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Energy Procedia 00 (2017) 000–000

Energy
Procedia

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International Conference – Alternative and Renewable Energy Quest, AREQ 2017, 1-3 February 2017, Spain

Embodied Energy Policies to Reuse Existing Buildings

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Abstract

When dealing with the existing stock of buildings, energy strategies usually focus on the improvement of their performance by means of technical upgrading. However, taking architecture as a resource helps raising another question: to what extent the embodied energy in already built structures could be a key factor to develop sustainable strategies based on an adaptive reuse and a subsequent extension of their lifespan.

The aim of this paper is to discuss on the benefits and architectural implications of a public policy addressed to establish a protocol on reusing existing buildings in order to take advantage of their embodied energy.

Peer-review under responsibility of the organizing committee of AREQ 2017.

Keywords: Embodied Energy; Adaptive Reuse; Public Policies; Existing Buildings; Refurbishment.

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Peer-review under responsibility of the organizing committee of AREQ 2017.

1. Introduction

Energy strategies to renovate existing buildings are usually focused on improving their efficiency. This technical upgrading can be regarded as a basic repair to optimize consumption and reduce emissions — even extend their lifespan reasonably — but it does not actually involve the use of the building. Providing they are in a good condition to bear a refurbishment, the genuine potential of the existing stock of constructions is to be reused once their original function is over. Although this process can be approached in different ways, the one endorsed here is an adaptive reuse aware of the cultural, social, environmental and economic value of the building. The discussion is not only about the ability of a building to adapt to new requirements but also the very program to adjust to diverse circumstances.

Built architecture can be understood as a resource in itself, expressed by means of its potential performance and the energy embedded within. This energy that was spent during construction — and is regularly increased by ordinary maintenance — is not easily recoverable. Considering management and maintenance as a constant, the longer the building provides a function, the better the rate per unit of time. Consequently, a sort of *amortization* in architecture can be formulated as the quotient between the embodied energy of a certain building and its lifespan.

When a change of use applies, renovation comes into consideration and the effects of this amortization are modified. In the above-mentioned quotient, a renovation implies a new balance between a variation of the existing embodied energy — which may be conserved or diminished —, a new injection of energy, and a longer lifespan. Depending on the overall strategy, solely certain renewals are favorable to sustainability in these terms: those aware of the importance of re-programming the building in consonance with its potential and implementing strategic design measures to preserve embodied energy.

The scale in which these operations occur is also relevant, since sustainability does not depend on single initiatives but on a general outcome. Thus, refurbishment should be of a general interest. Public policies must address such processes, by establishing clear and useful criteria to evaluate transformations and boost low impact ones. Political support is definitely needed to facilitate the low carbon emissions [1]. The duty of experts is to provide background analysis and establish an operational methodology to make this possible. Taking the stock of buildings in Barcelona as a case study of adaptive reuse can help establishing a local basis for discussion that takes social, economic, environmental and technical issues into account at the appropriate scale to establish a protocol on reusing existing buildings as a basis for a public policy.

2. Adaptive reuse as a recurrent strategy

As other man-made artefacts, buildings undergo complex processes of obsolescence both as a physical phenomenon and as a function of human action and disregard that only regular reinvestments in maintenance and adaptation can modify [2]. Although being structures in a continuous transformation, buildings are rarely studied from this standpoint at a large scale and in a systematic way.

A key factor in the life cycle of a building in relation to obsolescence is a change of use that occurs when the initial function it was designed for is over. Analyzing thoroughly cases of this nature and identifying their characteristics at each stage can result in a set of general and specific guidelines about their ability to accommodate various programs over time, despite not being designed for such purpose. The ongoing research project Atlas of Architectural Reuse[1] focuses on Barcelona as a case study to provide operational information about this current yet understudied situation. If appropriately contextualized, architectural and urban processes generated systemically as a result of reuse and

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[1] Research group HABITAR, Universitat Politècnica de Catalunya. “Atlas of Architectural Reuse. Critical Studies on Barcelona's Converted Buildings” (hereinafter referred to as Atlas) funded by the Spanish *Ministerio de Economía y Competitividad* under the national R&D program “Retos Investigación / Research Challenges 2013”.

conversion of buildings could be evaluated and become applicable to other urban environments with similar dynamics. Some of the preliminary results of the project are used in this paper to help discussion about the benefits of considering embodied energy of the existing stock of buildings and its variations as part of local energy policies. The Atlas has identified so far 878 existing buildings of all periods which have undergone at least one integral conversion over the years and can now be first compared using the basic data collected.

