sustainability

MDPI

Article

The Origin and Architectural and Technological Characteristics and Opportunities for the Reuse of Portugal's EPAC Silo Network

Víctor Marcelo [1,*], Arlindo Almeida [2], Pablo Pastrana [3], F. Javier López-Díez [3] and José B. Valenciano [3]

[1] Departamento Ingeniería y Ciencias Agrarias, Universidad de León, Avda. Astorga, 24001 Ponferrada, León, Spain
[2] Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal; acfa@ipb.pt
[3] Departamento Ingeniería y Ciencias Agrarias, Universidad de León, Avda. Portugal 41, 24071 León, León, Spain; ppass@unileon.es (P.P.); javier.lopez@unileon.es (F.J.L.-D.); joseb.valenciano@unileon.es (J.B.V.)
* Correspondence: v.marcelo@unileon.es; Tel.: +34-987-442029

Abstract: Portugal's EPAC (Empresa Pública do Abastecimiento dos Cereais) silo network, initially planned in the 1930s but constructed and utilised primarily in the 1970s, consisted of 31 silos with a total capacity of 841,100 t. The network's usage declined, however, due to market liberalisation and Portugal's accession to the European Economic Community in 1985. This study focuses on adapting a methodology to inventory and analyse the 31 silos in the EPAC network, considering their general features, construction, technological facilities, and socioeconomic aspects. The silos are situated in 30 cities and towns, predominantly in the country's key grain-growing regions, particularly the Alentejo region. While there are variations in design and construction, most EPAC silos contain two or three rows of circular reinforced concrete cells and use the spaces between cells for storage. Their capacities range from 6000 to 35,000 t. Some are inland grain reception and storage silos, while others are larger-capacity port silos designed to unload grain rapidly onto ships using mechanical or pneumatic unloaders. These structures are a significant part of Portugal's agro-industrial heritage and have, in some cases, been repurposed as museums or event venues. Compared to other agro-industrial buildings, silos pose unique conversion challenges due to their height and design complexities. Examples of successful reuse in countries like Spain and Italy may provide insights for potential silo projects in Portugal. However, analysis suggests that such proposals and similar initiatives may be viable only in the more highly populated towns.

Keywords: wheat; grain store; silo; EPAC; industrial heritage

check for updates

Citation: Marcelo, V.; Almeida, A.; Pastrana, P.; López-Díez, F.J.; Valenciano, J.B. The Origin and Architectural and Technological Characteristics and Opportunities for the Reuse of Portugal's EPAC Silo Network. *Sustainability* **2024**, *16*, 2116. https://doi.org/10.3390/su16052116

Academic Editor: Aliakbar Kamari

Received: 15 January 2024
Revised: 19 February 2024
Accepted: 27 February 2024
Published: 4 March 2024

1. Introduction

Since ancient times, the storage of grain, especially wheat in the Mediterranean area, has been particularly important [1]. In Europe, castles and monasteries were used until the 19th century as wheat storage facilities [2]. Storage methods changed radically with the introduction of the grain elevator in Buffalo, USA, in 1843: traditional horizontal granaries were replaced by tall structures called 'silos' or 'vertical storage units' [3–5]. In late 19th-century Portugal, wheat imports sparked protests by domestic producers, which resulted in the enactment of protectionist laws from 1889 to 1899 [6–8] aimed at ensuring a minimal profit for producers without harming consumers; this led to an increase in domestic production [9–11]. At the beginning of the 20th century, over half of Portugal's wheat production came from the districts of Evora, Portalegre, and Beja. The Alentejo region, which boasted favourable growing conditions but a large amount of uncultivated land, was targeted to increase national production [11]. From 1914 onwards, multiple political and social crises impacted protectionist wheat policies, and urgent measures were taken accordingly to reduce the cost of bread. Under these measures, collectively known as Pão Político (political bread), the state imported wheat and sold it to flour mills below the market value [10]. The authoritarian regime known as the Estado Novo (New State) arrived in 1926. That same year, the I Congreso Nacional do Trigo (First National Wheat Conference) was held with the aim of achieving national self-sufficiency in wheat production [12]. In 1929, the Campanha do Trigo (Wheat Drive) (Figure 1) was run to bring large unfarmed areas, especially in the Alentejo region, into production, leading to deforestation, landscape change, and subsequent erosion issues [13–15].

Figure 1. (**a**,**b**) Campanha do trigo posters. (**c**) Campanha do trigo 20th anniversary poster [16].

Production was supported through subsidies and loans for wheat growers [10]. As a result of the Campanha do Trigo, production rose, and the price of wheat fell, leading to conflicts between wheat growers and flour millers [9,17,18]. So, the national authorities created the Federação Nacional de Produtores do Trigo (FNPT, National Wheat Growers Federation) in 1932 [10] and the Federação Nacional dos Industrais do Moagen (FNIM, National Milling Industries Federation) in 1934, in an endeavour to control wheat production, processing, and marketing [12–19]. In 1935, the FNPT commissioned Professor Ruy Mayer of the Instituto Superior de Agronomia (ISA, School of Agriculture) in Lisbon to prepare a study in which the country was divided into eight zones based on the amount of grain produced (Figure 2). Zones I, II, III, and VIII were wheat-exporting zones, while the others were wheat importers. The study proposed the construction of a network of 30 silos to store and distribute wheat, using the railway to link production zones with consumption zones. Three types of silos were envisioned: (i) central silos, (ii) auxiliary silos, and (iii) other (smaller silos and granaries) [12,15,20].

