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THE SUSTAINABLE ADAPTATION OF EXISTING BUILDINGS THROUGH THE EMBODIED ENERGY ANALYSIS: THE CASE STUDY OF PARCO DORA SKATEPARK IN TURIN

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Abstract

This paper discusses and analyzes the embodied energy related to existing buildings throughout their adaptation interventions, advocating for the inclusion of the concept of 'retroactive embodied energy' within the preservation discourse. To illustrate this, the paper examines the case of the Parco Dora Skatepark adaptive reuse project in Turin, focusing on the flows of embodied energy between the original structure and its transformed state. The concept of embodied energy emerges as a valuable metric for integrated sustainability in existing buildings.

Keywords

embodied energy, buildings adaptation, material intensity, retroactive embodied energy, existing buildings.

Introduction

Assuming that the choice of preserving an object that has required the use of natural resources and energy is relevant in considering the framework of sustainability, the environmental impacts should be challenged in the preservation/adaptation discourse. In the Western context, the preservation argument has recently expanded to the reuse of existing buildings, regardless of their official heritage label as a function of embracing the sustainability agenda. (Elefante, 2012; Koolhaas *et al.*, 2014) Most studies on energy-related interventions on heritage focus on reducing operational energy use and underline the need for a deeper understanding of building heritage values should also consider energy as an added value. (Lidelöw *et al.*, 2019; Amini Toosi *et al.*, 2020; Hashempour, Taherkhani and Mahdikhani, 2020)

The revitalization and repurposing of existing buildings hold significant global importance. Within the European Agenda, the 11th goal among the 17 Sustainable Development Goals established by the United Nations General Assembly in 2015 focuses on "sustainable cities and communities."(Benjamin, 2017; Birgisdottir *et al.*, 2017; Guidetti and Ferrara, 2023)[1] Notably, within the SDG targets and indicators, target 11.4 aims to "Preserve the world's cultural and natural heritage," thus establishing a clear link between sustainability and the sustainable development of urban areas. In the European context, the refurbishment of both public and private structures is a pivotal measure highlighted in the European Green Deal. It plays a central role in enhancing energy efficiency within the sector and aligning with regulatory requirements.[2]

In this context, adaptive reuse, meant as "the process of reusing an obsolete and derelict building by changing its function and maximizing the reuse and retention of existing materials and structures" (Shahi *et al.*, 2020, p. 4), may play a crucial role in fostering the buildings' preservation and sustainable use of resources.
Several studies expound the process of assemblage of construction materials not just by classifying buildings according to their essential materials, but also by considering construction materials and the construction process as a storage of energy. (Benjamin, 2017; Birgisdottir *et al.*, 2017; Guidetti and Ferrara, 2023). This type of energy is termed "embodied energy".

Traditionally, the impact of embodied energy in the field of building adaptation is understudied, particularly the calculation of such energy in historical buildings. (Jackson, 2005; Fuertes, 2017) Embodied energy is part of the Life Cycle Assessment (LCA) framework, but research on the LCA subjects lacks an account of embodied energy in existing buildings, as the focus is on new projects rather than existing ones. (Guidetti and Ferrara, 2023)
The present paper proposes to examine the whole embodied energy (EE), including the EE already spent to build historical buildings in other words, it proposes a study in terms of "retroactive embodied energy" instead of the estimation of a predictive value during the design phase. (Guidetti, Ferrara 2023)
The retroactive embodied energy (EEex) means the approximate energy that has been already spent to collect, manufacture, assemble, transport and build.

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[1] See also: Horizon 2020, Getting Cultural Heritage Work, 2020. Available at https://ec.europa.eu/programmes/horizon2020/en/news/getting-cultural-heritage-work-europe. Accessed on 06/12/2022.

[2] RenovationWave EU. Available online at https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en Accessed on 25 February 2022.

