syndicate data in 2015, the total building shares were distributed as follows (Lebanese Center for Energy Conservation (LCEC) 2018):

1. Residential: 85 %
2. Commercial: 8 %
3. Industrial: 4 %
4. Health and Education: 3 %
5. Offices: 2 %
6. Hotels: 2 %

2. ENERGY EFFICIENCY OF EXISTING BUILDINGS

Several action measures that tackle energy efficiency in the building sector were proposed in the Lebanese "National Energy Efficiency Action Plan 2016-2020", of which the mandatory double wall construction for new buildings, implementation of a building code, energy performance certificates for buildings. However, the legal aspect and bureaucracy hindered the implementation/enforcement of these measures. Moreover, the lack of data in the building sector was also an obstacle, in addition to the lack of awareness in rural areas in all aspects related to energy efficiency. However, a financing mechanism supporting green energy has boosted the energy efficiency implementation (discussed below).

2.1. Implementation level of energy efficiency of the construction sector

In 2012, Lebanon established the National Energy Efficiency and Renewable Action plan, a financing scheme that subsidizes green energy loans for the private sector. The financing mechanism enables residents and business owners to implement energy efficiency measures through a subsidized loan.

The top three measures that were supported are the following, along with their respective annual savings (total of all projects):

1. Lighting & Control : 66 GWh
2. Building Envelope Improvement (double wall, insulation): 34 GWh
3. HVAC & Systems Control: 32 GWh (Source: LCEC)

2.2. Tools currently used for energy efficiency design and interventions

The main software used when simulating the performance of building envelopes are HAP, Comfie, EDGE, eQuest, in addition to several other ones.

Additionally, all interventions are always preceded by an energy audit. In fact, a mandatory energy audit was forced on all consultants/clients wishing to benefit from the financing scheme mentioned, when installing large scale (>60 kWp) PV systems on buildings.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

At the moment, there is no definite approach to tackle energy improvement in historical building. As mentioned before, it is mainly due to the lack of awareness of the public bodies on energy efficiency and heritage conservation. Additionally, since most of historical buildings belong to the public sector (we do not have the exact number yet), therefore lack of funding is a major obstacle.

4. BIM ADOPTION IN LEBANON

BIM has not being widely implemented in Lebanon yet. LCEC is developing an ongoing survey with engineering consultancy firms to have an overview of current BIM status in the country. Active BIM organizations on the field are Dar Al Handasah, BIM International.

Existing case studies of BIM use in Lebanon are: ABC Verdun, American Embassy in Lebanon (ongoing identification of other case studies)

4.1. HBIM adoption in Lebanon

Lebanon has not yet developed a sensitivity towards the BIM application on historical/listed buildings. Most of the historical/listed buildings belong to the public sector, therefore a major obstacle is the lack of funds. Additionally, the lack of awareness from the public sector entities on BIM technologies, in addition to lack of commitment/engagement from the public sector towards the energy performance of historical buildings.

4.2. HBIM and interoperability

BIM and energy efficiency

There is no general database or documentation available on energy efficiency intervention through BIM based processes. A survey on the main BIM consultants who used BIM to tackle energy efficiency in their case study is ongoing.

HBIM and energy improvement

LCEC is currently conducting research in Lebanon on any historical building that was simulated using BIM.

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ANNEX 7 - ENERGY EFFICIENCY AND HBIM USAGE ACCORDING TO LOCAL BEST PRACTICES

THE CASE OF EGYPT

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1. GENERAL INFORMATION

1.1. General Egypt data (population, official language, capital, area, GDP total/per capita, currency)

Population	100,013,099 (“The Egyptian Central Agency for Public Mobilization and Statistics CAPMAS” n.d.)
Official language	Arabic
Capital	Cairo
Area	1,001,450 Km^2 (“Egypt Energy Situation - Energypedia.Info” n.d.)
GDP total/per capita	The Gross Domestic Product per capita in Egypt was last recorded at 2907.30 US dollars in 2018. It is expected to reach 3100.00 USD by the end of 2020, according to Trading Economics global macro models and analysts’ expectations (“Egypt GDP per Capita | 1960-2018 Data | 2019-2020 Forecast | Calendar | Historical” n.d.).
Currency	Egyptian Pound (EGP)

1.2. Description of Egypt building stock:

The Egyptian building stock encompasses about 12 million buildings in 2017, nearly 60% of buildings are residential, and 40% are commercial as shown in Figure 1. The Commercial sector, which includes office, retail and education is the fastest growing segment (Khashaba and Afify 2018).

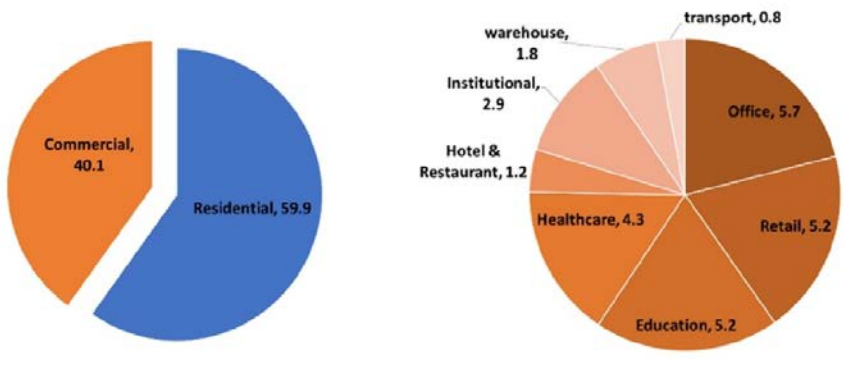

Figure 1:The Egyptian building stock classified by type. (International Finance Corporation, n.d.)

Egypt’s No of Buildings: Census data was reported at 16,185,063 buildings in Dec 2017. This records an increase from the previous number of 11,151,223 buildings for Dec 2006. The data reached an all-time high of 16,185,063 buildings in 2017 and a record low of 7,536,566 buildings in 1986 (“Egypt Number of Buildings: Census: By Region” n.d.), as shown in Figure (2).

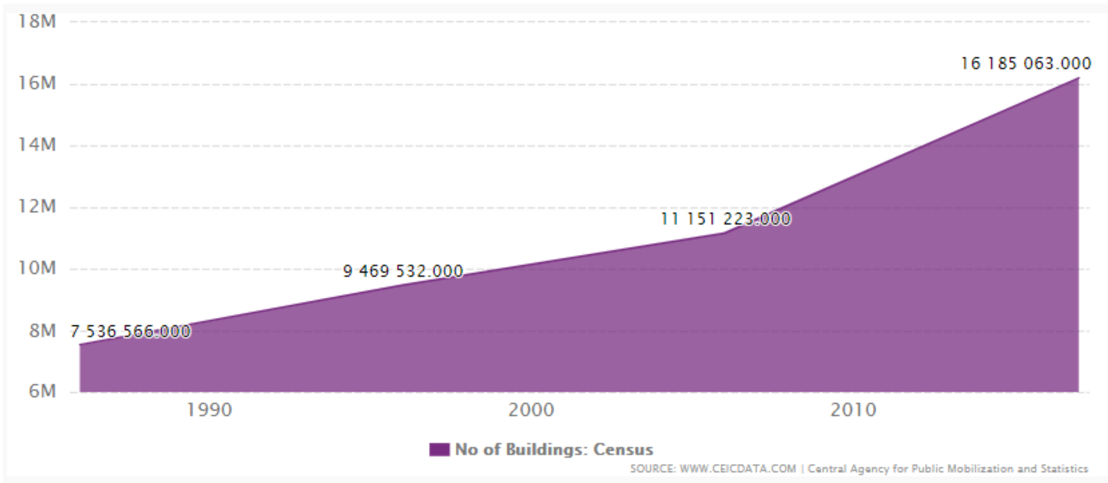

Figure 2: Egypt's number of buildings from Dec 1986 to Dec 2017 ("Egypt Number of Buildings: Census: By Region" n.d.)