Something similar to what happened in Portugal also occurred in other European countries under authoritarian regimes. In Italy, from 1925 to 1931, Mussolini decided to pursue self-sufficiency in wheat production, which ultimately turned out to be a complete failure [21]. Later, around 1936, the ammasso (stockpile) was established in Italy, which mandated the delivery of all wheat crops to the state [22,23]. In Spain, the Servicio Nacional del Trigo (SNT, National Wheat Service) established a monopsonistic grain market and set up the National Network of Silos and Granaries, which began building storage units in 1951 and continued right up to 1990 [24]. The Portuguese government established a free market for wheat in 1947, offering a guaranteed price for other grains, such as maize and rye. It also purchased all barley intended for breweries, resulting in significant growth for the FNPT [9]. This led to the creation of the Instituto dos Cereais (IC, Grain Institute) in 1972, which represented the entire grain sector and held coordination and discipline functions in economic intervention until its dissolution in 1977 [25].

Ruy Mayer's plan was a project to see how wheat could be stored in the event of a big boost in production, which Salazar believed could be accomplished with the Campanha do Trigo. The campaign turned out to be a fiasco, however, and there was no surplus. Instead, there was a civil war in Spain, followed shortly afterwards by World War II. Both conflicts rocked Portugal's economy and its priorities. So, in a country short on wherewithal, the Mayer Plan ceased to be a priority, outranked by other political priorities and interests of the dictatorship (sending goods and food to Spain and then Germany or the Allies, depending on the time) so that Portugal would not have to go too hungry. Wheat production and productivity only really rose in the late sixties and in the seventies, at the end of Salazarism and the start of Caetanism. It was then that grain storage silos were built [18]. In 1972, the FNPT revised Ruy Mayer's silo plan to include new categories. The objective was to build silos with a large reception and dispatch capacity, where different products could be stored and seeds could be selected as well. The FNPT was eager to own its own silos; it was leasing over 300 granaries in 1971, and this was proving costly. The construction of silos in the Azores was also considered. In 1976, the Empresa Pública do Abastecimento dos Cereais (EPAC) [26] was established to replace the IC. The EPAC ensured the country's supply of grain and seeds, defending the interests of growers and consumers and maintaining the quality of processing activities, all with the aim of protecting the interests of the Portuguese economy [12,27]. During this period, significant investments were made in storage silos, although some storage silos, such as the one in Beato, Lisbon, had already been constructed with partial financing under the Marshall Plan in 1956.

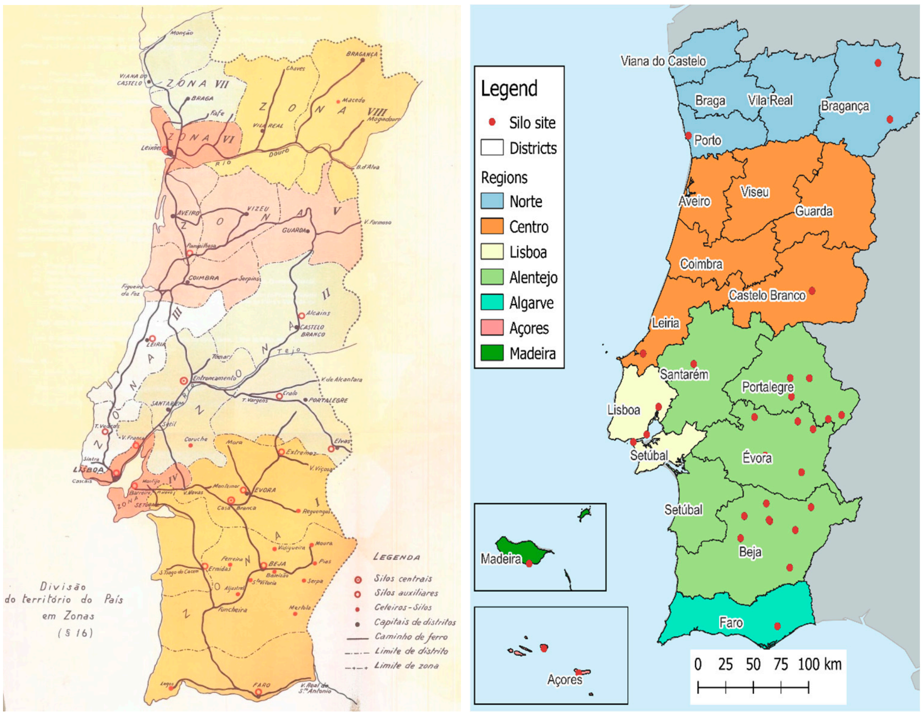

Figure 2. (**left**): sites of 30 silos designed by Ruy Mayer (1938) in Portugal; (**right**): sites of 31 silos built by EPAC in Portugal.

Portugal's admission to the European Economic Community (EEC) in 1986 brought market liberalisation and the policy of importing wheat at lower prices. In Portugal, as in other countries, like Spain, this resulted in a significant reduction in silo use [28]. In 1987, the state created a company, Silos Portuários, SA (SILOPOR), so that Portugal's port silos could continue to be used for international imports. The EPAC was transformed into Empresa para Agroalimentação e Cereais, SA, in 1991 [29], and in 1999, it was dissolved [30], and its assets were transferred to the Direção Geral do Tesouro e Finanças (DGTF, Directorate-General of the Treasury and Finances). In 2002 all the silos were placed under the responsibility of the Instituto Nacional de Intervenção e Garantia Agrícola (National Agricultural Intervention and Guarantee Institute) after the dissolution of SILOPOR in 2001 [31]. The objective was to improve storage management and transfer silo ownership to growers and corporations. Many silos were let to agricultural cooperatives or private companies under 25-year leases that made the tenant responsible for maintenance [10]. The port silos of Leixões, Beato, and Trafaria and the inland silo in Vale de Figueira, Santarem, are currently managed by companies under public concessions. These silos function as temporary customs warehouses, providing services for the reception, handling, storage, and dispatch of food commodities and products related to companies in the industry [27]. Over time, some tenants have returned silos they no longer use to the public authorities, and as a result, these silos' state of preservation has declined. In the 20th century, other countries, such as Spain and Italy, also set up networks of storage silos (primarily for wheat), most of which have since been either turned over to private interests or abandoned and only occasionally repurposed [9,32]. National silo networks can become important again since they are strategic elements of infrastructure that can mitigate dependency on grain-exporting countries in adverse scenarios, such as those caused by conflicts like the current war in Ukraine, pandemics, or blocked trade routes [23].

