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The Right to Comfort in Social Housing: Energy and Thermal Performances as Parameters of a Systemic Analysis

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Abstract: This paper proposes a critical analysis of the intervention, over time, in the housing estates built under the Improvement Plan for the city of Porto. This plan enabled the construction of a significant number of dwellings within a limited period of time, promoting a broad and impactful urban and social restructuring of the city in the mid-twentieth century. Several post-construction interventions over the last decades were important opportunities to improve the quality of life of the inhabitants and to enhance the energy performance of the buildings. However, these buildings are still subject to architectural and construction challenges in terms of 'energy poverty' and the adaptation of the domestic comfort parameters. Thus, this research analyses the intervention strategies used in these buildings and the constraints resulting from current legislation and funding conditions that significantly impact design decisions. The study points to significant changes in the implementation of measures to improve the state of buildings, becoming progressively more concerned with energy consumption and thermal comfort. The discussion also highlights the impact of current measures on the comfort of interior spaces, current problems, and alternative means of balancing energy and comfort. The relevance of this research lies in the joint analysis of the interventions and frequent efficiency and comfort problems as a motto to improve the implementation of future strategies in developing a more energetically balanced housing stock. The paper also aims to deconstruct the preconceptions often associated with interventions geared towards thermal comfort, especially in social housing.

Keywords: architecture; housing buildings; retrofitting; energy poverty; energy efficiency; thermal comfort

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1. Introduction

Human comfort in buildings depends on several factors, such as thermal comfort, humidity, ventilation, and lighting [1]. Thermal comfort, defined by the ISSO 7730 standard as a state of satisfaction with the environment temperature, is one of the main parameters regarding the direct influence on the energy consumption of buildings [2].

The significant impact of buildings' energy consumption on the climate crisis is a growing international concern. Buildings are responsible for 40% of European Union (EU) consumption and 36% of greenhouse gas emissions [3]. Furthermore, heating and cooling purposes account for 50% of energy consumption in Europe, and the residential sector is one of the main contributors [4] (p. 3).

Most residential buildings in the EU do not guarantee adequate thermal comfort levels due to several factors, such as lack of insulation, poor quality of windows, thermal bridging, high air infiltration, and poor heating and cooling systems [5]. The inadequate energy performance of buildings may also be associated with the increasing ageing and progressive degradation of buildings and the lack of specialised regulations in the respective construction phase [6] (pp. 1–2).

These factors contribute to the widespread scenario of energy poverty [7], defined as situations in which people cannot attain thermal comfort in their homes due to low

incomes, high energy costs, and/or the architectural and construction characteristics of buildings [8]. This problem is even more exacerbated in the social housing sector.

According to EUROSTAT statistics, 8% of the EU population were unable to keep their homes adequately warm by 2020 (around 35 million people) [9]. The same map indicates 17.5% of the population in this situation is in Portugal. The national census in 2021 [10] showed that 3% of the total conventional dwellings then-occupied as ordinary residence in Portugal was public property (0.8% central administration and 2.2% local administration). In Porto, this percentage scales to 14.1% (1.9% and 12.2%, respectively), making it the municipality where the weight of social housing is more representative in the context of the country.

The implementation of efficient renovation strategies in the housing sector can address energy poverty problems by improving inhabitants' quality of life and reducing energy consumption costs [3]. These strategies may also play an essential role in making Europe climate neutral by 2050.

The European Union and European Green Deal urge the implementation of a 'wave of renovation' in public and private buildings [11]. This strategy includes actions such as stricter regulations and standards on the energy performance of buildings, more incentives and accessible funding, and the production of more sustainable products and approaches in local communities [3]. The Energy Performance of Buildings Directive (EPBD) was created as a framework for energy performance strategies in European Union Member States [12]. This directive reinforces the importance of deep and assertive renovations for the decarbonisation and energy improvement of the existing building stock. The same document promotes the establishment of specific actions and measures for access to funding, namely for critical situations of energy precariousness and social housing contexts [12] (p. 2). In Portugal, financial support such as the *Vale Eficiência* [Efficiency Voucher] programme [13] or support for the implementation of Renewable Energy Communities and Collective Self-Consumption [14] have recently emerged as measures for energy transition. Some European funding also targeted social housing, highlighting the specific support of energy efficiency measures [15].

The reduction of global energy consumption depends largely on a significant change in the construction sector, which has led to the development of new constructive solutions for more efficient buildings. As far as intervention strategies are concerned, different methodologies focus on a variety of aspects: Ciardello et al. [16] have developed a multi-objective approach combining geometric variables and passive and active strategies; Ma et al.'s [17] methodology optimises the costs of rehabilitation; Capeluto and Ochoa [18] rely on a simulation-based method for façade rehabilitation systems; Serrano-Lanzarote et al. [19] analyse different scenarios with passive strategies for reducing the energy consumption of housing stock in Spain. In the specific context of social housing, studies with intervention proposals [20] and strategies for energy optimisation [21] are particularly noteworthy.

Several authors have already approached the issues of energy poverty and the improvement of efficiency and comfort in social housing in Portugal in different circumstances, mainly in the disciplinary areas of civil engineering [22,23] and social sciences [24]. Regarding the case studies, some studies are particularly noteworthy, such as those related to the characterisation of social housing [25], the social positioning of residents [26], the assessment of thermal comfort, and the definition of passive rehabilitation strategies based on the analysis of a neighbourhood [27] or set of guidelines for characterisation and diagnosis providing the basis for a decision support methodology for future interventions in public housing [28].

These studies and different approaches are essential tools for significant advances in the aforementioned issues and disciplinary areas. However, there is a dearth of studies geared towards the systematic and multidisciplinary evaluation of implemented interventions to optimise future strategies. Promoting the discussion of technical solutions to improve energy efficiency with architectural options and general integration in the social and local context is another relevant issue.

The present study analyses the interventions performed in the neighbourhoods built under the Improvement Plan for the city of Porto, including its respective extension. This analysis seeks to identify the strategies developed over time by the municipality to rehabilitate this housing stock, with a particular focus on measures mainly related to energy efficiency management and the improvement of thermal comfort. The complexity of these processes requires an overview of the context, actors, legislation, and funding to fully understand the results.

This research differs from the previous studies in its overview of the implemented actions in these case studies with the aim to identify the potentialities and limitations of the current strategies. The fact that energy efficiency and thermal comfort are examined as parameters of a systemic analysis of the interventions in these neighbourhoods should also be noted. This study aims to contribute to the future orientation of methodologies tailored to the complexity of these processes.

This study is part of the ongoing research undertaken at FAUP/CEAU. This research promotes an analysis of intervention strategies in housing heritage based on the relationship between energy performance and thermal comfort, considering the particularities of local and social contexts.

The structure of the present article includes the background and characterisation of case studies, the analysis of interventions, the discussion of results, and some conclusions and further challenges. The first section aims to understand the housing programmes in Portugal as a backdrop for the construction of these neighbourhoods, analysing the architectural and constructive characteristics of the buildings. This section also includes an essential framework for the intervention actions with a brief context of the stakeholders and main constraints associated with design issues, especially those related to thermal comfort.

The second part consists of the systematisation of interventions to understand the design strategies, mainly as far as improving the efficiency of the building and the comfort of the dwellings are concerned. Therefore, the analysis focuses on the levels of intervention in the envelope of the buildings according to the following parameters: external walls, window frame type, roofs, staircases, galleries/balconies, and drying spaces (original name for laundry care spaces).

The third section focuses on the results of analysing the intervention strategies, which includes a critical reflection of the current problems, the alternative means to improve energy efficiency and thermal comfort, and their constraints regarding a balance relation between preservation and transformation. The conclusions (fourth and last part) summarise the main results and integrate future challenges in the rehabilitation of these buildings.

2. Materials and Methods

This study focused on a restricted set of neighbourhoods built under the Improvement Plan for the city of Porto (Decree-Law 40616, 1956) and its subsequent extension (Decree-Law 47443, 1966), promoting a critical understanding of the municipality's interventions over time since their construction.

This research methodology includes the following phases: data collection, diagnosis, and interpretation of the analysis. The first phase consists of collecting the necessary elements for the literature review and characterisation of the case studies. The research begins with the reading and interpretation of a relevant set of bibliographical references for the definition of concepts and understanding of the central theme of the study (energy efficiency and thermal comfort in the context of social housing). By adopting the same process to understand the housing programmes under which the municipal stock in Porto evolved, it is possible to construct a framework for the case studies.

The analysis of the original projects (construction period) focuses on the drawings (plans, sections, elevations, and construction details), writings, and photographs available in the archives of Porto's Municipal Council and other elements compiled in the 'Mapping Public Housing' research project online database [29].

The information regarding the intervention actions, including architectural and constructive drawings, memoirs, and technical audits, were mainly provided by Domus Social E.M. However, the collection of this data encountered difficulties in terms of managing the stakeholders, from technicians to designers and the various archival sources. The creation of Domus Social E.M. in 2000 and the internal reorganisation of the municipal services in 2015 led to the compilation of dispersed information. In addition, this set includes neighbourhoods undergoing the intervention process (during the course of this research); hence, the material is constantly being updated. This study included some additional elements provided by the authors of the projects.

The first phase also involves visits to the buildings and photographic records of the neighbourhoods and urban surroundings.

The second phase comprises redesigning the graphic elements for a common interpretation of the case studies and drawing comparative details between the original project (built) and the current building (subject to intervention). The representations of the original project result from the articulation of several sources (documents, photos, and drawings with different levels of detail) in order to fill the information gap regarding this construction period. The analysis of the interventions is based on the final drawings (drawings delivered upon completion of the construction works) or on the last version of the execution project, later made compatible with the records of construction phases and site visits to ascertain potential changes to the project. This phase also includes a systematic record of the interventions (types and levels) for the subsequent definition of the analysis parameters and production of the supporting graphs and schedules.

The third phase analyses the results by defining the different phases understood within the framework of an articulated interpretation of the strategies, the various actors, and the regulatory and economic constraints.

2.1. Case Studies. Background and Characterisation

Understanding the significance, extent, and current state of the municipal dwellings built under the *Plano de Melhoramentos para a Cidade do Porto* [Improvement Plan for the city of Porto] from 1957 onwards requires a brief overview of the public development initiatives conducted in the city in order to contextualise the scale of this action within the municipal housing stock.

As in other European countries, the rise of housing shortages in Portugal evolved from the rural–urban exodus during the industrialisation period, where mass migration occurred during the second half of the nineteenth century, significantly increasing the resident population in the main urban centres of Lisbon and Porto. In Porto, the first solutions for housing needs were of a private nature and configured a local phenomenon referred to as *ilhas* (islands), occupying the backyards of middle-class houses (typically in narrow lots). This form of accommodation for low-income workers proliferated and became a focal point amid a surge in public health concerns [30–32]. At the end of the nineteenth century, almost 30% of the population in the city lived in these *ilhas*. Forty years later, the percentage of the population still living in these dwellings without satisfactory health conditions stood at around 20% [33] (p. 16). This percentage was circa 5% by 2014 [34] (p. 34).