The number of buildings classified by type in census 2017 is shown in Tables (1) and (2).

Building Type	**Housing Purposes**	**Work Purposes**	**Makeshift Buildings**	**Nondescript Buildings**	**Fenced or Unused land**	**Total**
No. of Buildings	13,467,333	832,037	268,625	201,302	1,415,766	16,185,063

Table 1: Type and number of buildings in Egypt in census 2017. ("The Egyptian Central Agency for Public Mobilization and Statistics CAPMAS" n.d.).

Building Type					
	Buildings for Work Purposes	Public Building	35,425	832,037	**14,299,370**
		Work Building with one unit or more	569,527		
		Mall	2,006		
		Boat House	376		
		Shop or more	224,703		
	Buildings for Housing Purposes	House / Apartment Building	12,102,155	13,467,333	
		Skyrise Apartment Building	11,843		
		Villa with one or more unit	192,217		
		Chalet	65,280		
		Country House with one or more unit	1,095,838		

Table 2:Number of buildings for work and housing purposes in Egypt in census 2017. ("The Egyptian Central Agency for Public Mobilization and Statistics CAPMAS" n.d.).

Private and public owned buildings

Type of Ownership	Buildings for Work Purposes	Governmental	189,285	832,037	**14,299,370**
		Public / Public Business	14,157		
		Private	624,768		
		Diplomatic / International	218		

		Other	3,609		
	Buildings for Housing Purposes	Governmental	189,364	13,467,333	
		Public / Public Business	24,787		
		Private	13,250,177		
		Diplomatic / International	330		
		Other	2,675		

Table 3: Type of ownership for buildings in Egypt in censes 2017(“The Egyptian Central Agency for Public Mobilization and Statistics CAPMAS” n.d.).

Building stock by age of construction

Year of construction	No. of Buildings
Before 1944	162,833
-1944	258,157
-1960	589,952
-1970	779,347
-1980	2,009,207
-1990	3,248,311
-2000	3,560,439
-2010	1,280,949
-2011	366,129
-2012	483,491
-2013	406,850
-2014	326,275
-2015	374,176
-2016	330,148
-2017	123,106
Total	**14,299,370**

Table 4: Number of buildings for work and housing purposes according to the year of building the oldest part. (“The Egyptian Central Agency for Public Mobilization and Statistics CAPMAS” n.d.)

Heritage listed buildings

According to the National Organization for Urban Harmony, there are 6700 heritage buildings (Buildings with distinguished architectural character, or belonging to a specific historical era, past private residence of one of the important and historical figures) in Egypt: 1163 are located in Cairo, 1135 in Alexandria, 505 in Port said, and the rest in other governorates (Hashem 2018; Riad 2018).

1.3. General description Egypt construction industry

The construction industry is poised to remain one of the most dynamic sectors of the economy. This has been apparent in an increase in the number of large-scale projects involving transport, energy, utilities and urban development. This ongoing burst of construction activity is part of an effort to address infrastructure gaps, and improve Egypt’s standing among domestic and international investors (“Egypt Construction & Real Estate Research & Analysis 2019 | Oxford Business Group” n.d.).

On the other side of the spectrum, real estate developers have been able to adapt their offers to the new needs of Egyptian buyers, and have progressed with ongoing plans for housing, office space and new retail areas. Efforts to construct new cities and the New Administrative Capital are also driving innovation within the sector. Even with a long list of construction projects in the pipeline a significant amount of attention and resources in the sector will be directed towards housing and other real estate developments in the near term ("Egypt Construction & Real Estate Research & Analysis 2019 | Oxford Business Group" n.d.)

Construction and Building GDP was reported at 83,474.600 EGP in Sep 2019, this records a decrease from the previous number of 90,823.000 EGP for Jun 2019. The data reached an all-time high of 90,823.000 EGP in Jun 2019 and a record low of 3,324.000 EGP in Mar 2003.

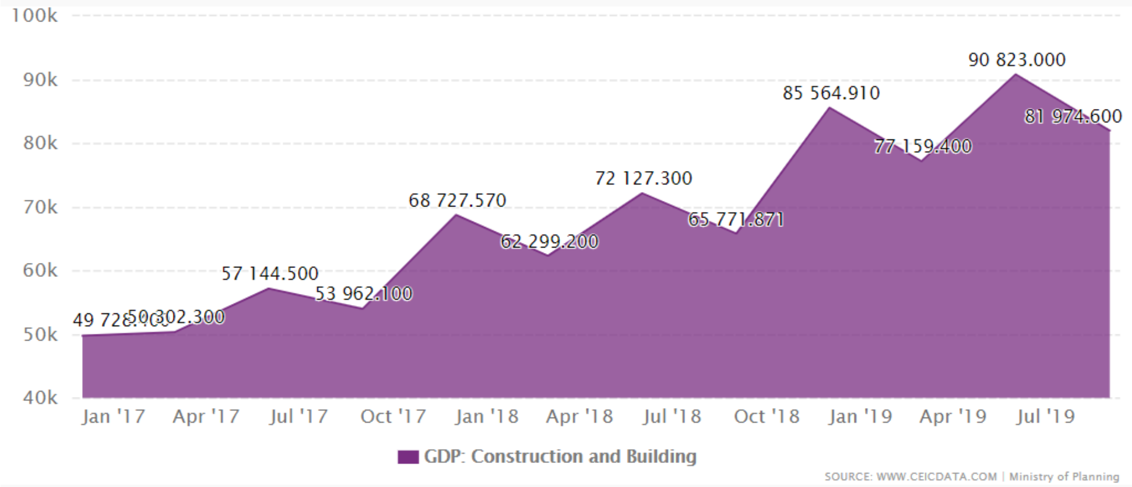

Figure 3: Egypt's Construction and Building GDB from Jan 2017 to Dec 2019 ("Egypt Number of Buildings: Census: By Region" n.d.)

Construction in Egypt is set to expand by an average of 11.3% each year between 2019 and 2023, data and analytics company Global Data predicts in its Q3 2019 Global Construction Outlook report ("Egypt's Construction Sector Set to See Annual Growth of 11.3% between 2019 and 2023 | Enterprise" n.d.).

Productivity

Labor in construction industry could be defined as all workforces involve in the process that had to carry out to accomplish and to achieve goal. There are many challenges that are faced by construction industry in Egypt, but one of the most important challenges is labor productivity in construction (Hafez et al. 2014).

Hafez *et al* (2014) identified and ranked the factors constraining labor productivity of Egyptian contractors in Egypt, which were measured, based on the views of construction professionals. The findings of the research are generally aligned with the results of previous studies related with labor productivity. The results indicated that the most significant factors affecting labor productivity are:

1. Payment delay and Motivation of labor.
2. Skill of labor and a shortage of experienced labor.
3. Lack of labor supervision.

Hafez *et al* (2014)recommended establishing special programs and training to improve the skills of the workforce and that the construction managers need to prepare professional techniques for labor motivation.