Figure 3 shows the evolution of cereal production and cultivated area over the last 100 years. The area reached its maximum, almost one million six hundred thousand hectares, in about 1960. At roughly the same time, the country also hit its maximum national production, around one million two hundred thousand tons of grain. Area and production then both declined gradually over the years until both area and production reached historical minimums in 2022. In the years with major droughts (2005, 2012 and 2022), production declined sharply. Additionally, Portugal is currently highly dependent on grain imports to supply its domestic market and is, therefore, very sensitive to international conflicts.

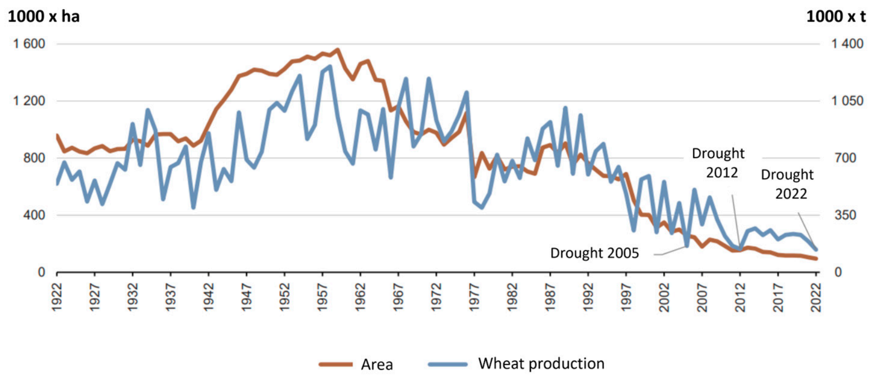

Figure 3. Evolution of grain-growing area and production in 1922–2022 in Portugal (INE, I.P.).

Silos form as much a part of the skyline of Portuguese towns and cities as castles and churches, and, like other agro-industrial assets, silos contribute to the country's cultural heritage [10,12,33,34]. In some cases, silos are being refurbished instead of being allowed to crumble away. These silos have value as part of Portugal's industrial heritage, so it is important to document them and showcase them through reuse [25,35,36]. Similar efforts are being made in other countries [24,28,37,38]. Drawing up a comprehensive inventory is the first step toward making decisions that factor in the present condition of silos and their environment. It is our duty to seek a second life for these structures, whose construction consumed significant resources in their day, so we can keep them from being demolished and work our way toward greater environmental sustainability and a smaller carbon footprint [24]. International efforts in this direction have been going on since the 1980s. In 2003, the International Committee for the Conservation of the Industrial Heritage (TICCIH) adopted the Nizhny Tagil Charter for the Industrial Heritage, where the concept of industrial heritage was internationally defined. The industrial heritage can be protected in two ways: specimen static protection (which focuses on "authenticity") and "development-oriented" dynamic protection, which gives the industrial heritage new life through reconstruction and repurposing [39]. It is our belief that this latter approach is the best for the silos in the EPAC network. Some authors even propose using a multi-criteria decision-making analysis (MCDA) to identify uses for Italian grain silos [40]. The main international system for inventorying industrial heritage is the DOCOMOMO Register, which was conceived to gather information on many different aspects of heritage sites (history, location, materials, current conditions, uses and actors) and to run different tasks fundamental to the protection, understanding, and management of immovable cultural heritage items, from identification and analysis to monitoring and conservation planning. In Spain, an inventory has been drawn up of the national network of silos and granaries in Andalusia, using concise, practical data sheets to gather descriptive and historical information about each silo, its context, and any restoration work done to it [41]. More recently, in Castile and Leon, a methodology was developed based on silos' general features, construction, and technological facilities in conjunction with a socioeconomic analysis of the communities where silos are located [24].

The main objective of this project is to inventory the silos in Portugal's EPAC network, analyse their construction and technological characteristics, and propose ideas for their reuse.

2. Materials and Methods

Given the lack of an inventory containing detailed silo information, the first step was to collect data from the EPAC archives in Lisbon and the records kept by other institutions, such as the Assembly of the Portuguese Republic, Universidade de Évora (Evora University), and the ISA.

Second, the variables proposed by Fernández-Fernández et al. (2023) [24] were screened to select the most appropriate variables for EPAC silos. While the Spanish silo network contains 20 categories of silos that vary widely in terms of materials, cell shape and other features, the silos in the EPAC network are much more uniform in terms of ground plan, storage cell shape, and storage cell building materials. The method was therefore adapted accordingly, and account was also taken of the great technological variability among the EPAC silos. With the adaptation of the variables proposed by Fernández-Fernández et al. (2023) [24], a larger amount of information about the silos was gathered than in the inventory run in Andalusia, Spain [41].

Third, fieldwork was conducted at all 31 silos in the EPAC network. Each silo was photographed, and its main characteristics were recorded and grouped into four major categories (general features, construction features, technological facilities, and socioeconomic aspects).