Adaptive reuse refers to "any building work and intervention to change its capacity, function or performance to adjust, reuse or upgrade a building to suit new conditions or requirements" [3] and this definition makes no distinction whether the building is part of the heritage or just an ordinary one; only the objective capacity to change is considered. In this connection, the Atlas does only contemplate the potential of buildings to address a conversion — what could be called its *value in use* — and will focus on the nature of this transformation in a second stage. Out of this argument the very meaning of heritage could be widely debated considering environmental value along with architectural, historic or social value although it is not a concern in this paper.

3. A brief assessment of embodied energy

As Jackson states [4], "the benefits of reusing historic and existing buildings versus those of constructing new buildings are frequently discussed in terms of economic, cultural, and design values. If those discussions are expanded to include environmental impact, one must also address the topic of embodied energy". There is a broad agreement to describe what embodied energy is but current interpretations are quite unclear and vary greatly [5]. Even Jackson does not consider maintenance or management when he defines embodied energy as "the sum of all the energy required to extract, process, deliver, and install the materials needed to construct a building".

When dealing with already built structures, the concept of embodied energy itself is an ex post facto approach intended to evaluate buildings erected when energy reduction was not a goal. Thus, it is not surprising that they are not exactly efficient in consonance with current parameters and concern. In addition, the energy needed to demolish those structures when a new one is contemplated must also be taken into consideration. It can take more than 30 years before any cumulative energy savings is achieved when a building is demolished and replaced [4]; a rough figure that can be modified if renovation focuses on efficiency consistently. This all points that expanding the lifespan of a building and continue to take advantage of its embodied energy should be fostered as an active policy.

Therefore, what is relevant here is not the embodied energy alone — although we could be talking about significant figures — but its impact over the years, considering this non-recoverable energy along with the lifespan of the building. In this context, we could define *amortization* in architecture and building construction, from the point of view of energy management, as the quotient between the *initial embodied energy* required to erect a building and the habitability that such building grants over the years, expressed in time (1). The lower the result the more sustainable the building. A building with no habitability cannot be sustainable at all.

$$\frac{\text{initial energy}\left(E_{ie}\right)}{\text{time}\left(T\right)} \tag{1}$$

Ordinary maintenance increases gradually the initial amount of energy with some *recurring embodied energy* [6, 7] to produce discrete increments of habitability — in terms of time — under certain conditions (2), e. g. when the initial use of the building does not modify significantly. Amortization is then rebalanced. To be more precise, one could agree that the recurring embodied energy is both related to activity — intended to grant habitability — and to the architectural particularities of a specific building. In order to evaluate more accurately any single case, methodologies should consider them both. Furthermore, maintenance energy is the only parameter in the numerator that can be reduced by means of new material and technical possibilities.

$$\frac{E_{ie} + \text{maintenance energy}\left(E_{re}\right)}{T + \text{increment of time}\left(\Delta t\right)} \qquad (2)$$

When a change of use applies, renewal comes into consideration as new programs may involve different performative standards. However, not all renewal strategies operate in the same direction. In the equation (3), a refurbishment could mean that the initial embodied energy is preserved or reduced — since the original structure is used as it is or parts of it are demolished or radically transformed. Additionally, the numerator is increased because of the new requirements and their associated embodied energy.

$$\frac{E_{ie} + E_{re} - \text{loss of embodied energy}\left(e_{ie}\right) + \text{energy of renovation}\left(E_{r}\right)}{T + \Delta t + \text{increment of time}\left(\Delta T\right)} \qquad (3)$$