Following the construction of a sparse set of neighbourhoods on municipal lands in Porto between 1899 and 1905 by a local newspaper for the low-income working population, from 1914 to 1917, the municipality of Porto promoted another four neighbourhoods for the working classes inspired by the former "colonies" experience of compact single-family houses with gardens. It was not until 1918 (Decree-Law 4137) [35], in the aftermath of the demise of the monarchy (Implantation of the Republic in 1910), that the government began to provide financial support for housing in order to meet republican concerns regarding housing needs. An ensuing experience of compact single-family houses with gardens in Porto fell far short of the quantitative needs being followed by other public developments after the coup in 1926 and subsequent implantation of the military dictatorship

(1926–1933) to the *Estado Novo* regime (1933–1974): several sets of semi-detached "single-family houses and yards" promoted in a rent-ownership scheme mainly in the peripheral areas of the city by the *Casas Económicas* [Affordable Houses] programme of 1933 (Decree-Law 23052) [36]. Recognising the housing needs of the least favoured populations [37] (p.81), the *Casas Desmontáveis* [Demountable Houses] (Decree-Law 28912) [38] and the *Casas para Famílias Pobres* [Houses for Poor Families] (Decree-Law 34486) [39] programmes were decreed in 1938 and 1945, respectively, still envisioning a temporary solution [28].

Based on a survey and inspections of the living conditions of the families to be re-housed in 1939 [40] in Porto, a municipal inventory in 1940 estimated that barely over a quarter of the almost 13,600 dwellings in the *ilhas* could be improved, while the remaining homes needed to be demolished and new houses would be built to replace them [37] (p. 82). A municipal campaign for 'sanitisation' was then initiated in a few *ilhas*, proving to be ineffective as it lacked "the necessary support to rehouse the population to be relocated" [40] (p. 8). In the meantime, the first collective housing for social renting promoted by the municipality in a central area of the city had begun construction in 1938 and would actually become "an exception in all the housing policies of the Estado Novo" as housing blocks would only reappear in the following decade, but not in the city centre [41] (p. 511). The next municipal initiatives were sets of single or two-family housing with one or two floors, grouped in semi-detached or terraced houses with yards in distant areas from the city centre. Legislation in 1945 (Law 2007) [42] established the *Casas de Renda Económica* [Affordable Rent Houses] programme, targeting the more disadvantaged classes and allowing four-floor buildings for social housing. Despite the limited number of dwellings produced, from 1940 to 1956, the municipal neighbourhoods in Porto gradually evolved from the single-house model to the low-sized collective building, exploring new concepts and urbanisation and building principles that would be crucial for the developments to come. In particular, social renting experiences of a compact-dwelling-typology in the first half of the 1950s substantiated the municipal option for "mid-rise multi-family housing buildings in peripheral urban areas, unveiling the municipal solution to the housing problem in the city of Porto: almost 1000 *ilhas* with 12,000 dwellings to "sanitise" in the oncoming 10 years" [28] (p. 57).

The 1956 Improvement Plan for the city of Porto (Decree-Law 40616) [43] triggered the construction of many of the existing housing neighbourhoods in the city, implementing the directives of the preceding *Plano de Salubrização das "ilhas" do Porto* [Sanitisation Plan] [40] under preparation by the municipality since the late 1930s. The 6,000 dwellings to be executed within a ten-year period were almost half of the existing housing units in the *ilhas* (families to be relocated and rehoused). The vacant dwellings were to be immediately demolished or radically transformed (re-housing part of the families in the original area) [44]. Since 1957, the number of municipal housing dwellings has increased significantly, as shown in Figure 1.

Having barely surpassed the estimated number of dwellings within the projected timeframe (1957–1966), this large-scale intervention relocated 15% to 20% of the population living in central areas to the peripheral "areas of expansion" [33] (p. 17) across 13 neighbourhoods (*Bom Sucesso*, *Pio XII*, *Carvalhido*, *Pasteleira*, *Outeiro*, *Agra do Amial*, *Carriçal*, *Fernão de Magalhães*, *São Roque da Lameira*, *Fonte da Moura*, *Cerco do Porto*, *Regado*, and *Campinas/Eng. Arantes e Oliveira*), two of which were built in central areas of the city. Part of *São Roque da Lameira* would be renamed (in homage to) *Eng. Machado Vaz*, while the original set of 13 neighbourhoods currently stands at 14 (Figure 2). The 5-year extension to the plan (Decree-Law 47443) [45] achieved over half of the estimated 3,000 dwellings in the projected timeframe (1967–1971) by building new developments and adding on new phases (*São João de Deus, Francos, Aldoar, Lordelo do Ouro and Monte da Bela (Corujeira)*). Nevertheless, some of the planned neighbourhoods were concluded after 1972, throughout the decade, following the same project type or presenting common constructive and architectural features (*Falcão*, *Dr. Nuno Pinheiro Torres*, *Lagarteiro*, *Bom Pastor*, *Aleixo* and *Contumil*). Thus, as already discussed [46], the present analysis considers the set of 11 neighbourhoods built by the

late 1970s as part of the Improvement Plan extension, following the research presented by Queirós [26,47]. Beyond the scope of this plan (or its extension), some of the neighbourhoods would be subject to further development (or phasing) during the 1980s and part of the 1990s [33] (p. 17).

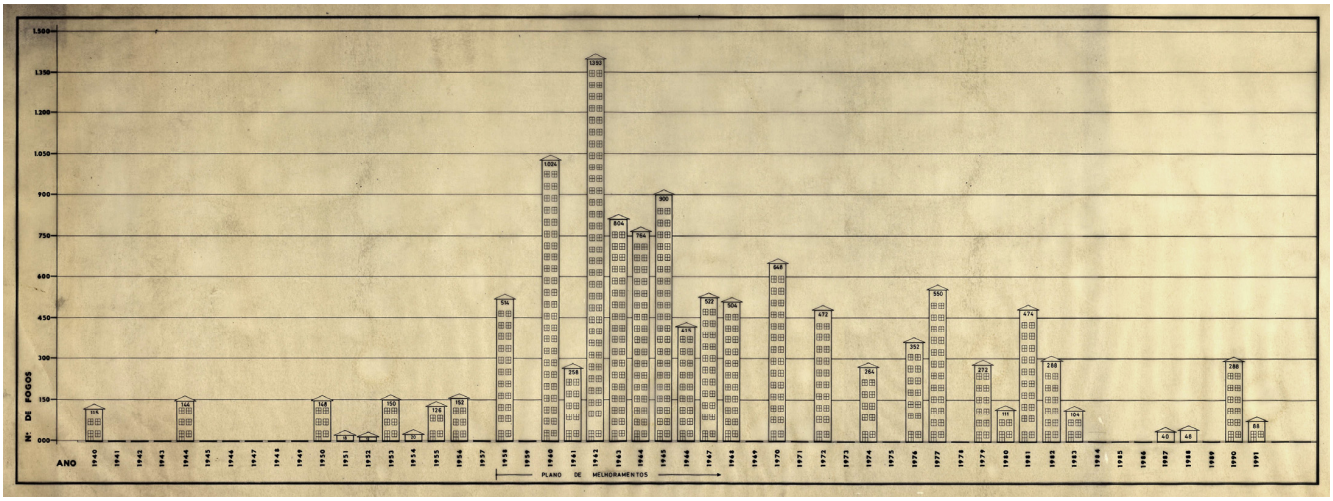
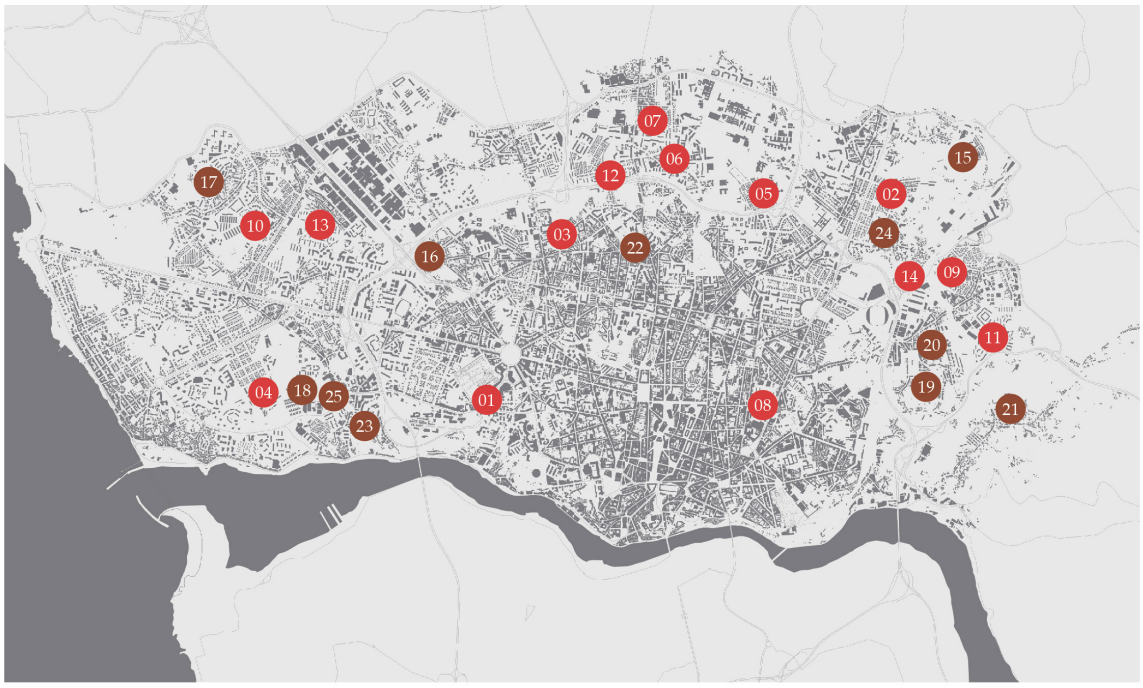


Figure 1. Number of municipal dwellings built in Porto per year between 1940 and 1991. The figure highlights the significant number of housing units during the *Plano de Melhoramentos* [Improvement Plan], especially after 1957. Reproduced with permission from: Câmara Municipal do Porto. Arquivo Histórico. Identifier: 638881.



Plano de Melhoramentos para a Cidade do Porto **(Decree-Law 40616, 1956)**
01. Bom Sucesso | 02. Pio XII | 03. Carvalhido | 04. Pasteleira | 05. Outeiro | 06. Agra do Amial | 07. Carriçal | 08. Fernão de Magalhães | 09. São Roque da Lameira | 10. Fonte da Moura | 11. Cerco do Porto | 12. Regado | 13. Campinas | 14. Eng. Machado Vaz

Plano de Melhoramentos para a Cidade do Porto **extension (Decree-Law 47443, 1966)**
15. São João de Deus | 16. Francos | 17. Aldoar | 18. Dr. Nuno Pinheiro Torres | 19. Monte da Bela | 20. Falcão | 21. Lagarteiro
22. Bom Pastor 23. Aleixo | 24. Contumil | 25. Lordelo do Ouro

Figure 2. Location of the neighbourhoods built under the PMP and its extension.

Unlike other state-subsidised housing developments, those built under the Improvement Plan (or its extension) for social rental are still public municipal property today, maintained and managed by the municipality for the population most in need. These neighbourhoods accommodate a significant part of the municipal dwellings in Porto, the city where the weight of social housing is most representative in the context of the country [10] (Figure 3).