In the fourth step, the data were analysed using basic statistical analysis, and lastly, lines of action were proposed (Figure 4).

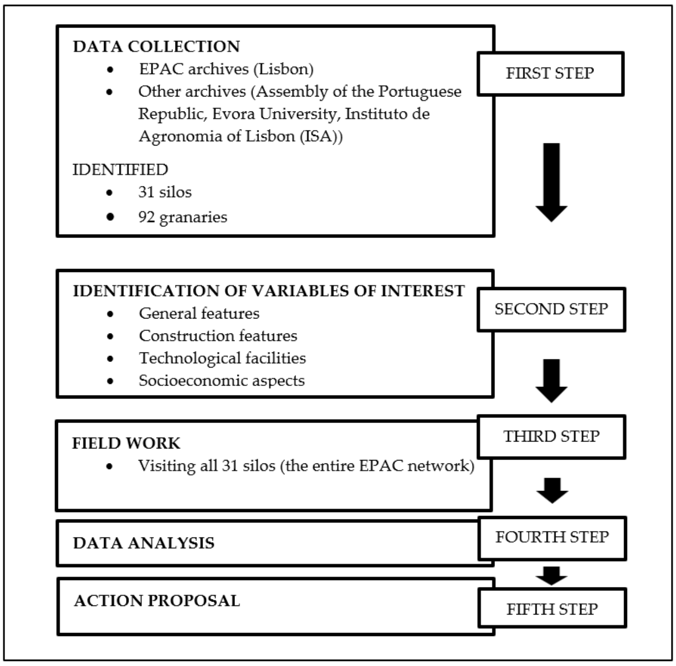

Figure 4. Methodology workflow.

A document search was used to identify 31 silos and 92 granaries constructed in Portugal and belonging first to the FNPT, then the Instituto dos Cereais, and finally to the EPAC. All of the granaries are either still being used to store grain or have been reused for other activities, so they were not included in the study. All 31 silos were then visited and photographed. The relevant variables were selected from among those proposed by Fernández-Fernández et al. (2023) [24] for Spanish silos, and additional variables of interest were added to inventory the EPAC silos properly. The variables fall into the following four categories listed in Table 1.

Table 1. Fieldwork variables used to inventory the 31 silos in the EPAC network. Adapted from Fernández-Fernández et al. (2023) [24].

Categories	Variables of Interest
General features	Region District Town Geolocation Year when built Ownership (state-owned; leased to cooperative, institute, or private company; owned by private company or municipality) Use State of conservation
Morpho-typology and construction features	Category Storage capacity (t) Height (m) Ground plan Roof shape Tower position Number of storage cells Number of rows of cells Number of rows of internal cells or intercellular spaces Cell shape Cell dimensions Façade types (straight or semicircular type I, II, or III) Cell construction material
Technological facilities	Receiving machinery capacity (t/h) Number of elevators Number of upper-storey horizontal conveyors Number of lower-storey horizontal conveyors Existence of firefighting system Existence of lift Existence of temperature sensors Existence of railway Lorry weighbridge (t) Railway weighbridge (t)
Socioeconomic aspects	Population Demographic patterns Yearly municipal budget (EUR) Economic activity Land communications Distances to larger urban centers (km)

The information collected is all available in Supplementary Materials Tables S1 and S2. All data were subjected to basic statistical analyses.

3. Results and Discussion

3.1. Geographical Distribution, Development, and Evolution of the EPAC Silo Network

The silos in the EPAC network stand at 30 locations in Portugal's leading grain-producing districts, many of them in the Alentejo region (18 silos, 33.7% of the network's storage capacity). Within the Alentejo region, the district of Beja has eight silos (16.2% of the network's capacity), Portalegre has five silos (6.3% of the network's capacity), and Evora has four silos (8.5% of the network's capacity). The Lisbon region has only three silos, but they account for 38.8% of the storage capacity, as two of them (Trafaria and Beato) are port silos. The North region has three silos, accounting for 14.0% of the EPAC network's capacity (including the Leixões port silo in Porto). The Centre region has three silos and 4.8% of the network's capacity. The Azores region has two silos and 6.5% of the capacity. Finally, Madeira and the Algarve region have one silo each (Table 2).

Table 2. Location and capacity of silos silos actually built in the EPAC network.

EPAC Network			
Region	**Town**		**Capacity (t × 1000)**
Alentejo	Inside Beja		15.0
Alentejo	Outside Beja		26.5
Alentejo	Alter do Chão		8.0
Alentejo	Estremoz		16.0
Alentejo	Evora		23.0
Alentejo	Fronteira		16.0
Alentejo	Vila Viçosa		2.3
Alentejo	Pavia		18.0
Alentejo	Reguengos de Monsaraz		35.0
Alentejo	Moura		10.0
Alentejo	Serpa		19.0
Alentejo	Mértola		4.5
Alentejo	Portalegre		10.0
Alentejo	Vila de Boím		4.0
Alentejo	Ferreira do Alentejo		23.5
Alentejo	Aljustrel		14.5
Alentejo	Elvas		15.0
Alentejo	Cuba		23.5
Centre	Alcains		10.0
Centre	Vale de Figueria		24.0
Centre	Caldas de Rainha		6.5
Lisbon	Vila Franca de Xira		6.5
Lisbon	Beato		120.0
Lisbon	Trafaria		200.0
North	Mogadouro		6.0
North	Braganza		12.0
North	Leixões		100.0
Madeira	Funchal		16.0
Azores	Punta Delgada		34.0
Azores	Angra do Heroismo		21.0
Algarve	Santa Catarina da Fonte do Bispo		1.3
Total	**31 silos**	**Total**	**841.1**