Here EEex, it is meant as a proxy to analyze materials in adapted buildings and their impact across the evolution of form. This method evaluates this energy in two main stages: 1) the existing building and 2) the adaptive reuse intervention. In the latter stage, deconstructive and constructive actions will be equally taken into account.
Considering that each construction material has a diverse intensity value that represents the energy intensity required to transform it into constructive elements, and these intensity values are measured in MJ/kg or MJ/m3 of materials, the analysis here proposed applied the I-O simplified survey method. (Advisory Council on Historical Preservation, 1979) using the ICE database.(Hammond and Jones, 2006, 2011)

To do so, the paper will analyze one case of adaptation of an existing building through the lens of embodied energy, accounting for the variations in terms of embodied energy shift between the building as found and the building transformed after the adaptation process. The selected case is the Parco Dora Skatepark, one of the former Vitali's factories in Turin. The case is critically redrawn (Boesch, Lupini and Machado, 2019)

The outcome will lead to the conclusion that 1) embodied energy matters in terms of impact on environmental sustainability 2)the amount of energy loss in a deconstructive intervention during the adaptation process could be extremely high 3) the definition of existing buildings as a depot of energy and embodied carbon might affect decision-making choices.

Methodology and Methods: The retroactive embodied energy assessment

The leading methodology employed is the case study analysis to propose a novel method for investigating the transformation of existing buildings through the assessment of "retroactive embodied energy." (Guidetti and Ferrara, 2023) This perspective focuses on the materials that compose architectural forms and their evolution through adaptive reuse interventions. (Benjamin, 2017; Guidetti, 2022)

Existing methods for assessing embodied energy predominantly concentrate on new construction rather than interventions in existing buildings. Embodied energy is a component of the Life Cycle Assessment (LCA) framework. Research on LCA subjects often overlooks the consideration of embodied energy in existing buildings, as the primary emphasis lies on new projects. (Jackson, 2005; Fuertes, 2017; Guidetti and Ferrara, 2023)

The methodological approach to the case study integrates three methods:

1. Critical Redrawing: This involves outlining original elements and new additions in 3D[3], to outline the relationship between old and new and enabling dimensional and embodied energy calculations.
2. Calculation of Cubic Variations: This calculates the cubic variations in terms of structural material flows required to adapt an existing building.
3. Calculation of Embodied Energy: This calculates the embodied energy related to demolished, preserved, and added structural materials.(Advisory Council on Historical Preservation, 1979)

Specifically, the method, which measures embodied energy in MJ/m2 for both the original and new buildings provides insight into material-related energy flows and allows for comparisons between different interventions.

This calculation does have some limitations:

1. Site and Time Specificity: Energy intensity values are site-specific and time-specific.
2. Estimations: The quantities of materials used in the calculation are approximated from a 3D model and are therefore estimations.
3. Boundary: The calculation provides an approximate value for the embodied energy used in the adaptive reuse project, considering only the primary materials' production phase.

The survey model employed in this study is a reduced version of the Input-Output (I-O) method, simplified to consider structural elements only and assessing the Energy Investment in Materials (EIM). This simplification is due to several reasons: the structural system's fixed nature, its higher chances of preservation during adaptive reuse, and the fact that the structural system and envelope together contain a substantial portion of the building's initial embodied energy.

The embodied energy assessment considers EIM as denoted by the following formula:

EIM = 1.4 * Σ [Quantity of material * Invested Energy per material Unit]

In this formula, 1.4 is an adjustment coefficient, accounting for approximately 50% of the total embodied energy in building construction (Advisory Council on Historical Preservation, 1979)
The embodied energy evaluation related to construction materials follows the ICE database version 2.0 from 2011, where the embodied impact of materials (Invested

[3] The model is realized in vector 3D drawing. Starting from two-dimensional plan and section and being organized by main layers of structural materials.

Energy per material Unit) is expressed in MJ/kg. EIM values are converted to MJ/m3 to match the 3-D model unit measure.