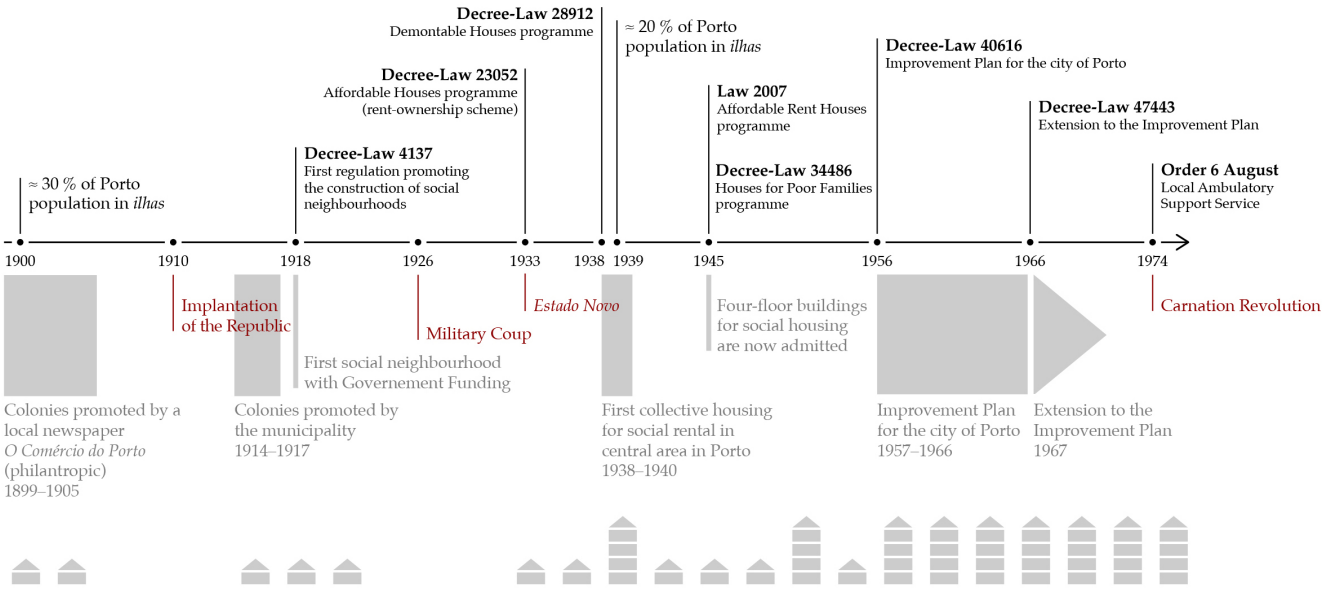


Figure 3. Chronological view of the public municipal housing initiatives in Porto in accordance with the main housing programmes.

Among the attempts to solve the housing problem, it is worth noting that the SAAL—*Serviço de Apoio Ambulatório Local* [Local Ambulatory Support Service] (Order of 6 August 1974) [48], arising from the first provisional government after the Portuguese revolution (25 April 1974), was soon abolished in 1976. Far from meeting expectations, this housing programme brought a new perspective by introducing a strongly participatory way of building housing for the most disadvantaged classes and populations to be rehoused in central areas of the city. This dynamic of 'continuity' (location vs. community) was itself a shift from the former social housing production logic, preceding what would become the cooperative housing statute created shortly afterwards. In the 1980s, a turnaround in the economic and social policies resulted in the state's disinvestment as a housing provider. Financial support was channelled to home-buying incentives, and public housing stock would not be expanded as much as in the previous decades.

2.1.1. Improvement Plan: Architectural and Construction Characterisation

Given the ambitious initial target, the "building conception had to be highly optimised regarding the global cost/total number of dwellings ratio, for which site plan strategies and local traditional construction methods were also recommended" [49], making the image of the sets quite recognizable. Information on the dwelling types and distributive schemes of the elected compact four-storey building typology may be found in a commemorative catalogue dating back to 1966 [44]. The rent affordability and the minimum number of dwellings within the projected timeframe "justified the reduced areas and restraint in construction costs" [49]. A further analysis of the dwellings' limited area in terms of current standards and applicable provisions may be found in the doctoral research of Restivo [28].

Despite some prior municipal housing experiences involving buildings with a reticular structure in reinforced concrete, they were not representative of the construction practices of that time in the city. In order to ensure the "rigorous economic conditions to achieve the

controlled rent aim" [43] (p. 632), the building conception was based on local tradition-bound constructive principles, performing mainly a hybrid system consisting of a perimeter wall made of stone granite supported by a continuous foundation, combined with concrete interior pillars built upon isolated foundations, and the floor slabs in lightweight reinforced concrete, as well as the galleries and semi-exterior staircases floors (Figure 4). As previously discussed [46,50], the roofs were mainly made of ceramic tiles (with no sub-tiles) supported by a wooden structure. As floor covering, the materials most used were wooden boards placed on battens and cement screed. The simple perimeter walls in stone granite, above the unclad base, were plastered and painted.

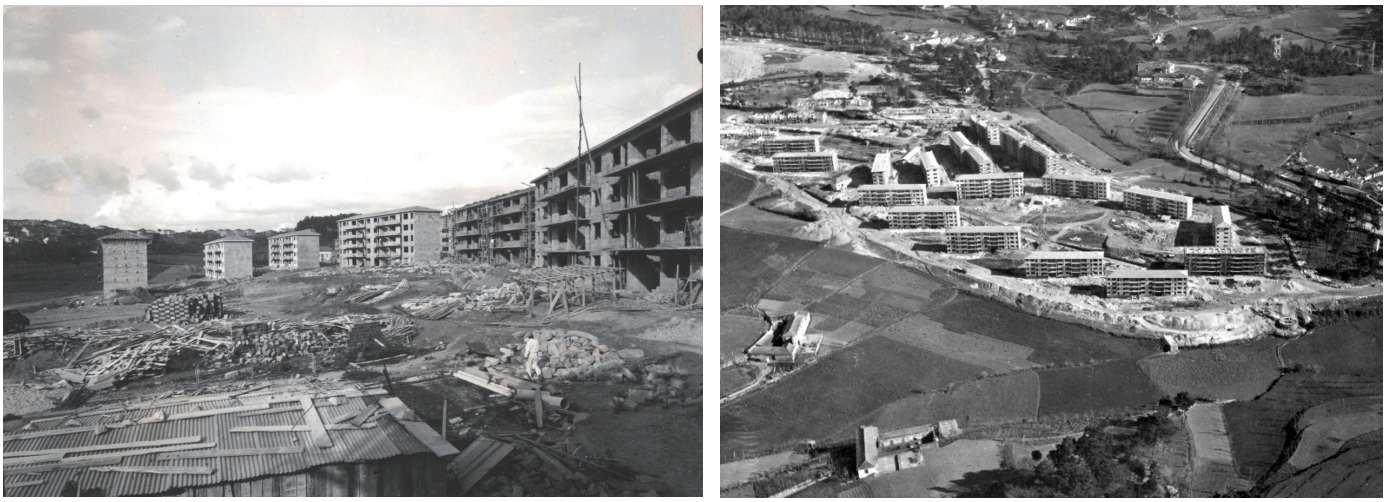


Figure 4. Cerco do Porto neighbourhood under construction, 1961. Reproduced with permission from: Câmara Municipal do Porto. Arquivo Histórico. Identifiers: 614667 (**left**); 849716 (**right**).

Regarding the set of 11 neighbourhoods considered part of the Improvement Plan extension, the first examples followed the principles of the first phase: a hybrid system consisting of a granite perimeter base and a reinforced concrete structure (pillars and beams), lightweight slabs, and ceramic tile roofing supported by a wooden frame. Nevertheless, other examples from this phase show there was some degree of variation by introducing particular constructive features that also correspond to a different architectural language of the buildings. In addition to a slightly larger area of the dwellings, the buildings also present a wider range of typologies (e.g., in the number of bedrooms), unveiling an overall *upgrade* of the construction through a continuous process of experimentation in the design of the buildings.

Constructively, "the structure of the buildings progressively adopted a porticoed system consisting of a grid of pillars (perimeter and interior) set on isolated foundations and reinforced concrete beams". This system, in most cases, "was also often reinforced with resistant concrete cores or stone granite walls built on continuous foundations in the staircase area" [46] (p. 574). The façades adopted a double-walled system without any intermediate insulation, the inner wall being made of hollow bricks and the outer wall varying in its composition—solid ceramic brick (the most common solution), lightweight aggregate concrete blocks, fibre-cement panels, or stone masonry—with exposed concrete used on both balconies and stairwells or as floor slabs. The roofs also presented a distinct structure consisting of prefabricated joists made of pre-stressed concrete, although they maintained the ceramic tile as their predominant covering material. Some cases also included fibre-cement panels on the roof with the same structure of prefabricated joists. For further analysis on the constructive features of these housing ensembles see Rocha and Póvoas [46].

2.1.2. Funding Programmes for Public Housing Rehabilitation: Stakeholders and Constraints

The *Programa Especial de Realojamento*—PER [Special Re-housing Programme], decreed in 1993 (Decree-Law 163/93) [51], was a renewed attempt to abolish precarious housing situations, providing for the construction of controlled-cost housing in the Metropolitan Areas of Lisbon and Porto. Around 1,000 dwellings were then built in Porto, occupying urban voids with smaller developments than those built in the previous decades. This number was increased with more than 350 dwellings following an amendment to the diploma in 2003 (Decree-Law 271/2003) [52] that created the possibility of funding for the refurbishment of vacant municipal dwellings "by favouring and stimulating housing dwellings' maintenance and reconstruction" [52] (p. 7182).

Regarding the requalification strategies for municipal housing in the city, up until the 1990s, there were "no conservation and maintenance programmes for the buildings in terms of quality or quantity" [33] (p. 18). The housing stock promoted by the municipality, publicly owned and managed, thus became highly degraded, no longer presenting satisfactory quality levels and not complying with many of the regulations and requirements for quality and safety in construction at that time.

In 2000, the municipality of Porto created a local company, *CMPH—Domus Social—Empresa de Habitação e Manutenção do Município do Porto, EM* [Housing and Maintenance Company of the Municipality of Porto]—to manage social housing (circa 12,500 dwellings across 48 neighbourhoods). This company was also entrusted with maintaining the municipal housing stock, as well as other public facilities and infrastructures in the city.

It was through the *Programa de Financiamento para Acesso à Habitação*—PROHABITA [Funding Programme for Access to Housing] (Decree-Law 135/2004) [53] in 2004, that the municipality implemented a more systematic rehabilitation of the housing stock from previous decades, covering around 6,500 municipal dwellings [49]. During this period, the design projects, initially undertaken by the municipal company, were mostly developed by external teams contracted for each case, which went on to become the standard procedure. The interventions were mainly geared towards the buildings' envelope and common circulation area—i.e., partial refurbishment [28]. In a few cases, the public space was also improved. Beyond these overall interventions, the dwellings' interior space is updated and refurbished (occasional interventions) over time whenever tenants move out, representing a continuous effort and financial investment on the part of the municipality.