Therefore, only certain types of refurbishment are favorable to sustainability, when the global increase of energy is minimum and the increment of time and habitability tends to a maximum. The question is how should this balance be addressed to take advantage of the embodied energy which, by definition, cannot be easily recovered. The scale of the response can only be confronted by public administrations as part of the emission reduction commitment. In this regard, two complementary public policy measures can be envisaged. On the one hand, the need to stimulate reusing the existing stock of buildings by establishing amortization targets for all construction works — either new or reused buildings — and on the other hand, the need for a protocol that sets operative parameters to deal with such conversion processes. This paper focuses on the latter.

4. Re-inhabiting as a performing strategy

Reusing and repairing architecture should not be observed as a circumstantial response to a period of crises, but a responsible attitude and a design strategy to approach our built environment from the domestic to the urban scales. Richard Sennett [8] describes a type of repair that he refers to as *dynamic*. Sennett claims that dynamically repaired artefacts improve their original use and condition since they gain from our knowledge and ability "inviting new tools for working with objects" as a tacit criticism to their initial appearance and function. Repairing gains from the qualities of a design process so, in this regard, we can observe dynamically repaired architecture as a chance to redefine the process itself [9].

Repaired buildings in this way can inspire users a distinctive approach, stimulating them to re-inhabit spaces through the new possibilities acquired. Inhabitants along with programmatic components change to the same extent that architecture does and this is an opportunity to reflect about habitability, defined as socially and culturally accepted living conditions, ensured by means of state or local regulations. The notion of re-inhabiting reveals itself useful to foster a strategical approach to the preservation of embodied energy.

In the context of a homonymous research project [10], re-inhabiting was described as a critical review on how architecture is used, identifying opportunities and managing restrictions of existing buildings, considering architecture itself as a resource, developing solutions to overcome obsolescence and extend the lifespan as a sustainable strategy to re-amortize the embodied energy and reformulate habitability with greater involvement of the inhabitant. In other words, this methodology is focused, on the one hand, on the potential of transformation of host buildings and the corresponding ability of architecture programs to adapt to different supports and, on the other hand, on the recognition of certain design strategies to meet these objectives. This paper uses preliminary results of the Atlas to support an approach to embodied energy amortization through compatibility and adaptability — as re-programming strategies — along with complementarity, durability and reversibility — as design strategies.

Disregarding these parameters may result in a substantial loss of embodied energy and a consequent need of an extra injection but also a higher environmental footprint in later renovations, as some preliminary results of the Atlas suggest. Data show a relevant tendency to convert housing buildings in hotels and residences — 212 out of 878, representing a 24 per cent of the overall cases considered. Among them, a pattern of veiled demolition and almost complete renovation is revealed, to the extent that, in these cases, only facades and individual elements listed as part of the architectural heritage are preserved. Research does not consider this a case of incompatibility — since similar cases succeed — but an inadequacy that can be interpreted as the evidence of a legal weakness that does not consider the environmental impact and eventually as the need for a protocol to help administration to manage renovations taking their impact at the urban scale as a framework.

4.1. Re-programming strategies: Compatibility

In order to operate strategically, this protocol should consider first of all the availability of abandoned, obsolete or misused buildings and the compatibility between existing constructions and the requirements of new programs. Compatibility is especially relevant to preserve embodied energy. The structure and envelop alone contain a 49 per cent of the initial embodied energy of an average building [4], but other components may increase this figure substantially depending on how much does the new program match in the existing configuration of spaces and their capacity to host other programmatic requirements with little change.

In this respect, a distinction should be made between actual and potential performance [2] including technical, environmental and living aspects. Actual performance is the result of an initial design process affected by continuous decisions of management and actions of maintenance over time, which may eventually derive in obsolescence. Potential performance emerges when a building can outlive its current use — which is not necessarily the initial one — and adapt to others taking advantage of its specificities, not to mention the efforts of designers and developers to stress such capacity. Potential performance is the substance with which dynamic repairing works.