The case of Vitali's sheds, Parco Dora, Turin

The former industrial area in the northern part of the city of Turin, along the Dora River, was transformed in 2011 into Parco Dora, a multifunctional park of about 456,000 m2, with the partial demolition of the previous industrial warehouses and infrastructure and with the integration, instead, into the new project of Michelin's cooling tower, the Vitali stripping station, and the thermic plant of FIAT steelworks. The adaptation project started in 2004 when the city of Turin launched an international competition for the design of a park for this large and dismissed area, the so-called “Spina 3”, won by the group directed by Peter Latz and consisting of Servizi Tecnologie Sistemi S.p.a., Latz + Partner, Studio Cappato, Gerd Pfarrè, Ugo Marano, Studio Pession Associato. The group designed a park that alternates natural areas with facilities, maintaining a solid relationship with the preexisting industrial elements, and repurposing them with new functions.[4]
The following analysis focuses on the former Vitali factory and, in particular, on the former stripping building.[5] Historically, the plant dates back to 1973, it was abandoned in 1992 and officially dismissed in 2001. However, the first plant dates back to 1920, and its history is much longer than this.
The plant, abandoned in 1992 and officially dismissed in 2001, was realized in 1973, although the original plant dates back to 1920 with an even earlier documented history. In 1973, the Vitali plant hosted the main steelworks of the Ferriere Fiat complex, covering a surface of about 90,000 m^2, in which ingots were produced for the semi-processed products required for the production of sheets, pipes and springs.

[4] See Comitato Parco Dora, Parco Dora, 2013.
Available at: http://www.comune.torino.it/comitatoparcodora/parco/. Accessed on 10/10/2021

[5] The action of “stripping” refers to the extraction of steel ingots from the mould in which they are produced, carried out by hydraulic pistons hitting the ingot mould.

Figure 1) View from South-West of former Vitali’s sheds 10 years after the adaptative reuse, designed by Latz and Partners, June 2021, Parco Dora, Turin

The factory was made up of two connected sheds placed side by side and arranged parallel to the axis of Corso Mortara. This building hosted different processing phases: furnaces, melting and stripping sectors were located. The area was highly polluted, remediation has been carried out, and the monitoring is still ongoing to maintain the levels of hexavalent chromium under the risk threshold.[6]
Latz's project removed the roof of the most significant part (23,500 m^2) of the steelworks and maintained three concrete settling tanks, a perimetral wall and the massive steel pillars (about 25 meters high).
The preserved roof is the smallest of the Vitali steelworks sheds, the “stripping” one, about 12,400 m^2 and 24 m high, which is named after the industrial procedure. On the other hand, the main shed (B), of which the high pillars have been preserved, has been transformed into a garden with flowerbeds, play areas, paths and a raised

[6] See the Offical Soil Pollution Report, Comune di Torino, Monitoraggi ambientali Spina 3, 2012-2021. Available at http://www.comune.torino.it/ambiente/news/monitoraggi-ambientali-spina-3.shtml.

walkway. The new elevated path connects the Vitali plot with the Ingest area, accessible by stairs and elevators in the former concrete towers.

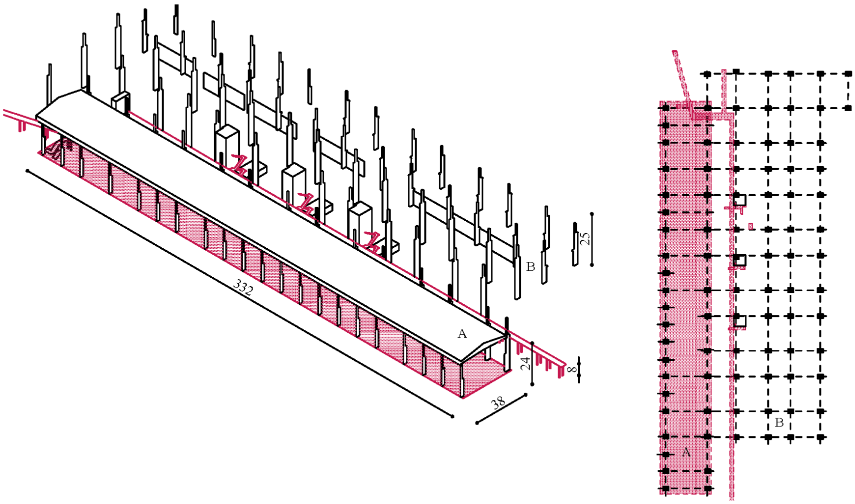

Figure 2) Vitali's sheds, Dora Park, critical redrawing, axonometric view and plan. In red the addition, in black the existing.