A new round of interventions was framed by the subsequent and ongoing programme entitled *Reabilitar para Arrendar* [Rehabilitate to Rent] [54], after the organic law of the *Instituto da Habitação e da Reabilitação Urbana*—IHRU [Institute for Housing and Urban Rehabilitation] (Decree-Law 175/2012) [55], gradually covering all the municipal housing stock. The neighbourhoods to receive the first interventions are currently undergoing another partial refurbishment (Figure 5). With this milestone achieved, the municipality is now tackling a more systematic intervention on the public space, aiming at a more effective regeneration of those areas [56].

In line with previous contributions for a strategic plan for housing developed between 2008 and 2013 [57–59], an *Estratégia Nacional de Habitação*—ENH [National Strategy for Housing] was created in 2015 (Council of Ministers Resolution 48/2015) [60]. A strategic vision and objectives and action tools for a *Nova Geração de Políticas de Habitação*—NGPH [New Generation of Housing Policies in Portugal] were approved in 2018 (Council of Ministers Resolution 50-A/2018) [61], proposing an integrated approach to housing policies based on two priority objectives: to guarantee access to an adequate home for all (targeting the people), and to create conditions for rehabilitation to become the main form of intervention. Since then, with a view to tackling the current housing crisis in Portugal, a legislative package with several diplomas—action tools (programmes)—has been published, the main one entitled *1º Direito—Programa de Apoio ao Acesso à Habitação* [First Right—Programme to Support Access to Housing] [62,63]. The elaboration of an *Estratégia Local de Habitação*—ELH [Local Housing Strategy] is an eligibility requirement of

this programme, which was fulfilled for the city of Porto in 2019 [64]. At that time, the promulgation of the *Lei de Bases da Habitação* [Basic Housing Law] (Law No. 83/2019) [65] was "also a reaction to the shortage of affordable housing solutions, addressing the need to guarantee the role of social housing and to promote its access through rents based on the specific incomes of families" [66] (p. 231). This last action envisages the creation of a *Carta Municipal de Habitação* [Municipal Charter for Housing], which is currently being prepared by the Municipality of Porto.

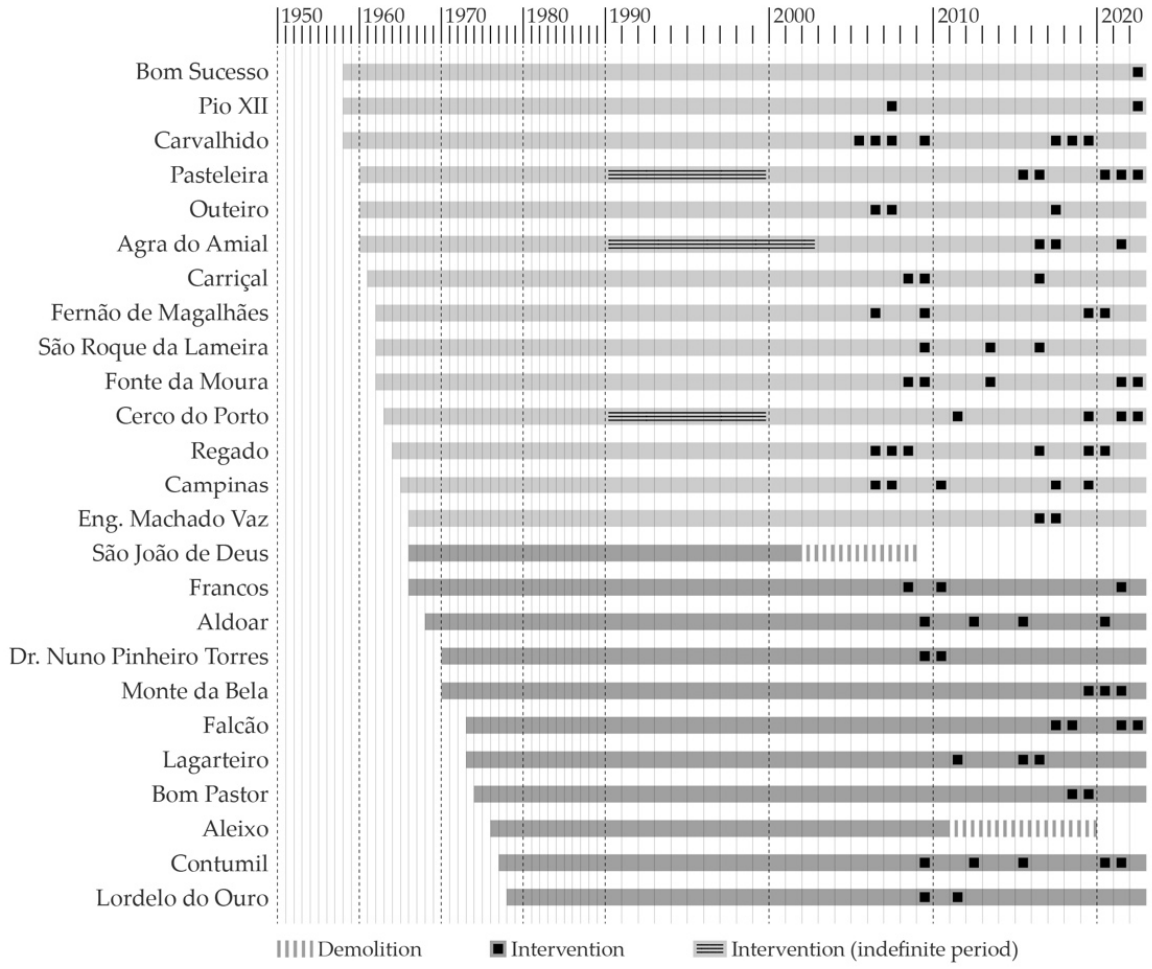


Figure 5. Intervention actions in the neighbourhoods built under the Improvement Plan and subsequent extension period.

2.1.3. Portuguese Legal Framework Regarding the Thermal Performance of Buildings

The first legal basis for establishing thermal comfort conditions and energy requirements in buildings was the Thermal Performance Building Regulation (RCCTE), approved by Decree-Law 40/90 [67]. The subsequent reformulation of this document by Decree-Law 80/2006 [68] partially transposes the European Directive 2002/91/EC. This directive also gave rise to the Energy and Indoor Air Quality Certification System for Buildings (SCE) with the publication of Decree-Law 78/2006 [69].

The Buildings Energy Certification System (SCE) approval by law is the result of Decree-Law 118/2013 [70], following the revision of Directive 2010/31/EU. This regulation has successive amendments and was recently renewed by Decree-Law 101-D/2020 [71] as a result of Directive 2018/844/EU (Figure 6).

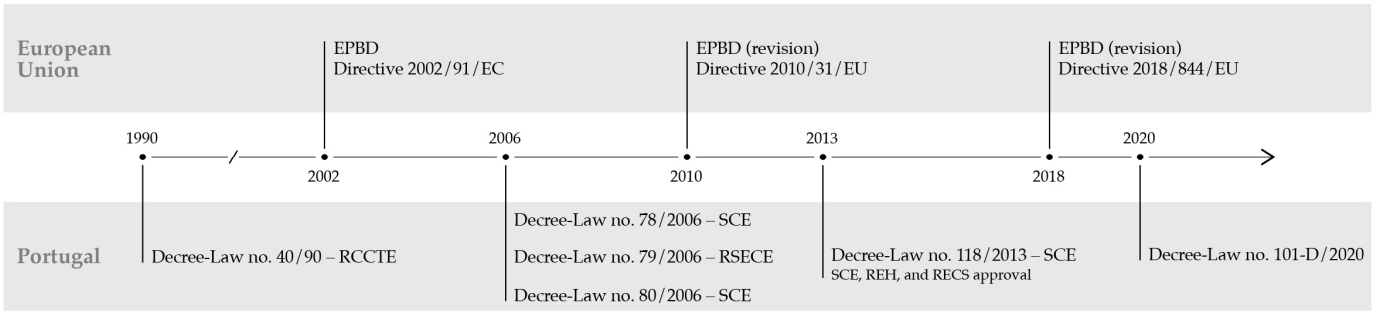


Figure 6. Chronological view of the legal framework. Adapted from: https://www.sce.pt/legislacao/ (accessed on 17 February 2023).

The SCE stands as a tool for assessing and evaluating the energy performance of buildings managed by the Agency for Energy (ADENE). The certificate thus measures the energy efficiency of properties with a scaling system from F (very poorly efficient) to A+ (very efficient), issued by a Qualified Expert [72]. This document includes data on the characteristics that influence energy consumption and recommends improvement measures.

According to the legislation, all buildings, new or subject to significant interventions, must obtain an Energy Certificate [70] (art.3, p. 1) [71] (art.18). Though urbanistic operations in the municipal housing stock are exempted from municipal licencing or authorisation [73] (art.7), a non-binding opinion is requested. Some neighbourhoods have been submitted to audits (e.g., *Monte da Bela*), energy evaluation reports (e.g., *Falcão*), or studies on hygrothermal behaviour (e.g., *Cerco do Porto*).

3. Analysis of the Intervention Strategies

The analysis of the interventions in these neighbourhoods derives from the actions undertaken to specific elements (parameters) according to different levels: external walls (new painting, new coating, addition of external thermal insulation, new wall composition); window frame type (single-glazing, double-glazing, double-glazing and a thermal break); roofs (new coating; new coating and thermal insulation; new coating and structure; new coating, thermal insulation, and structure); stairwells (access control, single-glazing, double-glazing, or double-glazing with a thermal break); galleries/balconies (roof addition, single-glazing, double-glazing, or double-glazing with a thermal break); and drying rooms (single-glazing, double-glazing, or double-glazing with a thermal break) (Figure 7). The data also include ventilation grids, outdoor clotheslines, solar panels, and other thermal insulation measures as relevant elements for the analysis. These parameters stem from the systematic recording of the interventions identified in the case studies and the organisation of these actions according to shared variables (levels). The parameters thus include various levels of intervention on the elements of the exterior envelope of the buildings for an in-depth analysis of the multiple strategies within the scope of a common logic.

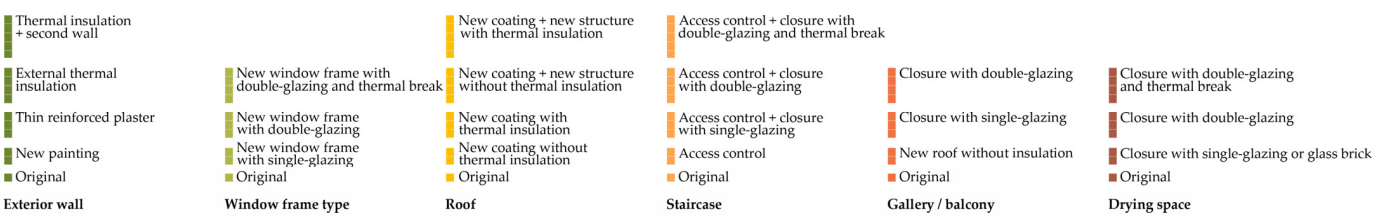


Figure 7. Analysis parameters according to intervention levels.

The following three phases result from crossing these data records with the previous context of the neighbourhoods and the complexity of public housing management and rehabilitation processes.