Figure 2 shows the territorial distribution of the silos in the EPAC network and the variations in their locations compared to Mayer's 1932 study. During the revision of the Silo Construction Plan in 1972, several options were considered for the construction of a new port silo in the Lisbon region, in addition to the silo already planned in Leixões, in the North (Porto) region. Harbour depth was an important factor in this plan to enable large vessels to dock. Ultimately Trafaria was chosen as the location for the silo's construction. The EPAC silo network may be said to be located in the leading grain-producing areas of the country, plus the ports of Leixões and Lisbon. The network mainly covers the regions of Alentejo, Lisbon, and Centre; Beja is the district with the most silos, eight, while only one silo was built in the Algarve region, which is a coastal area with limited grain production. The Campanha do Trigo (1929) heralded state intervention in and regulation of the Portuguese grain market. In the network's early stages, in 1938, Professor Ruy Mayer classified the planned silos into three types: (i) central silos, located at strategic crossroads (Casa Branca, Entrocamento, and Leixões), (ii) auxiliary silos, near farmers and production areas, and (iii) other, which included smaller silos and granaries [15,20] (Figure 1, Table 2). After the 1972 revision of the Silo Construction Plan, silos were classified as (i) regionais ('regional' silos, close to farmers), (ii) de concentraçao ou termináis ('concentrating or terminal' silos, close to farmers and for transfers of wheat from other regions), or (iii) portuarios ('port' silos, primarily for imports). Additionally, objectives were set to build silos with greater storage, reception, and dispatch capacity, designed to store different products simultaneously and enable seed grain selection [12].

Portugal built its first silos considerably later than other countries, like Spain, except for the silo in Mértola, Beja, which dates back to 1938. In the 1950s, four silos were built in Portugal (Vila Franca de Xira in 1956; Beato in Lisbon, whose first two phases were built in 1958 and 1962, respectively; the silo in Catarina da Fonte do Bispo, Faro, in 1958; and the silo in Caldas de Rainha, Leiria, in 1959). Three more were built in the 1960s (one inside the city of Beja in 1961, one in Vila de Boím, Portalegre, in 1964, and one in Alter do Chao, Portalegre, in 1969). Construction on the rest of the silos began in 1970 with the Aljustrel silo. The 1970s were the most prolific decade for construction [33], accounting for 64.5% of all silos in the network. In the end, a total of 31 silos were built in the EPAC network, very close to the number called for in Ruy Mayer's plan [20], but they had a capacity of 841,100 t, much higher than the 92,800 t Mayer proposed for his 30 silos. Half of these silos (51.6%) were enlarged in the mid-1970s and early 1980s (Table S1). Unlike Italy and Spain, which started constructing silos in the 1930s to 1950s, Portugal built its silos later, mainly in the 1970s. As a result, Portuguese silos had larger capacities than those of other countries. Only 4.7% of Spanish silos can hold more than 10,000 t (with a maximum of 40,000 t) [39], while only eight silos in the EPAC network have a capacity of under 10,000 t, and some, such as the Trafaria port silo in Lisbon, can hold up to 200,000 t.

Starting in 1986, with the liberalisation of the market, Portugal, like Spain, experienced a significant decline in silo use [28,42]. Some silos fell into disuse (38.7% of the total), and most were burgled. All the facilities they contained were destroyed. Currently, just over half of the silos in the network (53.3%) are leased to agricultural cooperatives, institutes, or private companies. They are mainly port silos, and they form the bulk of the silos that are still being used for grain storage (51.6%). Other silos are owned by private companies (10.0%) or have been transferred to municipalities (3.3%), and the remainder are state-owned (33.3%) (Table 3). The number of unused silos is expected to increase in the coming years, as the 25-year leases to cooperatives and private companies will expire in 2030–2035, and it is anticipated that several leases will not be renewed.

Table 3. EPAC silo statistics.

Category	Total	Min.	Max.	Mean	Silo Distribution in Percentages
Region	7				58.1% Alentejo; 9.7% Lisbon; 9.7% Centre; 9.7% North; 6.5% Azores; 3.2% Madeira; 3.2% Algarve
District					25.8% Beja; 16.1% Evora; 16.1% Portalegre; 6.5% Lisbon; 6.5% Braganza; remaining districts each contain 3.2% of the silos in the network
Town	30				
Year when built		1938	1986	1970	

Table 3. *Cont.*

Category	Total	Min.	Max.	Mean	Silo Distribution in Percentages
Year when expanded		1962	1985	1977	
Ownership					36.7% leased to cooperatives; 33.3% state-owned; 13.3% leased to private companies, 10.0% owned by private companies; 3.3% owned by municipalities; 3.3% leased to institutes
Use					51.6% grain store; 38.7% disused; 9.7% reused
State of conservation					51.6% good condition, 33.3% fair condition, 9.6% unusable, 6.5% demolished
Category	3				
Capacity (t $\times$ 10^3)		2300	200,000	27,132	
Height (m)		26	70	43.2	
Ground plan					96.7% square; 3.3% L-shaped
Roof shape					53.4% flat roof; 40.0% gable roof; 3.3% flat and gable roof; 3.3% vaulted roof
Tower position					83.4% front tower; 6.6% corner tower; 6.6% interior tower; 3.4% side tower
No. storage cells		11	157	36	
No. rows of cells		2	4	2.4	
No. rows of internal cells or intercellular spaces		1	3	1.5	
Cell shape					93.3% circular; 6.7% square
Cell dimensions		2	13		
Façade types					6.7% straight; 16.7% semicircular I; 53.3% semicircular II; 23.3% semicircular III
Construction material					93.3% reinforced concrete; 6.7% reinforced brick
Receiving machinery capacity (t/h)		50	3000	195.6	
No. elevators		2	14	3.2	
No. upper-storey horizontal conveyors		1	10	2.6	
No. lower-storey horizontal conveyors		1	9	2	
Firefighting system					53.3% yes; 46.7% no
Lift					85.7% yes; 14.3% no
Temperature sensors					86.6% no; 13.3% yes
Railway					56.7% yes; 43.3% no
Lorry weighbridge (t)		30	100	66.4	
Railway weighbridge (t)		200	200	200	