Innovation in the construction industry

In order to encourage innovation, a new National Strategy for Science, Technology and Innovation has been developed by the Ministry of Higher Education and Scientific Research. The strategy includes a number of actions to promote scientific research and encourage industry research links as well as private participation in R&D, including through the adoption of a new law on innovation (OECD 2018).

One of the R&D projects is WEB-TT, the Water-Energy-Building – Training and Transfer (WEB-TT) project was funded since the beginning of 2011 for a three-year period. The main goal was to develop appropriate training modules for the Egyptian construction industries. The project WEB-TT focused on the improvement of the highest level of construction workers not on qualification of engineers. The presented article focuses on a policy transfer project in TVET (Technical and Vocational Education and Training) between Germany and Egypt in the field of building and construction between years 2011 and 2014.. The R&D project was able to develop successful results of in-company training activities to improve the quality of site workers in Egyptian private construction companies (Wolf 2017).

Towards developing an economically sustainable society, public and private sector has to play a role towards investing in R&D, offering employment opportunities, increasing productivity, escalating market share, adding value, creating new markets, reducing cost through improving efficiency and reducing energy as well as raw materials consumption (A. A. E. Othman, Ghaly, and Zainul Abidin 2014).

Othman, Ghaly, and Zainul Abidin (2014) investigated the role of Lean Principles (LPs) as an innovative approach for achieving sustainability in the Egyptian Construction Industry (ECI). (LPs) have proven to be a powerful tool to minimize waste and adding better value to customers in the manufacturing industry. The application of (LPs) in construction helps defining customer value, eliminating waste, improving flow of work and information and increasing organisational perfection.

Egypt regulatory framework and policies - outlook (strength and weaknesses)

The main building code in Egypt is the Unified Building Law No.119/2008. Numerous parts of the Unified Building Law no.119 released in 2008, and its executive appendix released by the Ministerial decree no. 144 in 2009, show negligence of important green concepts. However, many of these concepts were considered in the Green Pyramid Rating System (GPRS) public review edition released by the Egyptian Green Building Council (EGBC) and the Housing and Building Research Centre (HBRC) in April 2011, but with no specific schedule for releasing the final rating system or a timeline for enforcing it (Ayyad and Gabr 2012).

The Unified Building Law No.119/2008 tackles a wide number of issues which includes regulations about national planning, regional planning, city planning, land divisions, unplanned zones, and special zones. On the other hand, the Green Pyramid Rating System (GPRS) is a national environmental rating system for buildings. It provides definitive criteria by which the environmental credentials of buildings can be evaluated, and the buildings themselves can be rated. The GPRS provides 4 levels of certification depending on score of the project in the weighted factors; 'Certified', 'Silver Pyramid', 'Gold Pyramid' and 'green pyramid' (Ayyad and Gabr 2012).

Ayyad and Gabr (2012) concluded that the Unified Building Law no.119 released in 2008 and its executive appendix released by the Ministerial decree no. 144 in 2009 were not formulated having green concepts in mind, while the GPRS was not designed to be in harmony with the Unified Building Law nor its executive appendix. However, it is also evident that integration opportunities are existent.

2. ENERGY EFFICIENCY OF EXISTING BUILDINGS

The Egyptian Code for Energy Efficient Buildings was first introduced in 2006 and was oriented to residential buildings (EECRB) followed by commercial buildings (EECCB) in 2007 and governmental buildings (EECGB) in 2010. These three versions of Energy Efficient Code (EEC) were the fruit of extensive studies done by the Housing and Building National Research Centre (HBNRC) in Egypt since 2000 (Sheta and Sharples 2010). EECRB and EECCB Compliance approaches include Building envelope, Ventilation, Thermal comfort, HVAC system, Water heating system, Lighting system, and Electrical system (Mahmoud 2014),

Hanna (2004) mentioned that the Egyptian Energy Code for Residential Buildings (EECRB) considered as a step forward to achieving sustainability in residential buildings sector, it specifies minimum building requirements to improve both thermal and visual comfort in non-conditioned buildings as well as conditioned buildings. Also, the code gives minimum performance standards for building windows and openings, natural ventilation and thermal comfort, ventilating and air conditioning equipment, natural and artificial lighting and electric power.

On the other hand, Sheta (2018) mentioned that he EECRB can be considered as a voluntary code and it was not clear the type of residential buildings this code should cover. Design requirements including architectural programming requirements for all the functions in the building and their relationship to one another, including energy efficiency targets, primary functions, occupancy and time of use, daylight potential and electric light requirements, indoor environmental quality standards, equipment and plug loads, acoustic quality, and safety and security, are still missing or neglected in EECRB and should be added and highlighted in updated versions.

Hanna (2015) investigated green pyramid rating system and the potential of energy efficiency, renewable energy and green building codes to reduce depends of the fossil fuel in Egypt. The study aimed to introduce the Egyptian efforts to improve the quality of life and highlight the barriers facing residential sector to deliver more sustainable buildings.

2.1. Implementation level of energy efficiency of the construction sector

According to the U.S. Green Building Council ("U.S. Green Building Council" n.d.) projects' directory, there are 19 LEED Certified construction projects from 52 registered projects in Egypt. The Certification Levels are 1 Platinum, 9 Gold, 7 Silver, and 2 Certified, whether it is for a new construction, core and shell, or commercial interiors.

Dabaieh, Makhlouf, and Hosny (2016) discussed a retrofitting approach for off-grid vernacular buildings in the Western Desert of Egypt. The study hypothesis argues that, when retrofitted and equipped with renewable energy solutions, vernacular structures can act as nearly zero energy buildings. Results showed that combining vernacular passive strategies with affordable active renewables such as roof top solar panels results in a hybrid energy efficient retrofitting solution for deprived off-grid vernacular buildings. This is an aim capable of contributing to a reduction of energy consumption that would also encourage retrofitting using renewable solutions for existing housing stock in Egypt.

El-Darwish and Gomaa (2017) aimed at proposing a retrofit strategy in an attempt to improve energy efficiency in a sample of higher educational buildings located in a hot arid climate (Egypt). The study results show that simple retrofit strategies such as solar shading, window glazing, air tightness then insulation can reduce energy consumption of an average of 33%.

2.2. Regulation and approaches in the energy efficiency of the building stock

Abou Leila and Madkour (2018) studied an international model of transforming a heritage building into a green building (Christman Building). In the case study the research presented an important heritage building (Mansoura Opera House), and tests the possibility of restoring and transforming it into green building, (ASHRAE 90.1.2013) is used to compare the properties of current building and number of virtual scenarios use minimal energy.

Eltahan (2017) presented a framework for developing a local decision support model that helps decision makers in Egypt to select the best and optimal scenario to retrofit existing buildings factoring in a predefined budget. Energy assessments were compared with systems original design documents (the benchmark for all HVAC systems materials specifications is ASHRAE standards).

2.3. Tools currently used in for energy efficiency design and interventions

In Egypt, some studies experimented through simulation the impact of renovation strategies and approaches on the building energy performance in Cairo. Aboulnaga and Moustafa (2016) studied through Design Builder the impact of renovation strategies on the energy consumption and CO2 emissions in the Architectural Engineering Department, the study resulted that 15% of the electrical energy loads was reduced due to changes in glazing, roof and insulation materials.

In another study by El-Darwish and Gomaa (2017), they experimented through Design Builder the impact of renovating the building envelope of three higher educational buildings, about 33% reduction in the energy consumption was achieved when using solar shades, different window glazing, and insulation materials.