3.1. First Interventions

The first interventions in the neighbourhoods of the Improvement Plan occurred in the late 1990s during the period of the Special Rehousing Plan in the Metropolitan Areas of Lisbon and Porto (PER, Decree-Law 163/93). This phase is noteworthy for the actions related to security (access control) and occasional repair and maintenance interventions. Another relevant step consists of closing the galleries as a formalisation of processes previously initiated by the inhabitants. This period was characterised by the interventions in *Pasteleira*, *Agra do Amial*, and *Cerco do Porto* neighbourhoods (Figure 8).

Figure 8. *Cerco do Porto* before (**left**) and after (**right**) the first intervention. Reproduced with permission from: Virgínio Moutinho, architecture office archive.

In the external envelope, the treatment of walls with plaster and/or painting and the closure of entrances with access control to the buildings are prevalent. The changes in the window frames correspond to replacements of wood with aluminium with single-glazing (*Cerco do Porto* and *Amial*). In the neighbourhoods of *Pasteleira* and *Agra do Amial*, the closure of galleries (buildings with gallery access) and balconies (buildings with vertical access) is notable, whereby in the latter, the closure of stairs (buildings with vertical access) and drying rooms (buildings with gallery access) is also observed.

The first intervention in the *Cerco do Porto* neighbourhood is noteworthy for a broader strategy, extended to the rehabilitation of public space and the creation of new facilities. This intervention by architect Virgínio Moutinho (integrated into the European Urban programme and developed by the *Fundação para o Desenvolvimento do Vale de Campanhã*) sought to minimise the problems related to the advanced state of degradation of the buildings and surrounding areas and to solve the lack of collective spaces. The project thus articulates the rehabilitation of public space, the creation of new facilities, and partial interventions on the buildings [46] (Figure 9).

The interventions focused on building envelope differences by preserving the open galleries, albeit with solutions for the closure of balconies and drying spaces, in a logic of systematisation of the actions already executed randomly [74]. The remaining actions include painting, roof repair, and the replacement of window frames. Another distinctive feature of this intervention consists of using bright colours and applying handmade tile panels on the buildings' gables, coproduced by the artist Elvira Leite with the local children, which, according to the author, seek to break away from the past and promote the buildings' individualisation [74].

Thus, this first intervention phase brings together a set of actions at controlled costs and with minimal concerns regarding energy issues (Figure 10).

Figure 9. General plan of the first intervention on the *Cerco do Porto* with the new facilities marked: 1. School; 2. Activity centre; 3. Market; 4. Square; 5. Sports complex; 6. Open-air amphitheatre; 7. Extreme sports area; 8. Climbing wall; 9. Plaza—Café and pergola; 10. Kiosk; 11. Children's playground. Reproduced with permission from: Virgínio Moutinho, architecture office archive.

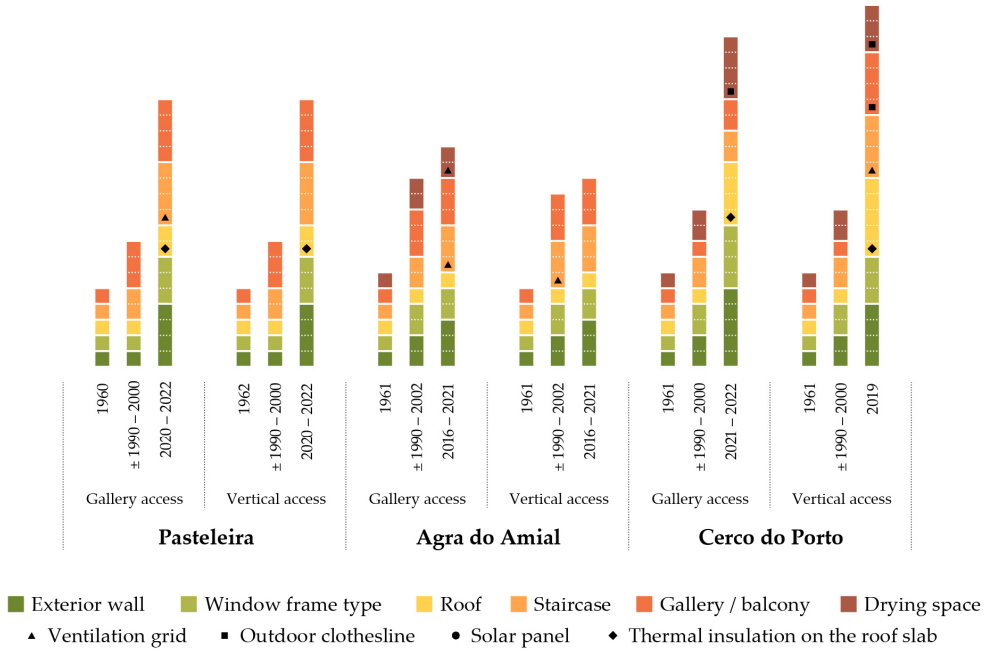


Figure 10. First phase of interventions according to the analysis parameters.

3.2. Experimentation and Strategy Consolidation

The constitution of Domus Social E.M. (2000) and the creation of the Funding Programme for Access to Housing (PROHABITA, Decree-Law 135/2004 of 3 June) [53] coincide with the second phase of interventions in the neighbourhoods under the Improvement Plan (Figure 11). A period of experimentation and subsequent strategy consolidation characterise this phase. In the first period, two types (A and B) with distinct strategies can be identified, mainly in actions on walls, window frames, stairs, and galleries. Type A excels by placing thermal insulation on the outside of the external walls (ETICS—External Thermal Insulation Composite System) and preserving the open stairs and galleries and the original window frames, as seen in the interventions performed in the *Fernão de Magalhães* neighbourhood in 2006 and 2009. The actions in this neighbourhood also include closing the drying spaces in buildings with gallery access.

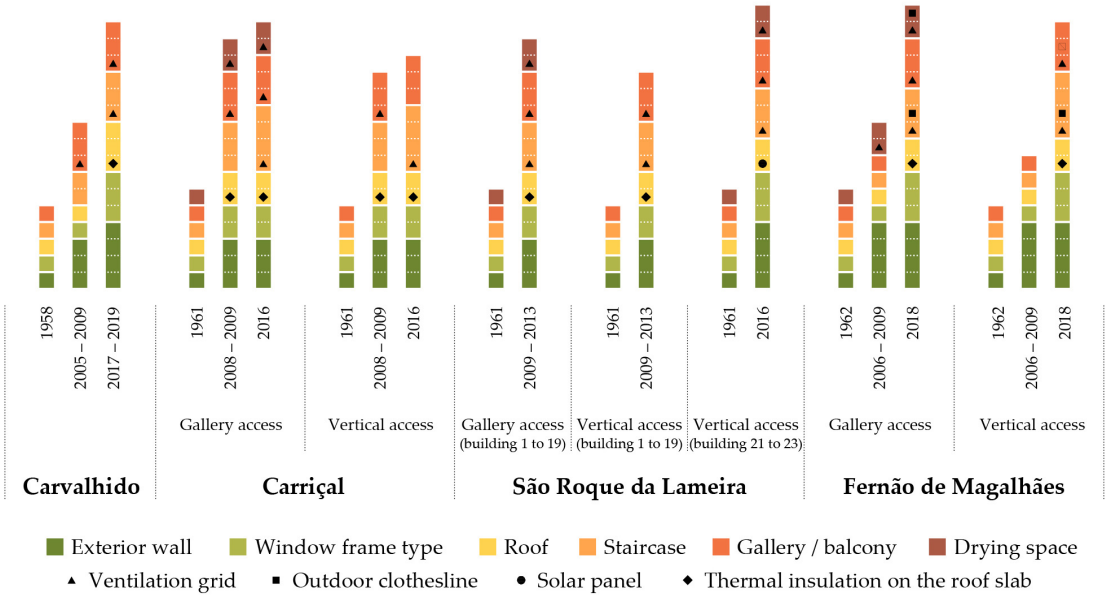


Figure 11. Second phase of interventions according to the analysis parameters.

Type B is distinguished by the application of thin reinforced plaster on the walls, gallery closure, and access control to the buildings, based on a similar rationale to the first phase (3.1). These actions are identified in the *Carvalhido* neighbourhood in the interventions between 2005 and 2009, which also excel in preserving the original window frames (Figure 12).

Figure 12. *Carvalhido* neighbourhood as an example of type B interventions. Original state (**left**, reproduced with permission from: Câmara Municipal do Porto. Arquivo Histórico. Identifier: 363947). After intervention (2005–2009) (**right**).

While type A had no continuity due to implementation difficulties, type B was the basis for developing a more consolidated strategy, following the model identified in the *Carriçal* neighbourhood (2008–2009) and applied in other neighbourhoods such as *Fonte da Moura*, *Dr. Nuno Pinheiro Torres*, and *Francos*. The actions undertaken in the *Carriçal* include the application of thin reinforced plaster on the outer walls; replacing wooden window frames with aluminium with single-glazing, access control, and closure of galleries

and stairs; and the closure of the drying spaces (buildings with gallery access). Another significant action of this strategy was a more conscious integration of ventilation grids.

The complexity and extension of these processes have resulted in several experiences and frequent strategy changes. Therefore, variations and sets of buildings with different interventions can be identified, such as the *Aldoar* or *São Roque da Lameira* neighbourhoods. As an example, the first actions in *São Roque da Lameira* (2009 and 2013) followed the consolidated strategy, while the most recent intervention (2016) differed by returning to thermal insulation outside the walls. However, the latter now also includes the application of aluminium window frames with double-glazing, access control, closure of galleries and stairs, and application of sub-tile under the ceramic tile roof. This intervention is also noteworthy for the application of solar panels on the roof, in a clear transition to a new phase and a paradigm shift.

The PROHABITA programme also fostered the development of small-scale interventions inside the dwellings, especially in kitchens and bathrooms, in vacant houses or in tenant changeover situations. However, the main actions of this second phase only minimise the critical shortcomings of domestic comfort and thermal discomfort.

3.3. Paradigm Shift

The third phase of interventions reveals significant changes in the management of these housing complexes, arising after the creation of the organic law of the IHRU (Institute for Housing and Urban Rehabilitation, Decree-Law 175/2012) [55] and the *Reabilitar para Arrendar—Habitação Acessível* [Rehabilitate to Rent—Affordable Housing programme] [54] dedicated to intervention processes for affordable rents. These changes reflect current energy consumption concerns (energy efficiency and thermal comfort) but also greater appreciation of these neighbourhoods' architectural and urban values. Actions such as the continuous application of thermal insulation to exterior walls and uppermost floor slabs, double-glazed window frames, and solar thermal panels on the roof for heating domestic water characterise the third phase. However, this stage is also salient for the development of different strategies according to the characteristics (architectural and construction) and particularities (state of conservation and needs) of each neighbourhood (Figure 13).