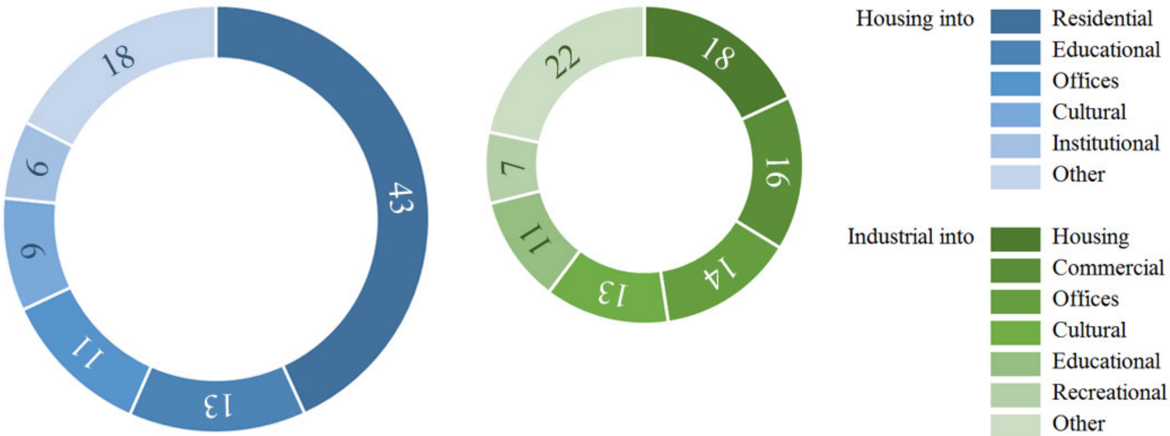
What does the Atlas reveal in this direction? Preliminary results show that 491 cases of converted buildings in Barcelona out of 878 — more than half of the sample — were initially constructed to house dwellings and 166 were industrial premises. In the architectural and urban context of Barcelona, evidence indicates that these two programs, which together amount a 75 per cent of cases, can be considered the most responsive to change. Hence studying these two prevailing cases should provide useful responses to adaptation that could be useful to evaluate variations of embodied energy.

The predominance of transformed housing buildings should not be surprising — since these represent an 85.7 per cent of the overall buildings [11] — although they are often considered as inflexible because of their intricate layout. Industrial buildings however are usually open-plan spaces which are supposed to match many purposes. Beyond these clichés, that would situate housing and industrial structures as opposite ends of the spectrum, the Atlas suggests a different and more complex situation. Housing along with industrial buildings undergo processes of reuse according to their potential performance, plausibly distorted by their location in the urban fabric, their availability or the pressure of certain emerging programs such as hotels. It is too early to draw conclusions about the incidence of each case but a reflection on the compatibility of host buildings and new programs is imperative to consider reuse at a large scale as a question of public interest.

4.2. Re-programming strategies: Adaptability

A corollary of the previous reflection is the capacity of reuse to subvert some of the conditions commonly agreed to define a specific program in order to better accommodate in the host structure. What is suitable for a new construction may not be a solution to a reused one. A provisional estimation (Table 1) shows that housing buildings' first conversion is mainly into residential — hotels and residences —, educational, offices, cultural and institutional programs, while industrial structures principally become housing, commercial, offices, cultural, educational and recreational buildings. This divergence of programs that match in such a limited amount of host buildings suggests the complexity of urban dynamics — especially visible in the hotel and residence sector with a 43 per cent of cases — but also the adaptability of diverse programs and requirements to similar supports. An office program adapted to a former housing building may differ significantly from the same program adjusted to a converted industrial one. They both function as offices but the actual layout is predictably different because of their individual adaptation.

Table 1. First conversions of housing (left) and industrial buildings (right) in percentage.



This capacity to host different uses — and their specific requirements — can be compared to the way operative systems in computers work with software. The same application adjusts its internal configuration to different systems to offer a very similar performance. Software changes according to the support. An architectural program can also operate in an analogous manner, adapting to distinct typologies of host buildings, favoring the preservation of embodied energy. Based on this statistic, the Atlas will focus, in a second stage, on this divergence which suggests an inclination to reform the way to use and program buildings rather than the building themselves.