On the other hand, Attia and De Herde (2009) evaluated through TRNSYS the impact of using PV panels, solar protection, natural ventilation, and solar thermal AC on the energy and CO2 emissions savings of three residential buildings, which reduced approximately 83% of the total electric energy use.

Ahmed (2019) analysed the financials of converting an existing residential building to net zero energy building. The research utilizes energy simulation (Design Builder) to compare the amount of energy saving between the current and retrofitted cases of the case study building. An nZEB building was reached using envelope retrofit and PV panels on the case study building. The results of the financial study showed that the conversion is feasible and the return of investment is adequate compared to the current price of electricity.

Elbeltagi et al. (2017) raised a visualized strategy for building parametric analysis in the early design stage. Through Rhino, Grasshopper and its plugins couple a parametric design tool and an energy simulation tool to construct a building energy-consumption database. These two types of tools' parallel cooperation can visualize the energy model database and help an operator to evaluate building performance in a more flexible manner.

3. ENERGY IMPROVEMENT AND HISTORICAL BUILDINGS

The current conservation strategies of heritage buildings in Egypt (whatever they are residential or nonresidential buildings) that have been classified as monuments (whatever they are palaces, villas, or public buildings) aim to expose and restore the internal and external heritage features and values of the assets, retain their original character ,and transform the usage of them (in most cases) into tourism activities such as museums, or cultural activities (Foda 2016).

There are few conservation strategies that have been carried out at the state related to the listed heritage buildings level; most of them are individual projects, that have been executed by their owners or buildings' inhabitants; the others have executed by the public sector, mostly superficiality restoration. The strategy based on painting the exterior façades of the listed heritage buildings without any upgrade or restoration works for their internal parts (Foda 2016).

Most of the conservation strategies of the heritage Buildings in Egypt whatever they were classified as monuments or listed buildings don't include strategies that improve the operating performance of those buildings in energy, as well as water, or indoor environmental quality (Foda 2016).

<u>Case studies on energy improvement interventions on historical buildings</u>

Villa Antoniadis in Alexandria, Egypt

Villa Antoniadis is a heritage building built in the mid-nineteenth century and it is listed as historic monument number 1250 at a national level, as a significant architectural style building.

Figure 4: Villa Antoniadis and its Garden before renovation by Ahmed Khalil in 2008 (Khalil et.al,2018).

The building was in a process of a restoration and adaptive-reuse project by its new owner (The Bibliotheca Alexandrina) from 2011 till 2018, which aimed to use the building as the premises for the Alexandria and Mediterranean Research Centre in addition to other cultural purposes, to ensure that the building is well restored and provided with ongoing maintenance.

Figure 5: The Villa after renovation (Khalil, Hammouda, and El-Deeb 2018).

A simulation was applied to the renovation project using the DesignBuilder energy modelling software to determine the project’s thermal behavior, energy consumption, and energy use intensity. The project was also simulated with six introduced interventions to achieve more energy efficiency when compared to the base case: (1) adding thermal insulation; (2) exterior openings with double glazing; (3) adding shading to the atrium; (4) internal lighting control; (5) using natural ventilation; and (6) adding photovoltaic panels on the roof to analyze their potentials and benefits.

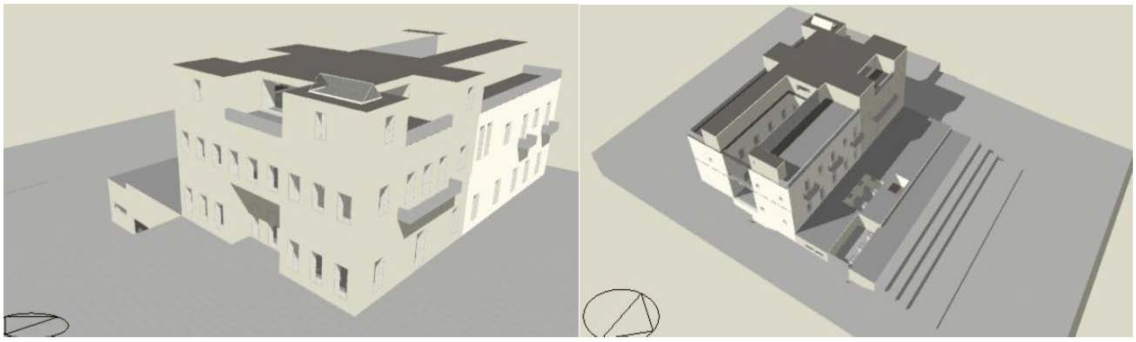

Figure 6: The Base case simulation model (Khalil, Hammouda, and El-Deeb 2018).

The simulation proved a possible reduction of 36.5% in the cooling, heating and lighting energy consumption as well as generated 74.7% of the energy required for cooling, heating and lighting from renewable energy sources.
On the other hand, due to the moderate climate of Alexandria city, passive treatments such as wall insulation and double glazing had a minimal benefit (in this case 0.4% and 5% savings, respectively), as the building does not rely on relatively high cooling loads

(compared to other cities within the hot arid climate zone) or heating loads, while active treatments such as lighting control and solar energy generation (in this case 23.9% and 48.1% energy use savings, respectively) can have the upper hand in energy consumption reduction.

Residential Heritage Building in Alexandria, Egypt

This residential building is a heritage building built in the nineteenth-century and it is listed as historical monument b with its eclectic Italian style that is located in the heritage business district of Alexandria, it is typical of the major part of the city's conservation area.

Figure 7: Picture of the Residential Heritage Building (Taher et al. 2019).

Figure 8: Pictures of the interiors of the Residential Heritage Building (Taher et al. 2019).

Taher et al. (2019) presented an assessment of wind driven natural ventilation performance in this European style courtyarded heritage building that was designed for passive energy use; yet, it is observed that its occupants currently rely on mechanical ventilation (air conditioning). It was assumed that the energy consumption and thermal performance of the heritage building can be improved if it performs as it was originally designed.

The assessment was conducted in two parts; (a) a detailed physical monitoring was conducted to measure air speed inside and outside the case study building. (b) Steady RANS CFD (computational fluid dynamics) simulation was conducted for the same building to expand on the measurement's findings. Simulations were validated against air speed measurements in parts of the building.

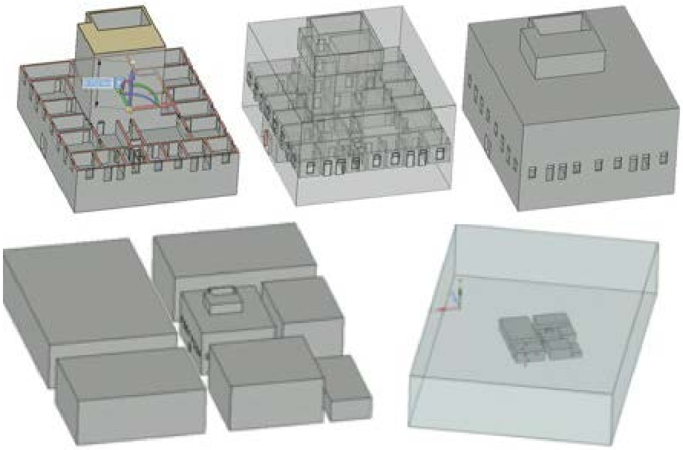

Figure 9:CFD Model of the Residential Building (Taher et al. 2019).