3.2. Layout and Construction Characteristics

3.2.1. Early Silos

The first silo was built in 1938 in Mértola. It consists of two rows of square cells raised off the ground and made of reinforced brick with reinforced concrete pillars at the corners. The elevator tower is located on the side of the silo and houses the staircase and grain-lifting machinery. The 12-cell silo has a small storage capacity (4500 t) and is 37.5 m tall. It was constructed adjacent to granaries and a flour mill, which remained in operation until 1961. The granaries and the silo were later used as storage facilities by the EPAC. It took 15 years to complete the first phase of the silo in Angra do Heroísmo, the capital of Terceira Island in the Azores archipelago. This was the first in a series of silos made with circular reinforced concrete cells. This 11,000 t silo has three rows of cells, with four cells per row. The cells are made of reinforced concrete and have a diameter of 6.5 m. The intercell spaces are also utilised as storage space, thus creating two additional rows of smaller cells between the main cells. The tower is positioned at the front of the silo. Three years later, in 1956, the silo in Vila Franca de Xira, near Lisbon, was constructed. This silo has a small capacity (6500 t) with two rows of cells. Each row has four circular cells, also made of reinforced concrete. The intercell space is used for storage, and the silo's tower is located at the front. Two years later, in 1958, the first phase of the Beato port silo in Lisbon was constructed on the right bank of the Tagus River. The second phase was completed in 1962, making for a total storage capacity of 43,000 t. With two subsequent expansions in 1975 and 1985, this silo eventually grew to a total capacity of 120,000 t and 128 cells. The cells built in the first three phases are 7 m in diameter, while those built in the fourth phase are 13 m in diameter. All cell walls are 0.20 m thick. This silo is the second largest in capacity, surpassed only by the Trafaria silo (200,000 t) on the left bank of the Tagus River, opposite Lisbon. This silo is actually a complex of three independent interconnected silos. One of them, which has a rectangular layout, consists of 63 cells arranged in three rows (the intercell spaces are used as well), with two towers at the north and south ends; this section was built in phases one and two of the complex's construction. The second silo is attached to the south tower of the original silo by a new elevator tower. It also has a rectangular layout and consists of 27 cells arranged in three rows; this constituted phase three of construction. In the fourth phase, a T-shaped building was raised with a tower in the centre of the T, housing 17 storage cells and 12 dispatch cells raised above six loading points. In the same year, 1958, the Santa Catarina da Fonte do Bispo silo was constructed, the only silo built in the Algarve region. This building has a small capacity, just 1300 t, and consists of two rows of circular reinforced concrete cells with a diameter of 3.6 m apiece. The Caldas de Rainha silo was built shortly thereafter, in 1959, with a capacity of 6500 t. It also consists of circular reinforced concrete cells with a diameter of 4.5 m arranged in a rectangular layout. In 1961 a silo was built right inside the city of Beja. It has three rows of main cells made of reinforced concrete; each row contains six cells, each measuring 6.3 m in diameter. The silo thus has a storage capacity of 15,000 t. It is worth noting that the construction of all these silos featuring circular cells differed from that of the silos built with circular cells in countries like Spain: in other countries, all such silos were constructed with two rows of cells and a significant separation between the rows, and the intercell space was not utilised for storage, as it was in Portugal [38]. The Vila Boím silo was constructed later, in 1964. It has a square layout and consists of 14 square cells similar to those in the Mértola silo, with a storage capacity of 4000 t. This silo has its tower at one corner, resembling the Type B silos of Spain's national network of silos and granaries [38]. The 1960s ended with the construction of the Alter do Chão silo, built in 1969, consisting of two rows of five primary cells, circular in shape and measuring 5.45 m in diameter. The silo therefore has a storage capacity of 8000 t. These silos are not very tall, ranging from 26 m (the Santa Catarina da Fonte do Bispo silo) to 45 m (the silo inside Beja). The Beato silo is much taller, 65 m. These silos are significantly taller than Spanish silos from the 1960s, which rarely exceeded 30 m in height [28].