The former stripping building, now named Skatepark, is a canopy hosting a multifunctional space equipped with fields for free play and dedicated to hosting events and sports activities, with a skatepark among the others.[7] Among the various events, this space hosts international events, such as the Kappa Future Festival, which once a year attracts about 50,000 visitors to the site. Moreover, the end of Ramadan brings under the canopy about 30,000 people.[8] This site is being continuously transformed through minimal interventions and the last design project was

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[7] Comitato Parco Dora, Percorso n 3, Le Ferrerie, project Sharing, Caring and Learning Parco Dora, 2015, pp. 9-12. Accessed on 10/10/2021. Available at http://www.comune.torino.it/comitatoparcodora/bm~doc/parco-dora_percorsi_.pdf

[8] See more at https://www.kappafuturfestival.it/en/who-we-are/ and https://torino.repubblica.it/cronaca/2013/08/08/foto/la_fine_del_ramadan_festa_al_parco_dora-64480746/3/#9. Accessed on 09/09/2022.

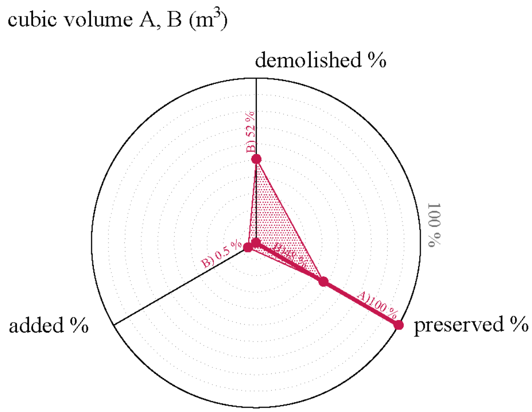
completed in August 2021, when the renovation of the former skatepark was inaugurated.[9]

Measuring the adaptive reuse intervention

Both buildings were mostly structurally stable, and thanks to the point elements structure, pillars are structurally independent of the buildings' skin. The steel structures have been cleaned and treated, yet their unpolished surface remarks their authenticity. Nature is grafted onto the steel structures, that were gradually colonized by climbing plants. The overall impression recalls an industrial thicket, where the preserved shed acts as a canopy covering this single large space. Dimensionally, the huge extension (23,500m^2 + 12,400 m^2) and the height of around 25 m allow diversified concurrent uses, including activities that require a large covered volume. Building A has been retained as a skeleton, a steel canopy supported by 35 pillars while Building B has retained only the pillars and reinforced concrete towers housing the stairwells. Additions are limited to the walkway approximately 130 meters long and two meters wide, connecting the preserved reinforced concrete blocks and re-supported between the remaining pillars. The remaining structure is a continuous open canopy on a rectangular base with a single aisle.
If only the stripping building (A) is considered, overlooking the interior demolition of partition and secondary elements and focusing instead on primary and structural materials, the cubic variations do not report any demolition and addition during the adaptation phase. Including the other building (B), only the pillars concrete towers and a few perimetral walls remain in place. In terms of material flows, in the skatepark building (A), approx. 2,972 m^3 of steel is still in place, considering the preexistence of pillars and roof. Besides, in the other Vitali's shed (B), more than 2,500 m^3 of steel has been dismantled, about 361 m^3 have been preserved, while 2,030 m^3 of reinforced concrete have been conserved too. Moreover, the new walkway and pillars impact with 25 m^3 of extra steel.
The former structure A's embodied energy is about 48,291 MJ/m^2, all conserved in place, while the EE of the main shed is now about 3,463 MJ/m^2, because of the 24,170

[9] Verde Pubblico, Città di Torino, *Nuove attrazzature a Parco Dora*, July 28th 2021. Available online at http://www.comune.torino.it/verdepubblico/parchi-e-giardini/nuove-attrezzature-sportive-nei-parchi-della-citta/. Accessed on 09/09/2021.