Modelling and measuring the current occupation of the building, the results obtained demonstrated unacceptable conditions for indoor comfort. This failure was evidently due to a combination of factors including occupants' behavior and modifications to the functional environmental principles of the building's original design. Alterations included the blockage of upper openings which have negatively affected the induction of cross ventilation and the stack effect throughout the building. Results showed a detailed example of how a deficiency of performance in natural ventilation is created in the case study building as modified today, and indicated potential for future improvement.

<u>Wekalet El-Ghouri Heritage Building in Cairo, Egypt</u>

Among Islamic Cairo Heritage buildings, Wekalet El-Ghouri is located in Al-Azhar area, was built in 1504 by the Memluk Sultan Qunsuwah El Ghouri.

Figure 10: Central courtyard of Wekalet El-Ghouri ("Wikala of Al-Ghuri - Wikipedia" n.d.).

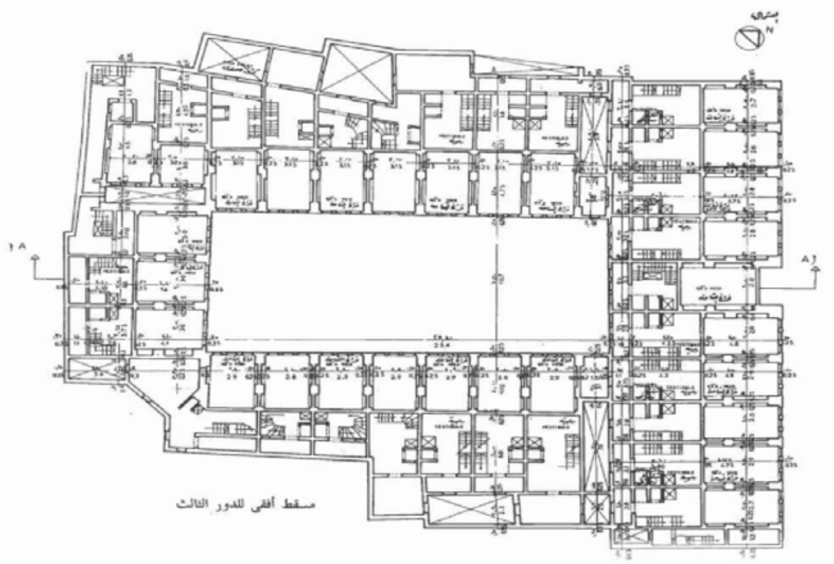

Figure 11: Wekalet El-Ghouri typical floor plan (Fahmy et al. 2019).

Fahmy et al. (2019) used three steps in the methodology to prove the efficiency of the passive design of one of the heritage buildings, which is Wekalet El-Ghouri. These steps are 1) the overview of the proposed generic energy criterion and its related factors and sub-factors; 2) the simulation procedures using the eQuest software, and 3) sustainability indexing and the assessment procedures. Simulations were divided into three parts; 1) as built limestone material of thicknesses 40 cm and 60 cm; 2) contemporary materials, which are 12 cm and 25 cm brick blocks; and 3) modified contemporary material in which insulating boards are added.

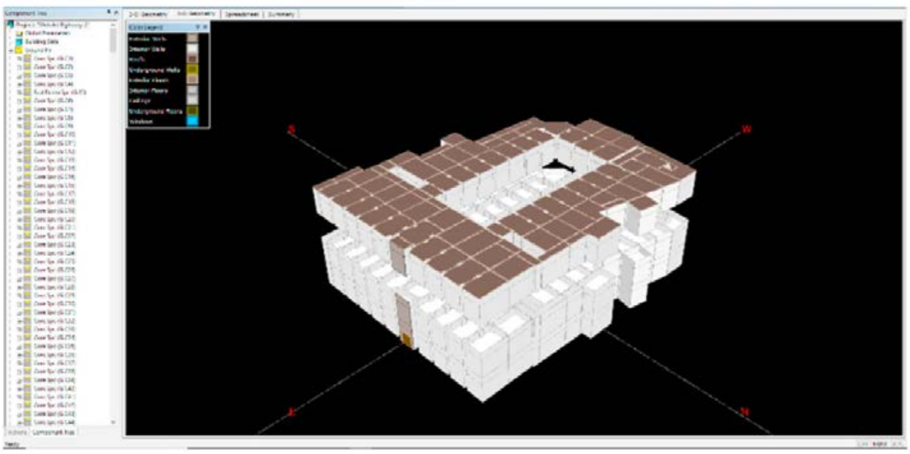

Figure 12: The graphical user interface of eQuest having the simulation model of the case study plan (Fahmy et al. 2019).

The Results showed the superiority of the as-built used construction material (limestone masonry blocks) over several contemporary construction blocks (12 cm and 25 cm concrete masonry units).

4. BIM ADOPTION IN THE COUNTRY

4.1. General introduction on the BIM adoption in Egypt

BIM Implementation Level

Within the Middle East countries, Egypt comes after the UAE in adopting the BIM in the infrastructure projects (Gerges et al. 2017). Nevertheless, the situation of BIM adoption in Egypt is limited and controversial, however the following literature is discussed for clarification. In 2016, an online survey has been conducted among 10 consultancy firms and 120 contracting companies in Egypt, and only 17.2% responded to the survey. Accordingly, the author suggested that this low rate of response may be related to the limited knowledge and understanding related to the field of BIM within the different Egyptian firms. But the respondents pointed the role of BIM as a tool for achieving sustainable building and that it is spreading within the construction field. Also, the conducted research highlighted the absence of governmental actions in the process of BIM implementation, and the majority of responses supposed that the government needs to involve in attempt to support the adoption of BIM in Egypt (Elyamany 2016; Mohamed 2018).

Another study has been prepared in 2017. A survey was spread among 98 architectural organizations, 76 Multi-disciplinary firms and 22 houses of experience, all based in Egypt. Like the previous survey, the results showed the early stages of BIM situation in Egypt. This study also showed the use of BIM in Egyptian firms is for its potentials including: the coordination, time saving and early conflict detection (Laila Mohamed Khodeir and Nessim 2018). In contrast to other researches that states the use of BIM in Egyptian firms is for the strong demand of its adoption into international projects (Mohamed 2018). Finally, this study concluded "that the application of BIM in Egypt is currently in the phase of spreading and is undergoing continuous developments" (Laila Mohamed Khodeir and Nessim 2018)..

Egypt regulation on digitalization of the construction industry and BIM

In case of BIM application in Egypt, there is a lack of certain standards, guidelines, codes of practices and sufficient available technologies. Egyptian Standards are strongly needed to be generated, in the attempt to suit Egypt and its overall context.

But there is a recent popular policy related to the environmental policies and Building Energy Models (BEM) in Egypt, the LEED, which works on saving the different type of resources through the use of renewable energy instead of the non-renewable alternatives. For example: reduction in water consumption, healthier choices of building materials, etc. And in the context of business, organizations use the LEED to increase their buildings' efficiency, through freeing up valuable resources that can be used to create new jobs, attract and retain top talent, expand operations and invest in emerging technologies.

In Egypt, there is 22 registered buildings acquiring LEED certification, most of them are situated within the two major cities: Cairo and Giza, while only one is located near Alexandria in new Burj Al-Arab. Only 6 buildings are officially certified, including two owned by the government and the rest are owned privately (Laila Mohamed Khodeir and Nessim 2018).

Active BIM organizations on the field

Some efforts are made in order to adopt BIM methodology in Egypt, including the 2018 BIM Egypt Day, TEMPUS project and BIM in Universities.