3.2.2. Silos from the 1970s

The silos built from the 1970s onwards all contain circular cells and have a rectangular layout, with the tower located at one of their front ends. In these silos, the cells are grouped into two or three rows, although the intercell spaces are also utilised for storage, effectively creating three or five rows of cells (alternating between the circular primary cells and the intercell spaces). Silos with three rows form the majority, 58.6%, and they tend to have larger capacities. The rows of cells are elevated four meters above the ground, leaving a practically open ground floor for unloading grain. Their storage capacities vary from 6000 t (the Mogadouro silo) to 35,000 t (the Reguengos de Monsaraz silo). These silos are taller, ranging from 37.5 m (the Aljustrel silo) to 70 m (the silo outside Beja). The Leixões port silo was built in 1978. It has a rectangular layout with the elevator tower at one end and three tows of 60 m tall circular storage cells having a diameter of eight meters per cell. The main cells have a capacity of 2000 t, while the internal cells have a capacity of 600 t. All are raised off the ground. The silo has a storage capacity of 100,000 t. The tower is connected via a 30 m-high metal walkway to a battery of 3 × 3 dispatch cells, which are 5 m in diameter and 30 m tall. These dispatch cells are positioned above three truck unloading points. The last silos in the EPAC network were built in the 1980s. One of the last two was constructed in 1984 in Funchal, the capital of Madeira Island. This silo was later demolished. The other was built in 1986 at the port of Trafaria. That is the last EPAC silo built to receive large ships and unload grain from them quickly for storage in the silo, transfer to smaller ships, or transfer to barges that would then sail up the Tagus River to unload at shallower ports. The Trafaria silo consists of circular cells with diameters of 8 and 10 m, raised off the floor. They are grouped into four rectangular modules, two of which have three rows of cells apiece, and the other two have four rows, for a total of 114 storage cells. Standing 70 m tall, the silo can hold 200,000 t. Its elevator tower is located at one corner of one of its cell groups. Additionally, the silo has an elevated bulk discharge cell module consisting of 10 cells located above five truck-loading points. This silo is a true building/machine complex, to use the term Azcárate [43] coined for modern Spanish silos. In capacity, these silos far surpass contemporary Spanish silos, only two of which can hold more than 30,000 t [5].

3.2.3. Construction Features

Only in the early silos is the structure made of reinforced concrete pillars and beams with square-shaped reinforced brick walls. The vast majority of EPAC silos (93.3%) have circular cells constructed of reinforced concrete. This differs greatly from Spanish silos, only the most modern of which are made of reinforced concrete [5]. All silos have one or more receiving hoppers where the grain from incoming vehicles (lorries and/or trains) falls into a pit to be subsequently lifted to the top of the silo. Likewise, all silos have an elevator tower. This is where the grain-lifting machinery, seed selection machinery, the staircase, and the elevator are located. The tower is, therefore, always several metres taller than the rest of the silo, so that grain can be dropped from the vertical elevators to the upper horizontal conveyors and from there to the cells (Figure 5). The tower is usually positioned at the front of the silo, at one of its two ends (in 83.3% of silos), or else at one of the corners of the silo (as at the Vila de Boím and Trafaria silos) or in a lateral position (as at the Mértola silo). Sometimes, when a silo is expanded, the tower ends up inside the silo (Vale de Figueira and Beato silos). The elevator tower is built out of reinforced concrete pillars and slabs, with brick walls that are rendered on both sides and painted a cream colour on the outside.

In the most modern silos, the walls in the storeys housing the selection machinery are made of reinforced concrete. The tower has windows on all storeys, with variations between silos. The Evora silo's tower is exceptionally spacious, as it was designed to accommodate a large amount of cleaning, sorting, and weighing machinery (Figure 6a). In 53.4% of the towers visited, there is a 10,000 L reservoir at the very top to provide water for the firefighting system. The layout and characteristics of the towers closely resemble those of Spanish silo towers, as they serve the same purpose [38]. The most common silo roofs are flat roofs (found in 56.7% of silos) and symmetrical gable roofs (40.0%); of the remainder, some are domed, while others are inclined flat roofs or inclined roofs (Figure 6b,c). Most of the flat roofs are finished with waterproofing membranes installed on top of a reinforced concrete support structure. Inclined roofs are covered with fibre cement sheets or metal plates, supported by rafters and concrete beams in older silos, and by steel frames and metal rafters in newer ones. All silos except the oldest have downspouts outside. The facades are formed by the outer walls of the storage cells. The vast majority (93.3%) of these storage cells form a wall that is semicircular in outline, the exceptions being the silos in Mértola and Vila de Boím, whose cells form straight walls. The facade material is reinforced concrete painted white, except for the silos in Mértola and Vila de Boím, which are made of reinforced brick and are rendered with mortar. The semicircular walls may be divided into three types. In Type I semicircular facades, which account for 16.7% of the cases, the semicircles stand on top of the ground storey, which is rectangular with straight walls. The semicircular portion ends at the top of the cells, where there is another straight-walled, rectangular section that forms the upper corridor (Figure 6d). In Type II semicircular facades, which account for over half of the silos (53.3%), the semicircles stand on the ground, rise as far as the cells do, and are topped with a section similar to the one found in Type I (Figure 6e). Most modern silos (23.3%) have Type III semicircular facades. In Type III, the semicircles start at ground level and rise to several meters above the end of the cells to create the upper corridor, providing continuity of line and giving the building structure a more robust appearance (Figure 6f).