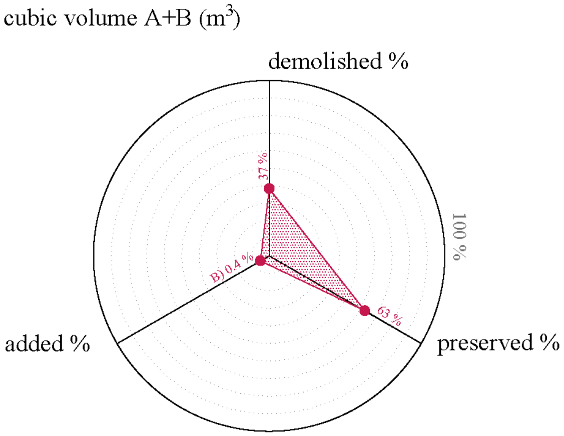
MJ/m² lost during the demolition process.[10] The additions in the former building B account for 236 MJ/m². Therefore, considering the whole former steel factory (A+B), the embodied energy related to materials is currently about 696,464,664 MJ (approx. 52,000 MJ/m²) and considering the addition, it is about 702,017,812 MJ (19,414 MJ/m²).[11]



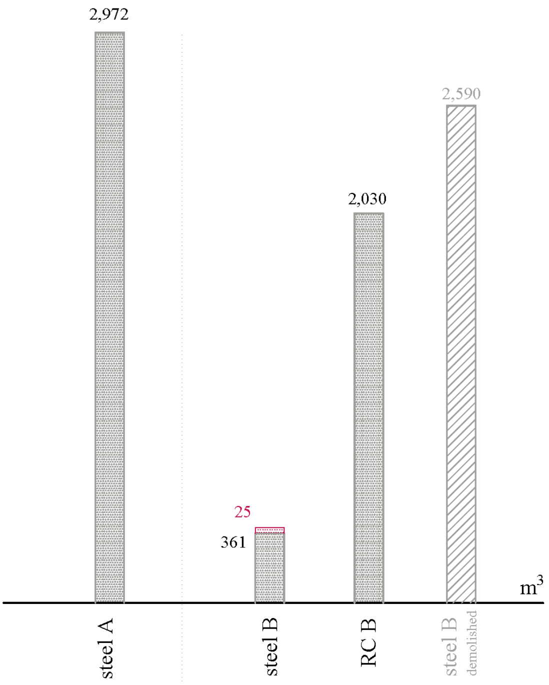
Graph 1) Vitali sheds, building A-B cubic variation of materials

[10] In terms of energy variation, it is not correct to talk about "energy loss" and the demolished material would not be included in LCA-based evaluation. Here, the term "lost energy" is employed to remark the impact of demolition concerning the energy embedded in the existing materials. However, dismantled materials are not accounted in the embodied energy calculation. See the section "Methods" in Chapter 2 for details.

[11] See *Annex* reporting calculations.



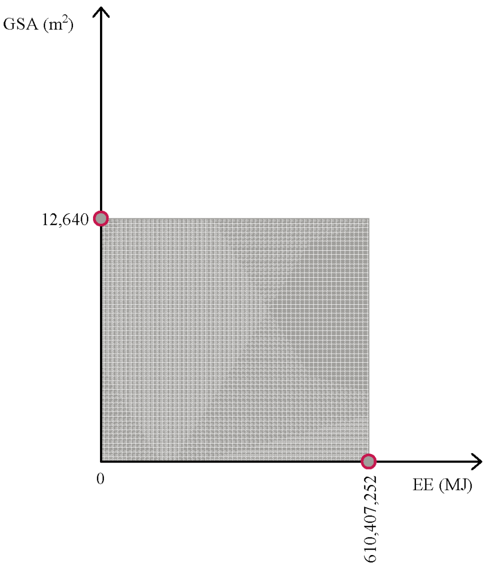
Graph 2) Vitali sheds, cubic variation in materials