First, The BIM Egypt Day included experts in the field from different AEC firms, who talked about the various benefits of BIM implementation, also Autodesk shared its sale plans to help medium and small enterprises in licensed software purchasing. All these efforts were subject to encourage the Egyptian market in the adoption of BIM.

Second, the TEMPUS project was a fund from the European Commission that started in 2013 and ended in 2017. It included the participation of 4 European universities (Northumbria University, Leeds Metropolitan University, University of Twente and Chalmers tekniska högskola AB) and 6 Egyptian Universities (Cairo University, Mansoura University, El Shrouk Academy, The German University in Cairo, Beni Suef University, Sohag University), 2 industry partners (Kemet Corporation, Orascom Construction Industries) and the Egyptian Ministry of Housing (Erasmus+ 2018).

TEMPUS IV "Building Information Modeling: Integrated Design Environment for Engineering Education", "The project aims at promoting Digital Engineering for Construction (DE4C) and the related BIM concept of Integrated Project Delivery (IPD) to professionals from different disciplines within the Built Environment in Egypt in order to develop skills and create better value through smarter and more sustainable processes." One of the project's aims was to initiate a master program focusing on both the (DE4C) and the (IPD), funded by the project at Cairo university, and it started at 2015 and ended by the end of the TEMPUS at 2017. Also, the project worked on establishing training center in each of the six Egyptian partner universities.

Third, In 2016, a report has been made to investigate the BIM education within both governmental and private universities in Egypt. The report included Cairo University, Ain shams and Al-Azhar from the public sector, and the American University in Cairo (AUC), the British University in Egypt (BUE), the Canadian University in Cairo (CIC) and the German university in Cairo (GUC) as private universities. All showed the consideration of BIM in their curriculums and projects, also some private universities plan to expand the education of BIM in all years. While the GUC has a BIM unit and conducted a related forum in 2017 (Admed 2016; Mohamed 2018).

Average user's (enterprises, design firm) year of experience using BIM

Based on a conducted online questionnaire in 2018, It was sent to architects and engineers working in contracting firms, consultancy offices and academic institutions in Egypt. It targeted a sample of 70 architects, engineers and classified contractors in Egypt. A total 42 of responses only replied and their classification was as follow: 31 civil engineers, 7 architects, 1 academic and 2 contractors.

80% of respondents have experience less than 2 years to deal with BIM, 20% of respondents have BIM experience ranges from 2 to 5 years and It is noticed that no respondent has greater than 5 years of experience commensurate with the BIM technology.

In their answers for the training, only 10% of responses have been trained with BIM at home courses, while an equal percentage 45% for self-taught and university courses. According to Figure (6), 85% of respondents have used Revit as a BIM tools, while 5%, 5% and 5% used Naviswork, Sketchup and Synchro respectively (M. Othman, Elbeltagi, and Hassan 2018).

Perceived benefits and issues on BIM

Based on previous researches and studies, challenges and opportunities in BIM application in Egyptian firms are as follow (Elyamany 2016; Laila Mohamed Khodeir and Nessim 2018),

Challenges & Barriers include:

1. The limited numbers of firms working with the BIM technologies,
2. The BIM course not being mandatory during undergraduate studies,
3. Limited amount of training courses,
4. High cost of BIM system implementation, leading to a loss of interest from the side of owners to adopt this tool.
5. lack of demand from the client

Opportunities & Advantages include:

1. Higher productivity and visualization.
2. Time saving and Better quality.
3. Better collaboration, communication and coordination of construction documents.
4. Faster decision making and delivery.
5. project cost reduction.
6. Increased profitability.

Case studies of BIM use

Mall of Egypt, 6th of October city

Virtual Projects (VPs) was hired as BIM consultant and undertook the responsibility of developing a BIM adoption plan for the constructed “mall of Egypt”, located in the 6th of October City in Egypt (Adjallah, Birregah, and Abanda 2020).

About the Mall:

The mall of Egypt is a mixed-use retail, located at the 6th of October city in Egypt. It serves as an entertaining center for residents of both 6th of October city and Cairo. It includes mainly the shopping mall (of approx. 380 retail outlets), hypermarket (Carrefour), entertainment center, cinema complex, three car parking and an indoor ski park. Also, an open-air food court is provided at the mall entrance. It has a total built up area of 412,500 m2, and uses concrete and steel as a mix for structure.

About the BIM adoption plan brief:

The project delivery method was the “design and build” procurement method. The construction company’s BIM department was responsible for checking and validating the design models that has been received. And for better interpretation of the proposed design the BIM department used: 3D visualizations, real-time simulations and accurate quantity take-offs

Figure 13: Photo showing Aerial view of the Mall of Egypt ("Mall of Egypt - BESIX" n.d.).

4.2. HBIM adoption in Egypt

Egypt examples of HBIM interventions

A research analyzed the trial of HBIM in the restoration of the historic Baron Empire Palace, located in Cairo, Egypt (Salam 2020).

About the "Baron Palace"

The well-known heritage listed and worldwide masterpiece "the Baron palace" is owned publicly by the Egyptian government. The government took the decision of its restoration within a plan of restoring eight heritage buildings and sites. A budget for the restoration of the palace was set apart from the rest of the project and it was about 113.738 million Egyptian pounds.

Palace pre-restoration condition

The palace faced a period of deterioration and was neglected for a long time which negatively affected the whole building and its different parts including: walls, slabs, windows, doors, glass, statues and ornaments. In addition to a deterioration in some parts of the palace structure, which was seen on the lost layer in some parts of the ceiling in each of the three floors.

Palace restoration project

The project adopted three main stages for the restoration, that include:

1. The pre-restoration phase/preparation;
2. Restoration action / implementation;
3. Post restoration phase / usage suggestions.

This analysis will focus on the implementation action, where the role of HBIM in the restoration took place.

The Implementation phase

In August 2017 the actual restoration action took place. The first target of the restoration was to document the as-exist palace's condition. Also, detailed surveys encompassing the structural, archeological and architectural contexts were carried out. Both electrical and mechanical geophysics analysis were used for the geological surveys. Test were carried out in both locations, on-site and in-lab, for the palace's foundation and structure inspections. All these examinations, surveys and analysis were documented and reported formerly.

In the context of Architecture, the need for HBIM was a must. In this project the BIM use was mainly for the documentation of the palace's recent state. The internal and external architecture of the palace were captured using photogrammetry and 3D laser scanning. From these scans, a 3D surface model was generated through ReCap software, in addition to the emerging of the palace's real photos with the 3D model, to be re-rendered on 3DMAX software. From the output, it was stated that the as-is 3D model, with details for every part forming the palace, was satisfying and helpful especially for the on-site team work.

For more accuracy, each element forming the palace was identified, classified and coded. The elements were manually traced in scale 1:1 after their documentation in on photographs. Also, each restored part in the palace was documented in the form of CAD drawings. All data related to materials, fabrication and techniques were studied and attached to their elements. Each element holds a code, the code contains information related to the element including: place, specification, changing situation (before and after restoration), and other important related data. The archeological studies were documented using the same system of coding. Also, Primavera software was applied for construction and project management related facilities. All the process was documented digitally and printed for a hard copy archiving.

From the previously illustrated study, it has been proved that the role of HBIM in the baron palace restoration was mainly geometrical documentation of the pre-restoration state of the palace. However, there were challenges related to the 3D printing in attempt to complete some missing elements of the palace. These challenges included: cost, material and the absence of an accurate prototype. On the other hand, both the preparation and implementation actions were undertaken accurately.