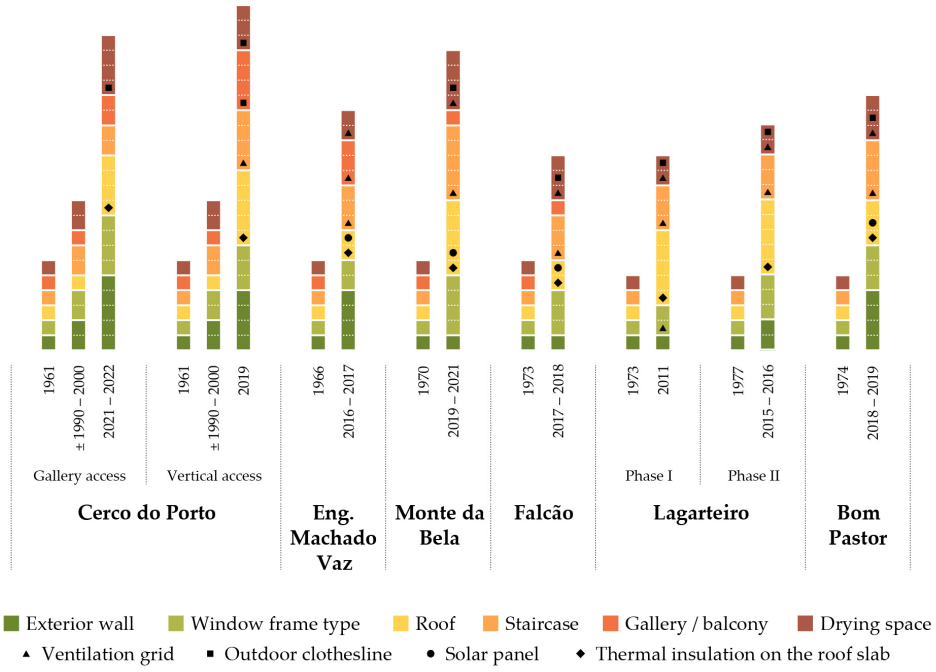


Figure 13. Third phase of interventions according to the analysis parameters.

The intervention in the *Eng. Machado Vaz* neighbourhood (2016–2017, execution phase), by architect Nuno Abrantes, represents the strategy frequently used in neighbourhoods built with stone granite walls. The solution involves applying an ETICS system—thin synthetic coating on expanded polystyrene thermal insulation—over the walls, preserving the original granite base. The intervention also includes replacing the exterior windows (new aluminium frames, single-glazed, without a thermal break) and closing balconies, drying rooms, and staircases (single-glazed and ventilation grids). As in the *Lordelo do Ouro* intervention, this action pays particular attention to ventilation by installing devices in the windows beside the kitchen exhaust ducts. The interventions on the tiled roof include the application of sub-tiles, thermal insulation in the uppermost slab, and the placement of solar thermal panels [75] (pp. 5–6) [76] (Figure 14).

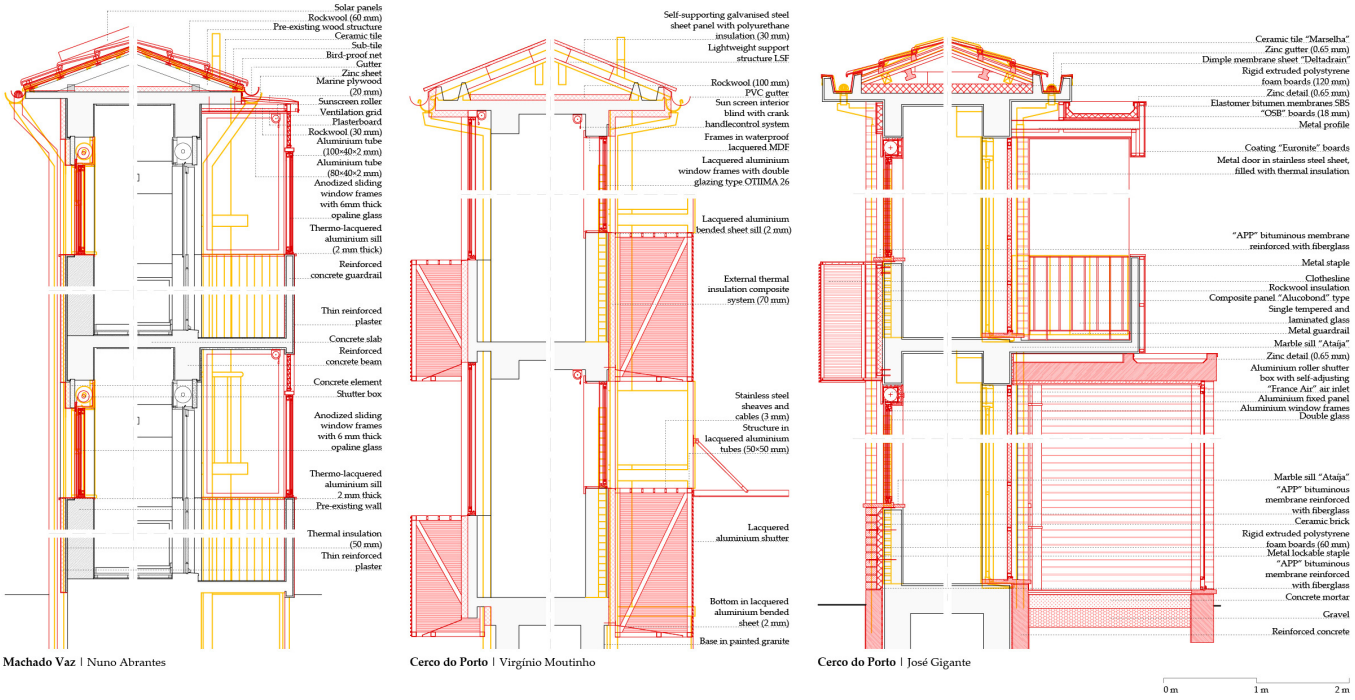


Figure 14. Constructive details of interventions in the *Machado Vaz* (**left**) and *Cerco do Porto* neighbourhood ((**middle**) by Virgínio Moutinho and (**right**) by José Gigante). Additions in red and demolitions in yellow.

The intervention in the *Cerco do Porto* neighbourhood, in buildings with multiple vertical access by architect Virgínio Moutinho (2019), reveals a similar strategy. The main differences lie in the choice of new aluminium frames with double-glazing and in the general alteration of the roof with a galvanised steel sheet coating, polyurethane insulation, and a new support structure, but without solar panels. This intervention is also noteworthy for the creation of outdoor clothesline spaces with a tubular structure, which has particular relevance in the architectural language of the buildings [77,78] (Figure 14).

The project for the buildings with gallery access in the same neighbourhood, by architect José Gigante (2021–2022), ending construction, presents an alternative strategy for the wall structure in stone granite. The intervention involves the construction of a new external ceramic brick panel and the application of thermal insulation in the intermediate air gap. This double-wall composition gives rise to a new architectural language of these buildings, further intensified by the formalisation of the volumes on the ground floor previously initiated by the inhabitants. This project also ensures the application of new external aluminium window frames, with double-glazing and a thermal break, which also close the drying rooms, as well as a metallic support structure for laundry care (outdoor clothesline). However, the project differs in the preservation of the open galleries. The

actions on the roof include the rehabilitation of the ceramic tile over a new structure and adding insulation in the uppermost slab [77,79] (Figure 15).

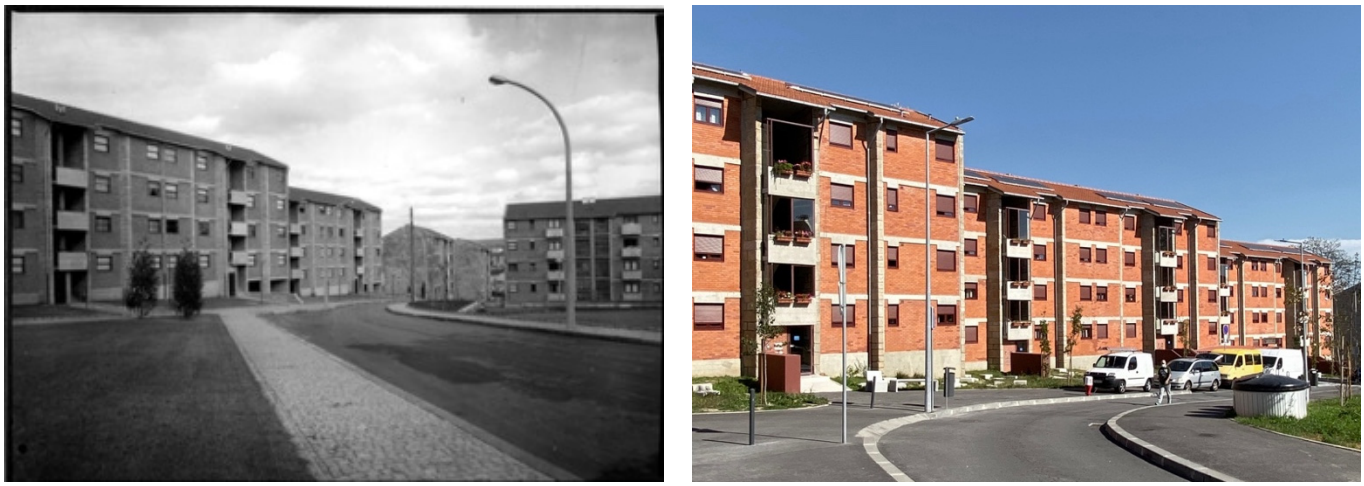


Figure 15. *Falcão* neighbourhood before ((**left**), reproduced with permission from: Câmara Municipal do Porto. Arquivo Histórico. Identifier: 291870) and after the intervention project (**right**).

The third phase is also notable for the unique strategies employed in the more recent neighbourhoods built with portico systems and double exterior walls with intermediate air gaps, without insulation [46] (pp. 573–574) [50], and coatings such as ceramic brick (*Falcão* and *Monte da Bela*) or prefabricated concrete (*Lagarteiro II*). These examples also evidence particular attention to preserving the architectural language of the buildings (Figure 15).

The project developed by Castro Calapez Arquitetos Lda. for the *Falcão* neighbourhood (2017, provisional acceptance) proposes the preservation of the exterior walls in ceramic brick and stone granite, as well as the open balconies. Thus, the intervention on the façades results in the treatment of original materials and the removal of additional elements. However, these actions include replacing the exterior wooden frames with aluminium windows with double-glazing, without a thermal break, and closing the staircases with new iron frames with single-glazing and ventilation grids. Another significant intervention on the façade is the closure of the drying spaces and the installation of a tubular grill for clotheslines. The intervention on the roofs involves the replacement of the roof tiles with sub-tiles and repairing specific elements such as eaves and ridges, as well as installing thermal solar panels and insulation of the uppermost slab [75] (pp. 7–8) [80] (pp. 11–12) (Figure 16).

The intervention in *Monte da Bela* neighbourhood by *Menos é Mais Arquitectos Associados, Lda* (2019–2021) reveals an identical strategy regarding the preservation of exterior walls and open balconies. The main difference consists of choosing exterior window frames with a thermal break and closing the staircases with double-glazing and a thermal break. Another significant difference is in the roofs with the alteration of the structure—a new covering in aluminium with thermal isolation (roof detail) and thermal solar panels and thermal insulation in the uppermost slab (Figure 16).

Another relevant strategy, especially in managing different materials, can be identified in the intervention in the *Lagarteiro II* neighbourhood. The project by architect Paulo Tormenta Pinto (2015, 2016) proposes the preservation of both original double walls with external cladding in precast concrete and ceramic brick walls. The actions thus involve the treatment of cracks, painting the concrete walls, and cleaning the ceramic bricks. Other actions include the alteration of the exterior frames (double-glazing) and closing staircases (single-glazing with ventilation grids) and drying rooms (single-glazing with ventilation grids and outdoor clotheslines). As in the previous case, the main intervention appears in the roof with the application of thermal insulation in the uppermost slab, the alteration of

the structure and a new coating in aluminium with thermal insulation, but without solar panels (Figure 16).