4.3. Design strategies: Complementarity

In the words of French architects Lacaton & Vassal [12], "extending existing structures, adding, aggregating, combining, expanding, overlaying, assembling to build something new is very effective. Urban, architectural and landscape infrastructures are already there and we must simply take advantage of them" [translation by the author]. Their own work along with Frédéric Druot operate in this direction and yet reveal a particular ability to deal with complex situations. Dynamic repairing as stated by Sennett applies: existing structures are preserved and complemented to enhance their performance. When in a good condition, this strategy is a legitimate and feasible alternative to demolition but also to major transformations and their associated loss of embodied energy. The goal is not the preservation of all built structures but to unlock their potential performance [13]. Focusing on a specific housing neighborhood, the Cité Lumineuse at Bordeaux, Druot [14] asserts that "renovating the building, by transforming each of the remaining apartments, would demonstrate its incredible capacity to evolve and change".

With this goal in mind, potential performance — or this incredible capacity to evolve and change — can be reached by adding and overlaying new complementary components, not necessarily modifying the existing support, which would preserve its embodied energy still intact. The detail required to draw conclusions in this field is probably out of reach of the Atlas, but the work of these French architects can help illustrating it. Over the past decade, they have developed a methodology to refurbish existing housing buildings [15], condensing the overall intervention in a few strategic measures. Among them, the most prominent is the addition of intermediate spaces — conceived as extensions of the dwelling — to improve at once energy efficiency, durability and habitability of the apartments, while at the same time minimizing the direct intervention on the existing fabric.

This methodology of dynamic repairing is not exactly an example of reuse, but it can be regarded as the epitome of a transformation that manages to preserve and re-amortize the host building's embodied energy. This sort of indirect approach can be easily compared to the Clip-On concept described by British architecture critic Reyner Banham [16] through an industrial design analogy: "given an [outboard motor] you can convert practically any floating object into a navigable vessel. A small concentrate package of machinery converts an undifferentiated structure into something having function and purpose". Intermediate spaces in the work of Lacaton, Vassal and Druot could be an instance of Clip-On architecture that include environmental impact of a renovated building.

4.4. Design strategies: Durability and reversibility

Reusing is, in a way, a reset process that results in the extension of the lifespan of a building so further conversions may apply in the future. Preliminary results of the Atlas show that 169 buildings out of 878 — one of every five — have undergone a second change; 50 of them a third change and 13 a fourth transformation. This will always be an in-transit result as a new conversion may be on the way and that is exactly why it provides relevant data about the nature of reuse. As the Atlas confirms, buildings analyzed outlive in a good condition the initial purposes they were intended for, to the extent that a significant amount of them are prepared for further transformations. In this respect, conversions should consider both durability and reversibility of the intervention as key parameters.

Durability is here understood as the capacity to adjust technical solutions and constructive systems to the time the use will last, i.e. adapting the increase of embodied energy to the expected habitability demands. An indefinite period requires a different response than a short stage, as proposed in some of the sport venues built for the London 2012 Olympics — using temporary modular structures and light materials which went eventually dismantled — that produced significant embodied carbon emission savings using efficient design [17].

In fact, not every action in a single intervention must be conceived with the same durability. Modifications related to accessibility, energy performance, fire prevention or basic equipment may be considered as structural to enhance habitability in a diverse range of potential uses and therefore addressed as permanent improvements, while other components may be assumed as less specific, temporary or associated to an expiration date. This diversity of performance periods should be carefully considered when reusing a building because they have an impact on the future management and maintenance.