4.3. HBIM and interoperability

In 2014, a conducted study with the aim of optimizing the building's life cycle cost (LCC), focused on specific building's elements that constitute the outer skin, external facades and roofs, and selected energy saving systems, to be assigned on these elements. This study used the Genetic Algorithm (GA), coupled with the (BIM) model, energy simulation tool (EnergyPlus) and a life cycle cost estimate model. The study was applied on a desert building in Egypt as a conceptual case, in attempt to optimize the buildings' design with a focus on the outer envelope.

From the study, the researcher found that there is a strong relation between the energy performance of a building and its lifecycle costs. In addition to the importance of energy efficient system at the design stage in order to facilitate the process of decision making and achieve the most suitable building design (Nour, Hosny, and Elhakeem 2015).

4.4. HBIM and energy improvement

According to Laila M. Khodeir, Aly, and Tarek (2016), both the BIM and sustainable attempts, on the sector of heritage buildings in Egypt, face a lot of challenges and are limited. These challenges may include: the lack of equipment, limited amount of professionals, funding and financial related issues.

So, it has been suggested to invite diverse international partners, who are interested in the conservation of the world heritage, in an attempt to share knowledge and experience, in addition to fund these projects.

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A3.1.1 REQUIREMENTS FOR AN INTEGRATED INTEROPERABLE AND MULTIDISCIPLINARY EE-HBIM WORKFLOW

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1. Requirements for an integrated interoperable and multidisciplinary workflow based on BIM approach with the use of performance simulations.

buildingSMART International has a well-established procedure to integrate specific information and parameters in IFC open standards. The problem in terms of interoperability within a process that involves heritage buildings and energy efficiency is dual: integration of HBIM specific data within IFC schema; development of a Model View Definition (MVD) for energy modelling.

1.1. Integration of HBIM specific data within IFC schema

It is necessary that the IFC schema is extended in order to allow for the storage of information typical of historic buildings, that currently do not find a place in the standard. Therefore, in most cases, even if the information can be integrated into a BIM authoring model of a specific software house, it cannot be exported in a structured way to other platforms (and other software environment) in an openBIM process. That means a loss of information.

1.2. Development of a Model View Definition (MVD) for energy modelling

The second aspect is the development of a specific model view definition for energy analyses. An IFC view definition also called Model View Definition (MVD) defines a subset of the IFC schema that is needed to satisfy one or more exchange requirements in the AEC industry. The method used by buildingSMART to define these requirements is the Information Delivery Manual (IDM). Generally speaking MVDs are used to filter BIM data to provide simple access to the most relevant data for a given purpose (GSA 2012).

MVD for energy uses appears particularly complex because interoperability between a BIM model and an energy model does not only involve the selection of information to be transferred or to be added to the BIM model, but also concerns the required transformation of information from the BIM model to the energy model.

In some cases, the problems arise from a difference in the internal logic between the two software environment in the description of architectural objects. Other issues are linked to the clash between a zone-based-modelling approach, usually preferred by energy simulation operators, against a space-based modelling usually made available by BIM authoring tools. Other issues are related to the transformation of a three-dimensional model, in which the architectural elements have their own thickness (BIM), to a simplified model made of two-dimensional surfaces with specific energy-modelling hierarchies and boundary conditions (GSA 2012; Pinheiro et al. 2016; O'Donnell et al. 2013; Giannakis et al. 2015).

Currently, beyond research groups, a buildingSMART building room is working on the Information Delivery Manual for building energy modelling.

1.3. HBIM and energy modelling interoperability

Historic buildings introduce other geometric and data specific complexities, both in the BIM and energy modelling domains, as shown in (Elena Gigliarelli et al. 2017; E. Gigliarelli et al. 2019). These complexities could require a further specification, even when the energy simulation MVD will be feasible for new construction.

Moreover, historic buildings provide case studies of exceptional complexity (and value), that can be seen as an opportunity to stress-test the interoperability between BIM and simulations, contributing ideas to solve the issue, highlighting rigidity and limitations that are generally underestimated on new construction (Gigliarelli et al. 2019).

With its selection of historical case studies, BEEP project could provide very useful data for in-depth study of the topic, particular on:

1. the definition of the requirements to be integrated into the IFC scheme, to ensure that the specific data of historic buildings can be integrated into an openBIM process;
2. the definition of major obstacles in terms of interoperability in the transition from BIM software to energy simulation software.

This information will be used to solicit the launch of an expert group within buildingSMART, to support HBIM approach and openBIM and to support the current group at work on the issue of interoperability between BIM and energy simulations.

A.3.2.1 BUILDING EXECUTION PLAN (BEP)

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Index

1. INTRODUCTION

1.1. Document purpose

This document provides a framework Building Execution Plan (BEP) for the development of a virtual model, using the Heritage Building Information Modelling (HBIM) process, of the case studies selected within the ENI CBC Med project BEEP (BIM for Energy Efficiency in the Public sector) described in § 1.3.

Within this framework, each partner, together with appointed HBIM consultants (if present), should develop a specific BEP adapted to the characteristics of each case study, following the Exchange Information Requirement (EIR) already prepared of activity 1.3.2 of BEEP project. The EIR, in fact, act as a guideline for BEP implementation, both for BIM consultancy, in the case of a BIM tender (when it also represents the technical specification of the tender), and for partners' staff, in the case of in-house BIM modelling.

In line with the definition of ISO 19650, the BEP (intended in the regulation as BIM Execution Plan), defines the methodologies, requirements and timeframe on which the information modelling will be carried out. A BEP should detail not only how information is created and delivered, but also the 'why' (defining the BIM use), and the 'who' (assigning responsibility for it). It specifies the management, technical, commercial and project information and deliverables required for the project in a way that is specific, measurable, achievable and realistic. All parties must adhere to and follow the BEP.

1.2. General Project Information

This framework BEP concerns the development of a HBIM model of the case studies selected within the ENI CBC MED project BEEP (BIM for Energy Efficiency in the Public sector). The BEEP project aims to enhance the capacity of public local administrations to design, and realise innovative energy rehabilitation interventions on historic public buildings, by the mean of a multidisciplinary and integrated ICT tool (BIM and performance-based design: the Energy Efficient Heritage BIM approach – EE-HBIM). The testing of this emerging technology on built heritage will be performed to demonstrate its scalability to the entire building stock. The project will provide public administrations with a powerful method for the energy rehabilitation of public buildings to be supported with private funds through the Energy Performance Contracting.

Each partner will be responsible for enabling, creating and/or delivering a HBIM model of its case study in two different stages, corresponding to specific WPs of the BEEP project.

In Stage 1 (identified as WP3 A3.3.2), the required HBIM model will integrate previously collected information on the building that will be further provided to the Consultant (geometric, diagnostic, energy and environmental data), to create a comprehensive documentation of the building's current state.

Within WP4 A4.2.1., the HBIM model of the first stage will be used as a basis to inform a subsequent energy-environmental improvement concept, through energy renovation scenarios that are both compatible with the identified historic buildings and capable of enhancing their energy and environmental performance. Scenarios' energy performance will be evaluated with specific energy software, selected for each partner by WP3 and WP4 expert panels.

In Stage 2 (identified as WP4 A4.2.2), the technical characteristics of each scenarios and its energy performance will be integrated within the HBIM model (4D - 5D – 6D – 7D), in order to facilitate a ROI analysis and the drafting of EPC.