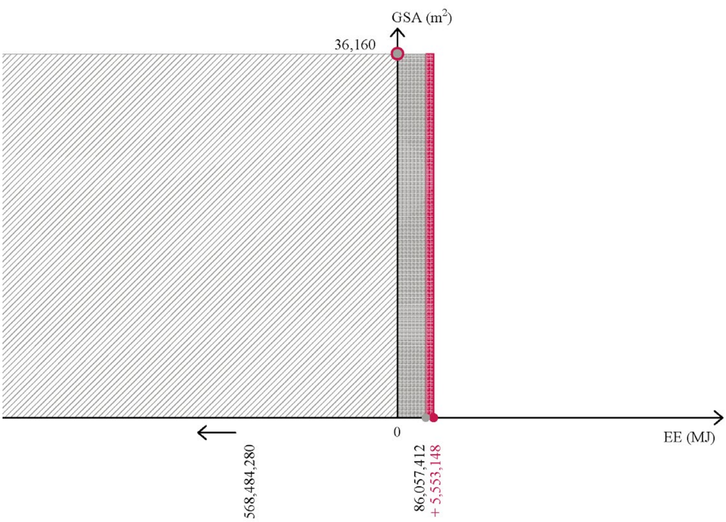
Graph 3) Vitali sheds (A, B) materials types and quantities

Discussions

In the intervention in Vitali's sheds deconstructive actions undertake constructive ones, both in spatial and material terms. Considering Building A only (See Graph 4) it is clear how the intervention may be considered a removal of material only.



Graph 4) Building A, Skatepark Parco Dora – former Vitali's stripping shed, embodied energy variations related to GSA



Graph 5) Building B, Vitali's shed demolished, embodied energy variations related to GSA

Looking at building B (see Graph 5) the addition gives a minimal contribution to the addition of new materials, even allowing an intense use of the space thanks to the new elevated path.
Even if, to understand the impact on the transformation of main construction materials and their relative impact in terms of sustainability of the approach, it is necessary to relate these quantities with the extensions (Gross Surface Area), the scale of this existing structure is relevant to assess the overall sustainability of the building itself. To give an estimation of these dimensions, it might be noted that the quantity of steel removed from Vitali's sheds is equivalent to the volume of an Olympic swimming pool[12], while the new steel elevated path has a volume analogous to 30 times the standard hot tub.
Vitali's sheds were crumbled, with water leaking inside and its outer skin partially destroyed, the dismantling was affecting obsolete elements.
Focusing on building A, the current skatepark.

In terms of retroactive embodied energy, Vitali's sheds originally had more than one billion MJ, considering the structure as found in 2004. Since then, more than two-thirds of steel has been dismantled, which means that the preserved existing energy is high, even if related to the large surface that the build overs. Considering both buildings embodied energy preserved is approx. 51,951 MJ/m^2 while the energy embedded in the new additions counts a relatively low value (236 MJ/m^2)
The former Vitali's shed, now a skate park and post-industrial thicket, currently embeds around 70 years' worth of electric energy for the houses in Rome.[13]

It is important to remark that such preserved structures, and even each demolition action (even if necessary), represent a partial waste of energy already in place. Retroactive embodied energy assessment might foster a better understanding of the environmental impact of preservation. (Jackson, 2005; Guidetti and Ferrara, 2023)
On the other side, the calculation of the features and amount of material requires an in-depth analysis of the building, fostering a better understanding qualitative and quantitative understanding of the building and its adaptation process.

[12] According to the Fédération Internationale de nation (FINA) it must measure 50 meters by 25 meters with a depth of at least 2 meters.

[13] Assuming the domestic use of electricity approx. 0.0135 GWh per day, it amounts to approx. 17.7 milion MJ per year. Source: Terna, "Dati Statistici sull'energia elettrica in Italia", Annuario Statistico, 2018.

Conclusions

Inscribing adaptive reuse in the framework of sustainability, construction materials employed in adaptive projects along with the original materials emerge as storages of non-recoverable energy. It is a fact that producing steel generally requires more energy than producing timber; therefore, it is relevant to perceive this energy as a part of the physical qualities of the material's nature.

The paper outlines three main conclusions: 1) the retroactive embodied energy matters in terms of impact on environmental sustainability; 2) the amount of energy loss in deconstructive intervention during the adaptation process could be extremely high 3) the definition of existing buildings as a depot of energy and embodied carbon might affect decision making choices.

In general, this paper highlights an attempt to overcome the gap between preservationist concern and environmental sustainability by considering "energy" as one of the features that might give strength to the overall value of existing buildings to foster their conservation.

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