Reversibility, as the ability to be changed back to an earlier state, is essential to deal with a stock of buildings which is immersed in a process of recurrent change. Understanding architecture as a resource, a sustainable intervention should align with the Brundtland Commission and "meet the needs of the present without compromising the ability of future generations to meet their own needs" [18]. An intervention of extension or overlay — in the direction shown by the words and work of French architects Lacaton, Vassal and Druot — can be an appropriate response to this requirement. Once the period of use is over, dismantling and recycling those building components should ideally restore the initial situation of the building, ready for a new conversion with little incidence on its embodied energy.

5. The need of a public policy for reusing architecture

Directive 2010/31/EU of the European Parliament and of the Council on the *Energy Performance of Buildings* and Directive 2012/27/EU on *Energy Efficiency* are focused on reducing the energy consumption of buildings. There is no such green legislation intended to preserve and re-amortize embodied energy in existing buildings by promoting their dynamic repairing. Reusing architecture is nothing new. Examples of reuse can be observed in every period of history, as the Atlas confirms — 572 out of 878 cases are over a hundred years old; 221 of them over two hundred. The only difference is that now we are aware of the sustainable implications of this approach at a large scale. Without forgetting energy performance and efficiency, there is a lot to say about converted buildings in relation to embodied energy. The ultimate objective of the Atlas is to set, at the local level, the basis for an operational protocol to program the reuse of buildings in the context and specificities of Barcelona [19].

Efficiency, in this case, is not the result of a better energy performance but the consequence of adequate re-programming processes and low-impact creative solutions to reuse buildings, providing these measures are taken at an urban scale — the suitable scale to legislate, execute and audit the results on a physically interconnected environment, but also the scale of communities who can embrace and claim those principles. Only then the discourse about embodied energy is coherent and can produce significant results. As Yung & Chan (2012) report, "the role of participatory governance is well recognized in achieving sustainable development, in the process of decision-making, and in [re]using historic buildings".

In contrast to new constructions however, the reuse of buildings cannot be programmed and regulated on the basis of comprehensive solutions but probably on performance standards which may differ from one another. Original materials are so diverse that every intervention must identify the way to activate them to benefit from their properties and attributes. Initiatives like the Los Angeles' *Adaptive Reuse Program* — first set in 1999 as an ordinance to create new housing opportunities and encourage community development — understand the need for a case-by-case approach to make interventions feasible [9].

Public policies should be concerned about these processes and their specific nature. Unequivocal and operational criteria to evaluate and foster suitable conversions based on performance guidance should be established. Eventually, since all parameters related to embodied energy are measurable, reuse may be triggered by amortization targets that evaluate its variations — as proposed in Section 3 — always considering the original construction, its potential performance and its possible demolition and replacement along with the habitability provided, expressed in time. This exhaustive survey should offer clear results in favor of an adaptive reuse, although further research is visibly needed on this specific issue beyond the scope of this paper.

6. Conclusion and discussion

Considering architecture as a resource raises the question of how to take advantage of embodied energy. "The historic built environment represents a huge resource that can be conserved and made efficient for the twenty-first-century challenge of fossil fuel exhaustion" [4], and efficiency here is not only about energy performance but also about programmatic performance. Like all other resources, the built environment and all transformations undergone are of public interest and should be regulated by public policies to grant the proper use of the resource. A new rhetoric must arise on this basis. Above all, the reuse of existing buildings — a particular case of transformation — is an opportunity to reconsider this situation at the appropriate scale and with the adequate means.

The urban scale seems to be a convenient one because of its physical, legal and social continuity. Also, because it allows reuse to be legislated, can encourage this practice to happen coherently and provides a metabolic environment to understand converted buildings as part of a general system which tends to be sustainable in a comprehensive meaning of the word.

The adequate means refer to a protocol on reusing existing structures considering embodied energy as an operative tool to manage this scenario. Supported by some preliminary results of the ongoing research project Atlas of Architectural Reuse, this paper has focused on two complementary approaches to further develop as a protocol: re-programming and design strategies. The former considers the compatibility between the host building and new possible uses along with the ability of the program to adapt to diverse supports. The latter supports complementing rather than modifying the existing structure and adjusting the intervention to the requirements in terms of durability and reversibility. In this context, re-inhabiting converted buildings has been described as the framework to review critically how architecture is used, bringing the inviting definition of dynamic repairing developed by Sennett to the field of architecture to deal with the potential performance of buildings.