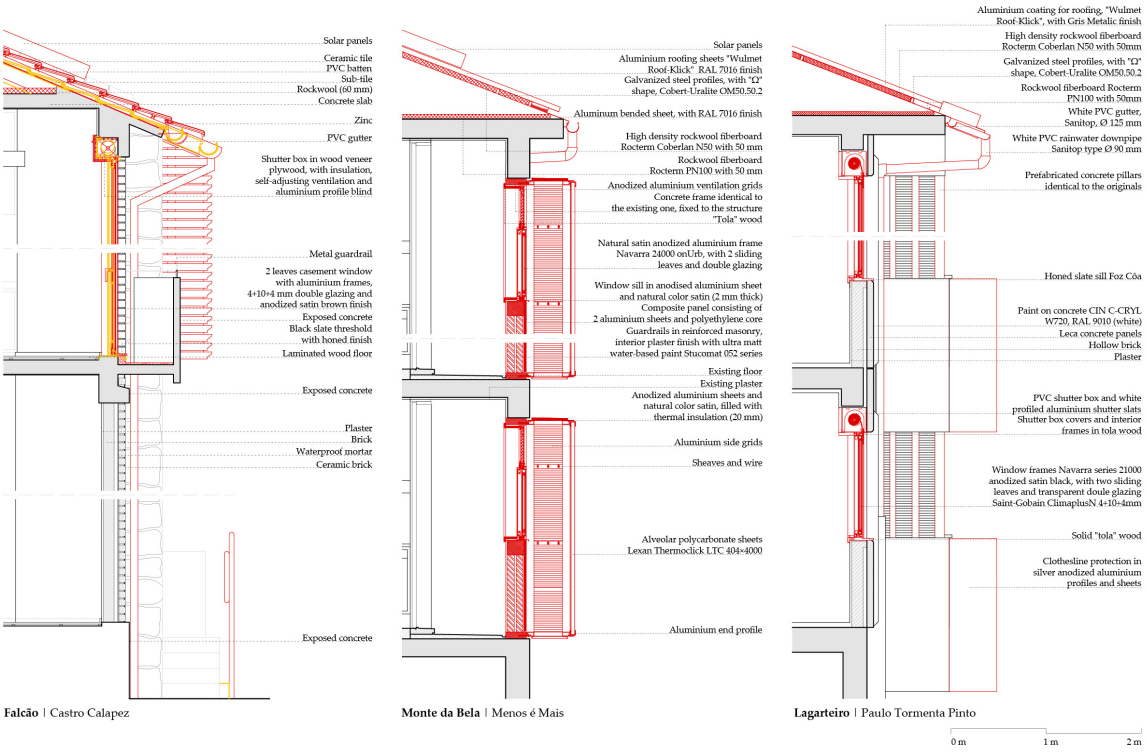


Figure 16. Constructive details of interventions in the *Falcão* (**left**), *Monte da Bela* (**middle**) and *Lagarteiro* neighbourhoods (**right**). Additions in red and demolitions in yellow.

Recently, a new strategy has emerged in several preventive maintenance interventions, revealing the promotion of cautious actions in these neighbourhoods. These interventions involve cleaning, repairing, or replacing elements of the external envelope or common spaces of the buildings (e.g., *Pio XII* neighbourhood, 2022) [81].

4. Discussion

The housing developments built under the Improvement Plan or its extension for social rental are still public municipal property today, maintained and managed by Domus Social E.M. for the population most in need. These neighbourhoods accommodate a significant part of the municipal dwellings in Porto, which is the city where the weight of social housing is more representative in the context of the country [10]. Following similar urban design principles, these housing sets have adopted, with some degree of variation, an analogous architectural design and constructive features. By the end of the 1990s, these neighbourhoods had become highly degraded, no longer presenting satisfactory quality levels. Since the 2000s, the municipality has gradually implemented a systematic intervention for the rehabilitation of these housing neighbourhoods.

The present research has fostered a broader understanding of the municipal intentions in rehabilitating these housing ensembles. These strategies present progressive changes in the implementation of measures to improve the condition of the buildings with an impact on energy efficiency and the thermal comfort of the inhabitants.

The first interventions consisted of occasional actions to solve basic but urgent problems. These actions involved access control to buildings and closing galleries, balconies, and drying rooms. The subsequent experimentation on a trial-and-error basis (second phase) enabled the consolidation of a standard strategy consisting of the application of thin reinforced plaster on the external walls, the replacement of the window frames, and the thermal insulation of the floor slabs. The choice of aluminium and single-glazing is pre-

dominant in the new window frames. However, the continuous installation of ventilation devices is particularly noteworthy, revealing evident preoccupation with the comfort of the spaces following the successive closures (galleries, balconies, and drying spaces). The systematisation of actions in the second phase also allows for better management of the process (materials, costs, logistics), resulting in a significant number of interventions.

The interventions of the third phase reflect the more significant concerns with energy consumption and thermal comfort. The exterior walls present diversified actions encouraged by the specific features of the construction systems and the increased valorisation of this heritage. These actions include the continuous application of thermal insulation in the stone granite walls and the preservation of double walls (more efficient) with coatings on ceramic brick or prefabricated concrete. The roofs also present major interventions with changes in structure, new layers with thermal insulation, and solar panels. Double-glazing with thermal breaks prevails in the new and more technologically developed window frames. Another significant action consists of the installation of outdoor clotheslines as a support system for drying clothes and as a shading device with a substantial impact on the architectural language of the complexes.

Nevertheless, the predominant strategy in the case studies derives from the standard interventions defined in the second phase. Some of these neighbourhoods have, in the meantime, undergone preventive maintenance.

4.1. Impact on the Comfort of Interior Spaces. Current Problems and Energy Poverty Issues

Recent studies have pointed to the significant impacts of third-phase interventions on the thermal performance of the buildings. The preliminary survey of the hygrothermal behaviour of the last interventions in the *Cerco do Porto* neighbourhood by architect José Gigante [82] mentions compliance with the principles of the Regulation on Energy Performance of Residential Buildings (REH), approved by Decree-Law 118/2013 [70] and the requirements of Ordinance 379-A/2015 [83]. The solutions in the roofs, exterior walls, and window frames have made it possible to obtain thermal transmission coefficients corresponding to the admissible values for the climate zone in winter (Porto) [82] (pp. 2–3).

The energy efficiency evaluation report for the *Falcão* neighbourhood (blocks 1 to 9) shows savings of over 34% in energy consumption for climatisation and hot water production and an improvement in the energy classification of 97% of the dwellings [84] (p. 17). These improvements have resulted mainly from installing solar thermal panel systems, replacing exterior windows and applying thermal insulation in the roofs [84] (p. 11). The energy audit report of the intervention in the *Monte da Bela* neighbourhood, prepared by a qualified expert, also stresses the importance of the intervention measures in reducing energy consumption and improving living conditions [85] (p. 15). The same document estimates a two-level improvement in the energy level of the dwellings at an average of B- (according to national certificate levels) [85] (p. 15).

Thus, these studies reveal the practical improvements in the neighbourhoods following the interventions; however, several problems remain, especially regarding the thermal comfort issues inside the dwellings. Reports from inhabitants highlight pathologies in the interior spaces related to condensation damp and thermal discomfort, especially in winter. These persistent problems motivate new enquiries into the intervention strategies for this particular social and local context, namely in the leading solutions for exterior walls, roofs, and window frames or in the choice of shading, ventilation systems, and solar panels. For example, solar thermal panels appear in the third phase mainly as a support measure for domestic water heating but are progressively abandoned or replaced with photovoltaic panels (e.g., *Bom Pastor* neighbourhood). Despite the advantages of reducing energy consumption, these panels have yet to prove to be a profitable solution due to the problems in managing the space to install the associated equipment inside the dwellings and the economic return for the inhabitants.

Another area for improvement lies in widespread energy poverty and standard use of spaces, with intermittent heating systems and subsequent fluctuations in temperature

and relative humidity and a cultural lack of natural ventilation practices [86]. Given the lack of environmental air climatisation practices and economic conditions to guarantee an adequate comfort level, this population depends expressly on passive intervention strategies. In these circumstances, applying an adaptive thermal comfort model is essential in evaluating the buildings' performance to guarantee greater flexibility in the use of spaces, as observed in a thesis on the *Lordelo do Ouro* neighbourhood [27] (pp. 88, 211).

The current living conditions in these neighbourhoods also stem from the absence of systematic actions inside the dwellings. In fact, the interior space is not considered in the intervention strategy adopted by the municipality, geared towards the buildings' envelope (and common circulation area)—i.e., partial refurbishment [28]. Rather, the dwellings' interior space is tackled through occasional interventions over time, whenever tenants move out, not covering some building infrastructures. This aspect gains particular relevance when considering the constructive and architectural features of these buildings with long-time service. Furthermore, previous analyses on the habitable area [28,49,87,88] suggest that, at the time of construction of the Improvement Plan, the conception of the dwellings did not comply with the minimum area measurements in the *Regulamento Geral das Edificações Urbanas*—RGEU [General Regulation of Urban Construction] from 1951 [89]. Although the habitable areas were improved during the extension to the Plan, the highly reduced area house-types should not be disregarded when considering these buildings' constructive and housing quality upgrade.

4.2. Alternative Means of Reducing Energy Consumption and Improving Thermal Comfort in Social Housing

Increased European investment in energy management in the context of affordable social housing has fostered the development of recent projects such as ENERPAT Interreg Sudoe [90], Social Green Interreg Europe [91], or SUDOE Energy Push [92], dedicated to innovative and sustainable solutions for good design practices. The guide promoted by the Energy Push research project reveals several solutions with a multicriteria analysis for global renovations or consumption monitoring applied to pilot projects [93]. The research on the Vila Nova de Gaia pilot project gave rise to an indoor environmental quality monitoring system (IAQ) for a better understanding of the indoor conditions of dwellings [23]. This study values the prior knowledge of the inhabitants and local specificities and applies an interesting methodology based on surveys and monitoring plans before and after interventions [23] (p. 3). According to this study, thermal comfort in social housing is not guaranteed solely by passive rehabilitation strategies, but rather with the support of renewable energy systems [23] (p. 21). An example of the necessary application of alternative measures appears in the *Falcão* neighbourhood with the installation of solar thermal panels to comply with Ordinance 379-A/2015, as concluded by Rocha and Póvoas [75].

Another innovative strategy lies in the Renewable Energy Communities (REC) approved by Decree-Law 15/2022 [94], such as those established by AdE Porto [95]. These communities seek to reduce energy production costs and optimise energy consumption management, particularly relevant features in social housing contexts.