1.3. Glossary

Unless the context otherwise requires, the following words and phrases shall have the following meanings:

Building information modelling (BIM) - Use of a shared digital representation of a built **asset** to facilitate design, construction and operation processes to form a reliable basis for decisions. Digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it, forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.

BIM Execution Plan (BEP) - Plan prepared by the Consultants that explains how the information management aspects of the appointment will be carried out, in response to the EIR. A BIM Execution Plan (BEP) defines how, why, when and by whom the information modelling aspects of the contract will be carried out. The use of BIM should be clearly agreed with the Employer and specified in the contract.

> **Pre-contract BEP -** The pre-contract BEP is to demonstrate the Consultant's proposed approach, capability, capacity and competence to meet the EIR. It is utilised prior to the appointment of any Consultant.
>
> **Post-contract BEP -** The post-contract BEP is the document defining standard methods and procedures adopted during the contract in order to meet the objectives and requirements set forth in the EIR. It is utilised following the appointment of project Consultant.

1.4. BIM Element Matrix (AIA)

BIM Element Matrix is a key document as it both allocates responsibility for preparation of the Models and identifies the Level of Detail and the properties by Uniformat/OmniClass classification for model elements.

Common Data Environment (CDE) - Agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process. It is a means of providing a collaborative environment for sharing and coordinating work as information can be transferred through information exchanges and managed through the CDE. Strict operating procedures ensure a consistent approach by all organisations involved.

EIR Exchange Information Requirement - Tender document setting out the information to be delivered, and the standards and processes to be adopted by the Consultant as part of the project delivery process.

Industry Foundation Classes (IFC) - The IFC format is an industry-wide open and neutral data format that is fast becoming the de facto standard for rich data exchange. Further information can be found on the buildingSMART website https://www.buildingsmart.org/. The "native format" refers to the original software used for production of models.

Model federation - Creation of a composite information model from separate models. An assembly of distinct models to create a single, complete building information model of an asset.

OmniClass - The OmniClass Construction Classification System, also known as OmniClass™ or OCCS, is a classification system used for the organising and retrieving of information for the construction industry. For more information, see https://www.csiresources.org/standards/omniclass

Level of Information Need - The level of information need defines the level of maturity required for a particular information deliverable at a particular plan of work stage. It provides a framework that defines the extent and granularity of information and helps to prevent the delivery of too much information.

Model - Digital representation of part of the physical and/or functional characteristics of the Project.

Project - means the project to which the EIR relates.

2. MANAGEMENT REQUIREMENTS

2.1. Roles and responsibilities

Each specific BEP for each case study shall indicate the Project Team Members carrying the following roles, indicating their capability and experience to fulfil the requirements of the roles. The same person can fulfil different roles:

Function	Role	Name	Title
Management of the information process	BIM Manager		
Management of the CDE	CDE manager		
Management of the asset	BIM Coordinator		
Information modelling	BIM Specialist		

2.2. Model uses

The purpose of this section is to define the model uses of the HBIM model to be developed, as listed below:

Phase	**Objectives**	**Uses**
Stage 1 (WP3 A3.3.2)	Constructive HBIM model definition	Integration and representation of building geometrical and technical information according to the documentation provided by

		the Employer (geometric survey, drawings, etc.) Definition of building elements Space, areas and volumes analysis
	Management of the knowledge documentation on the historical building	Integration of historical documentation provided by the Employer (information sheets, links, etc.) Integration of diagnostic information provided by the Employer (materials and structure survey, etc.)
	Management of the environmental-energy analysis	Integration of energy and environmental analyses developed by the Employer.
Stage 2 (WP4) A4.2.2	Support of three energy intervention scenarios and of choice of adapted renovation strategies and technologies	Integration of three energy improvement intervention scenarios (short/medium/long term) provided by the design activity of the Employer with data concerning Time, Costs and management (4D, 5D, 6D, 7D)
	Assessment of ROI of the environmental-energy intervention scenarios	Integration of Return of Investment evaluation method based on the intervention costs and energy saves of the interventions

2.3. Level of Information Need

The level of information need defines the level of maturity required for a particular information deliverable at a particular plan of work stage. It provides a framework that defines the extent and granularity of information and helps to prevent the delivery of too much information.

The level of information needs for this project will be defined using the BIM Element Matrix, which is a key document as it both allocates responsibility for preparation of the Models and identifies the Level of Detail and the properties by Uniformat/OmniClass classification for model elements.

2.4. Model federation and data segregation

Each specific BEP for each case study shall indicate a federated model strategy, depending on the case study dimension and on the energy simulation process. It is recommended to separate at least: Architectural model; MEP model including terminals and heating and cooling production system– useful for the energy analysis. A separated structural model is more useful with a frame concrete or wood structure.

For Stage 2 (WP4), a model federation strategy will be further developed to better represent the three energy improvement intervention scenarios.

2.5. Data sharing and collaboration

The Consortium as a whole and each team working on the same case study will establish an agreed protocol for coordinating and sharing models, including how they will be controlled for quality and for ensuring security of information. Information may flow both ways.

The Consortium will provide a Common Data Environment (CDE) complying with ISO 19650 and ISO 27001, to be used by partners and their employees and consultants for the management or sharing of data. This must facilitate collaboration and information sharing between members of the project team. It is essential that common BIM standards covering detailed processes within each organisation are established and agreed in advance.

2.6. Naming convention

For the file naming convention, the Consortium will provide a naming specification, to be used for all document types uploaded to a CDE, in line with IEC 82045-1 and BS 1192:2007(A2) 2016. For the object naming convention, Omniclass standard will be applied, as will be developed in the BIM Element Matrix (see § 2.3.1). If necessary on a given case study, the naming convention can be integrated for specific not supported elements, following the same naming methodology.

2.7. Modelling strategy

The modelling process will be based on the BIM Element Matrix.

The modelling process will be based on the geometric and technical information (geometric survey, drawings, etc.) collected during activities A3.2.1 and A3.2.4. Based on the provided information, the model will represent the constructive system and technological characteristics of the building (vertical and horizontal structural system, materials, etc.) and as accurately as possible within the Level of Information Need. The walls, roofs and floors will be modelled with their stratigraphy (know or assumed). Decorative elements can have a simplified representation, as long as their constructive system is detailed.

The HBIM model development will take advantage of the parametric tools of native software (e. g. system families) as much as possible, avoiding non-parametric tools such as mass modelling. The correct representation of the building technical, constructive and environmental features is paramount, even when leading to simplification of uneven features, typical of historical buildings. Each team working on the same case study shall develop a simplification strategy (e.g. assuming planarity of walls), if needed.

Historical and diagnostic information (materials and structure survey, energy analyses, etc.) collected during activities A3.2.2 and A3.2.5 will be incorporated in the model. If the information cannot be directly integrated in the elements, it can be linked using reports, sheets, drawings, etc.

In order to support environmental-energy intervention scenarios, the energy information collected in activity A3.2.6 (e.g. transmittance values for walls and windows, occupancy data, etc.) will be integrated in the model. Occupancy and uses profiles for each room and/or thermal zones, if not included in the model, will be linked as external files (reports, sheets, etc.).

Regarding MEP system, HVAC systems terminals and plants will be represented. If no specific MEP system is modelled, the room information must include data on plants and terminals.

Regarding object insertion and constraints, all objects (walls, roofs, ceilings, floors, HVAC systems, structures, windows, etc.) must be constrained to the corresponding lower and upper level.