Furthermore, these adequate means also include a sort of amortization in architecture to evaluate and rate interventions of reuse, considering the balance between embodied energy of every building and its lifespan as a satisfier of habitability. In order to foster low impact transformations — with a minimum increase of energy and a maximum increment of habitability — the need and feasibility to establish amortization targets for all construction works should be debated and this paper wishes to pose the question under discussion.

Acknowledgements

This paper is made possible by the funding of the Spanish *Ministerio de Economía y Competitividad*, as part of a research project ongoing under the national R&D program "Retos Investigación / Research Challenges 2013".

References

[1] Yung, E. H. & Chan, E. H., 2012. Implementation Challenges to the Adaptive Reuse of Heritage Buildings. Towards the Goals of Sustainable, Low Carbon Cities. *Habitat international*, July, 36(3), pp. 352-361.
[2] Thomsen, A. & van der Flier, K., 2011. *Obsolescence, Conceptual Model and Proposal for Case Studies*. Toulouse, LISST, University of Toulouse-Le Mirail.
[3] Douglas, J., 2006. *Building Adaptation*. 2nd ed. Burlington: Butterworth-Heinemann.
[4] Jackson, M., 2005. Embodied Energy and Historic Preservation: A Needed Reassessment. *APT Bulletin*, 36(4), pp. 47-52.
[5] Dixit, M. K., Fernández-Solís, J. L., Lavy, S. & Culp, C. H., 2010. Identification of Parameters for Embodied Energy Measurement: A Literature Review. *Energy and Buildings*, August, 42(8), p. 1238–1247.
[6] Cole, R. J. & Kernan, P. C., 1996. Life-Cycle Energy Use in Office Buildings. *Building and Environment*, 31(4), pp. 307-317.
[7] Holtzhausen, H. J., 2007. Embodied Energy and its Impact on Architectural Decisions. *WIT Transactions on Ecology and the Environment*, Volume 102, pp. 377-385.
[8] Sennett, R., 2008. *The Craftsman*. New Haven & London: Yale University Press.
[9] Fuertes, P., 2014. Learning Through Repairing. In: *Cohousing. Programs and Projects to Recover Heritage Buildings*. Pisa: Edizioni ETS, pp. 36-39.
[10] Monteys, X. et al., 2012. *Rehabitar en Nueve Episodios*. 1st ed. Madrid: Lampreave.
[11] INE (Instituto Nacional de Estadística), 2001. *Censo de Población y Vivienda*. Madrid: Ministerio de Economía, Industria y Competitividad.
[12] Lacaton, A. & Vassal, J. P., 2011. La Libertad Estructural, Condición del Milagro. *2G*, Issue 60, pp. 162-171.
[13] Buckley, C., 2012. Never Demolish: Bois-le-Prêtre Regrows in Paris. *Log*, Winter/Spring (24), pp. 43-50.
[14] Druot, F., 2009. Not Tearing Down is a Strategy = Ne pas Démolir est une Stratégie. *AA (Architecture d'Aujourd'hui)*, Novembre (374), pp. 65-74.
[15] Lacaton, A., Vassal, J. P. & Druot, F., 2007. *Plus. La Vivienda Colectiva. Territorio de Excepción*. Barcelona: Gustavo Gili.
[16] Reyner Banham, P., 1965. A Clip-On Architecture. *Design Quarterly*, Issue 63, pp. 3-30.
[17] Cullen, J. M. et al., 2011. *Reducing Embodied Carbon through Efficient Design*, London: Olympic Delivery Authority.
[18] WCED (World Commission on Environment and Development), 1987. *Our Common Future*. Oxford: Oxford University Press.
[19] Sauquet Llonch, R. & Taskin, D., 2016. Atlas Reuse: Studying the Metabolic Evolution of Barcelona. *WIT Transactions on Ecology and The Environment*, Volume 204, pp. 211-221.