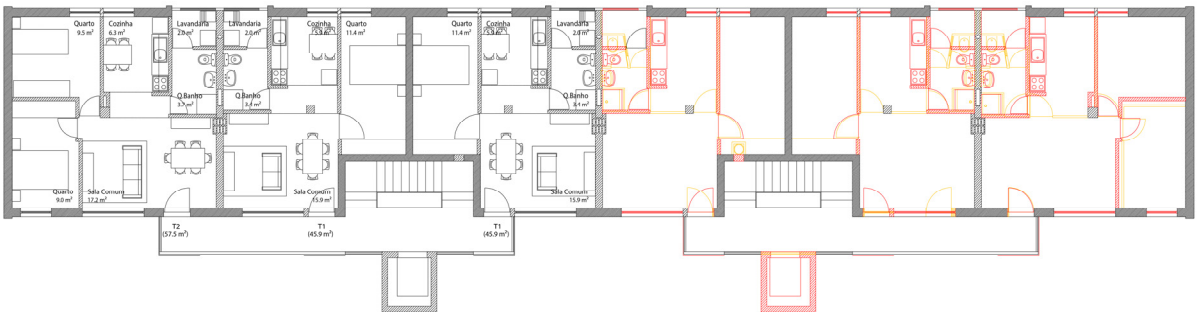
The development of innovative strategies also requires greater collaboration among universities, architects, and the community, as suggested by the initiative developed within the scope of the research "Off Campus. Il Cantiere per le Periferie" by the School of Architecture of the Politecnico di Milano [96]. This methodology promotes a dialogue between the design and construction phases, fostering "interactions with physical and social environments" [96] (p. 24) and experimentation with different architectural approaches and construction techniques.

Nevertheless, alternative means can involve innovations in architectural and construction solutions. In this regard, both the development of more sustainable materials and techniques and architectural solutions such as the PLUS strategy developed by Druot, Lacaton, and Vassal are worthy of note [97,98]. The intervention in *Grand Parc* (2017, Lacaton & Vassal with Druot and Hutin architects) involves the addition of new semi-open spaces

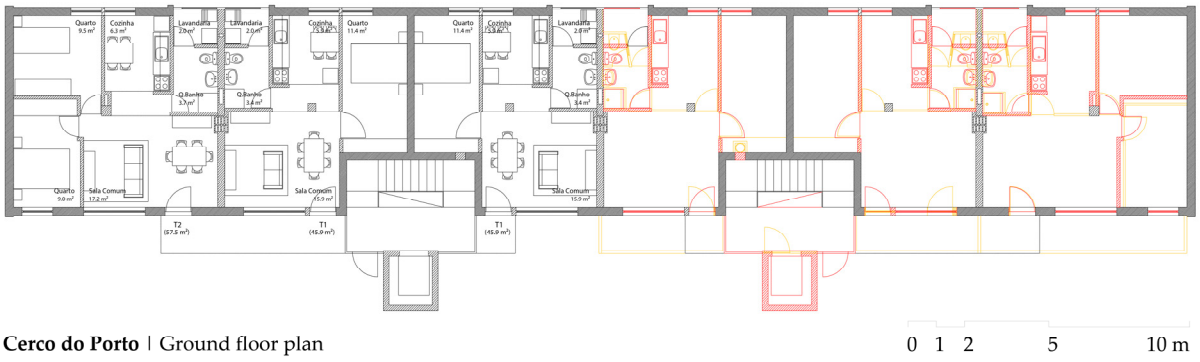
(winter gardens and balconies) attached to the original façades. This requalification of dwelling spaces has allowed for improvements in quality and comfort (light, use flexibility and views) [97]. The project also includes general interventions on the exterior envelope, vertical communications and entrance spaces, the restructuring of bathrooms, and improvements to the interior of the dwellings [99]. Furthermore, this intervention highlights the addition of winter gardens as devices for the thermal regulation of the spaces [100].

In Portugal, the intervention in the *Vila de Este* neighbourhood (Vila Nova de Gaia), by architect Nuno Abrantes, presents an alternative solution by applying shading devices to the façades with greater solar exposure. This project also highlights the need to include other proposals, such as new continuous balconies, although this was not implemented due to funding constraints [101] (p. 99).

In the interventions analysed under the Improvement Plan, some solutions should also be noted, such as the new double wall composition in the *Cerco do Porto* neighbourhood, the metallic structures for clotheslines (e.g., *Cerco do Porto*, *Falcão* or *Monte da Bela*), and external shading (e.g., *Carvalhido*). Architect José Gigante even developed a proposal to reconfigure the *Cerco do Porto* neighbourhood dwellings, which may be implemented in the future [77] (p. 567) (Figure 17), in line with the outcomes of a previous study on intervention strategies for the requalification of public housing in Porto that examined the transformability of the neighbourhoods built under the Improvement Plan [28]. The operational aspect (involving temporary rehousing with a reduction effect on the number of dwellings) discourages a more intrusive intervention, as municipal housing needs persist.



Cerco do Porto | Floor plan type



Cerco do Porto | Ground floor plan

Figure 17. *Cerco do Porto* proposal to reconfigure the neighbourhood dwellings by José Gigante. Reproduced with permission from: José Gigante.

However, the present research highlights the limitations in these interventions regarding the complexity of the processes, the urgent needs, and the limited funding.

4.3. Preservation or Transformation. Impacts, Funding, and Management

The PLUS strategy (2004, Druot, Lacaton & Vassal) promotes transformation and re-use rather than demolition as the most economic, effective, and qualitative response to housing needs [97]. This manifesto responds to a public programme set up for the deconstruction of some large-scale housing buildings from the 1960s and 1970s and was subsequently successfully applied to projects such as the transformation of the *Bois le Prêtre* tower (Paris, 2011) [102] and 530 dwellings in the *Grand Parc* (Bordeaux, 2017) [98,99]. However, the application of this strategy in the neighbourhoods of the Improvement Plan naturally presents several limitations regarding the architectural and construction characteristics of the buildings (e.g., limited areas), as concluded by Restivo [28].

In addition to economic investment, there is also an interest in preserving these neighbourhoods as architectural heritage. The Improvement Plan was one of the most significant public initiatives in Portugal, mainly due to its magnitude, duration, and impact on the sociodemographic and territorial structure of the city of Porto [26]. These neighbourhoods thus compose urban clusters and represent the architectural and constructive practices subsidised by the state in this period, therefore acquiring a particular heritage value. The buildings do not have particularly relevant architectural characteristics. Nevertheless, they show signs of modernity and formal and functional innovations, especially in the neighbourhoods built in the extension of the plan (e.g., *Falcão*). Many of these neighbourhoods also integrate areas with urban or architectural interest, according to the *Planta de Ordenamento—Carta do Património* [Management Plan—Heritage Chart] of the *Plano Diretor Municipal do Porto*, PDMP [Porto Municipal Master Plan] (e.g., *Carvalhido* and *Cerco do Porto*). These neighbourhoods correspond to representative areas of the history of the city, thus promoting their safeguard, as laid down in article 44 of the PDMP [94].

A more significant investment in preliminary studies according to the particularities of each case would allow for an assertive cost–benefit analysis for different degrees of intervention, establishing a relationship between heritage, energy, and comfort as a primary goal. A similar strategy was applied for analysing different possible interventions in the *Cité du Lignon* with research conducted in the *Techniques et Sauveguarde de la Architecture Moderne* Laboratory (TSAM, EPFL). This study seeks to balance heritage issues, economic constraints, and energy goals, allowing for a comparison between different actions [103,104].

5. Conclusions

The social housing developments built under the Improvement Plan (or its extension) correspond to a significant part of the municipal dwellings in Porto. Following similar urban design principles and analogous architectural design and constructive features (albeit with some degree of variation), these neighbourhoods became highly degraded in the late 1990s. The municipality has gradually implemented a systematic intervention for the requalification of these housing sets over the last two decades.

A broader examination of the municipal intentions to rehabilitate these housing ensembles shows that the strategies display progressive changes in the implementation of measures to improve the condition of the buildings with an impact on energy efficiency and the thermal comfort of the inhabitants. From the early interventions to the subsequent experimentation on a trial-and-error basis, the interventions of the third phase reflect more significant concerns with energy consumption and thermal comfort.

The impact on the comfort of interior spaces has been discussed. Recent studies have pointed to the significant impacts of third-phase interventions on the thermal performance of buildings, also unveiling several pending problems, especially regarding the thermal comfort issues inside the dwellings. Another area for improvement is widespread energy poverty and the standard use of spaces, with intermittent heating systems and subsequent fluctuations in temperature and relative humidity and a cultural lack of natural ventilation practices. Furthermore, the current living conditions in these neighbourhoods also stem from the absence of systematic interventions inside the dwellings, which only occur

occasionally over time, whenever tenants move out, and do not cover several building infrastructures. Additionally, the highly reduced area of these house-types should be observed when considering these buildings' constructive and housing quality upgrade.

Alternative means of reducing energy consumption and improving thermal comfort in social housing not solely by passive rehabilitation strategies, but rather with the support of renewable energy systems is also discussed. As alternative means, innovations in architectural and constructive solutions (both the development of more sustainable materials and techniques and architectural solutions) are also mentioned, despite their limitations (complexity of the processes, urgent needs, and limited funding).

The discussion around a more *transformative* intervention, albeit with examples of best practices, highlights several limitations regarding the architectural and construction characteristics of the buildings constructed under the Improvement Plan. An interest in preserving these neighbourhoods as architectural heritage should be noted, as they represent the architectural and constructive practices subsidised by the state during this period. Even if the buildings do not have particularly relevant architectural characteristics, they show signs of modernity and formal and functional innovations. Finally, a more significant investment in preliminary studies according to the particularities of each case would allow for an assertive cost–benefit analysis for different degrees of intervention, establishing a relationship between heritage, energy, and comfort as a primary goal. Additionally, methodologies based on surveys and monitorisation plans can further clarify the effective benefits of the interventions to inform better future actions.

Further Moves

Recent interventions promoted by Domus Social E.M. display increased investment in the preventive maintenance of neighbourhoods as an addition to general rehabilitation. These actions aim to avoid the frequent problems caused by the natural wear of materials and the use of spaces [105]. Another strategy confirmed by Domus Social E.M. involves the requalification of the public spaces surrounding the buildings with the support of experts. The projects already developed in the *Pio XII* and *Contumil* neighbourhoods by *Menos é Mais* architects [106] reflect the goals of these interventions. This procedure is now being extended to other neighbourhoods of the Improvement Plan, such as *Cerco do Porto*, *Bom Pastor*, *Falcão*, *Monte da Bela*, *Carvalhido*, *Aldoar,* and *Campinas*.

As mentioned before, the municipal management of this significant housing heritage effectively involves complex factors regarding the socioeconomic type of the population, the needs of the neighbourhoods, and the constraints of legislation and funding programmes. Issues such as improving the energy efficiency of buildings and the thermal comfort of inhabitants thus emerge as complementary parameters in this vast process.

The analysis of the intervention strategies has identified a growing investment in rehabilitating these neighbourhoods with particular attention to energy and comfort issues in the third phase. The same analysis acknowledges the limitations in the systematisation of actions, the restriction of solutions, and the limited management of alternatives with renewable energies. Further research with the monitorisation of the spaces will test the effectiveness of these solutions.

As a future hypothesis, this research proposes developing a multidisciplinary methodology based on guidelines and previously highlighted assumptions [28], together with the parameters of this analysis for a comprehensive overview of the social, economic, architectural, and constructive dimensions geared towards improving energy efficiency and thermal comfort. Beyond offering support in the complex management of this housing heritage, these guidelines should meet the expectations of the inhabitants and their right to comfort, especially in this particularly relevant context of social housing.

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