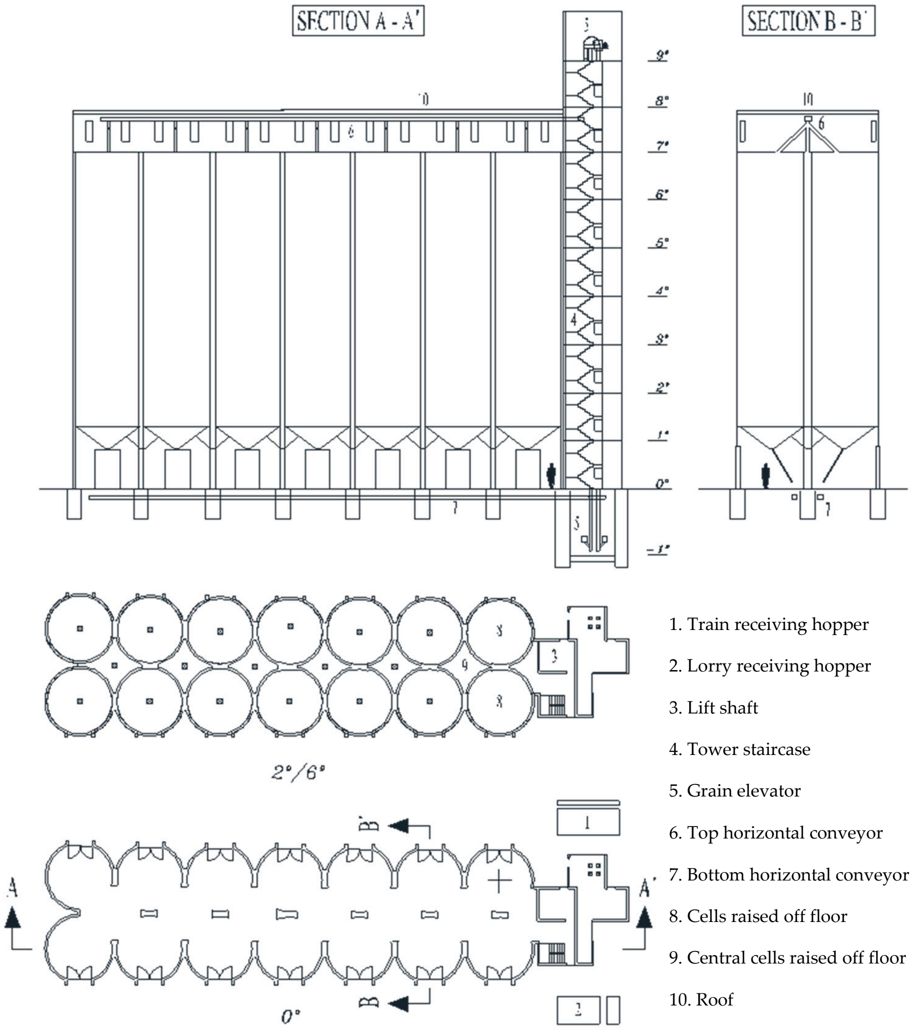

Figure 5. Cross-section and plan view of a typical EPAC silo.

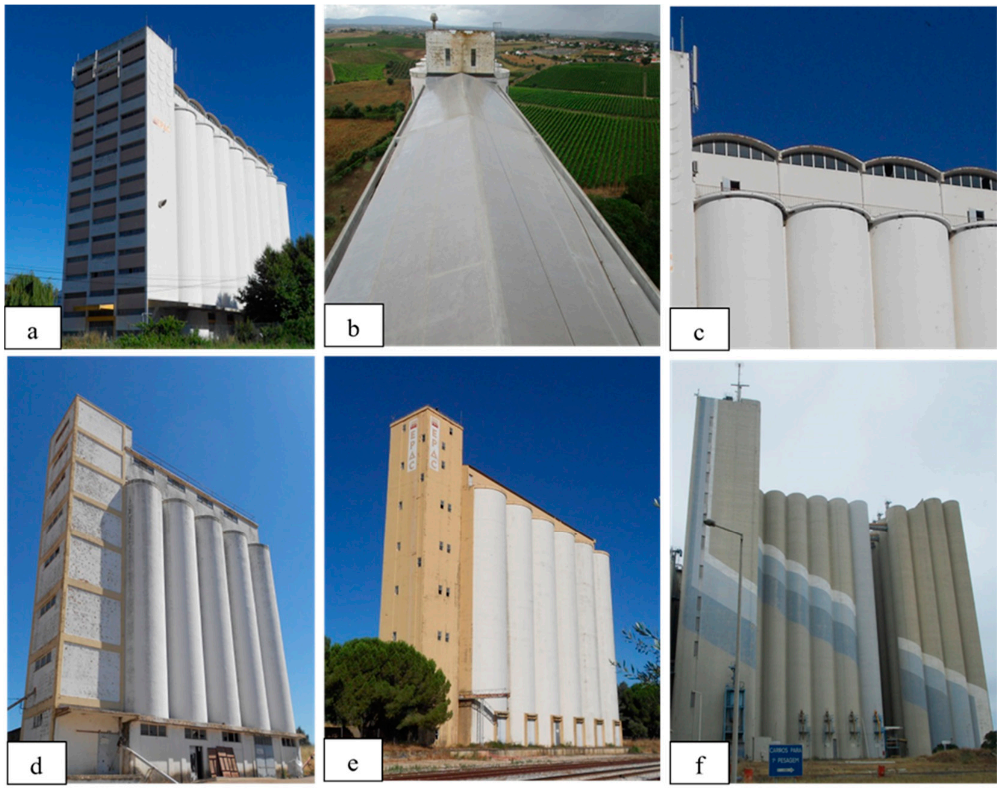

Figure 6. EPAC silo construction details: (**a**) tower at the silo in Evora, Alentejo, (**b**) gable roof on the silo in Vale Figueria, Centre, (**c**) curved roof on the silo in Evora, Alentejo; Different types of semicircular façades: (**d**) Type I, silo in Alter do Chão, Alentejo; (**e**) Type II, silo in Portoalegre, Alentejo; (**f**) Type III, silo in Trafaria, Lisbon.

3.3. Technological Development

3.3.1. Early Silos

The early silos (those built before the 1960s) have an elevator tower with two vertical elevators. These elevators receive the grain unloaded into the external receiving hopper (Figure 7a). One elevator runs to the top of the silo to feed one or two upper horizontal conveyors that drop the grain through tubes to the cells. The other shorter elevator carries grain to the cleaning machinery and is used only if grain has to be weighed, selected, or processed to remove impurities. The cleaning machinery is located halfway up the elevator tower. The elevators have a housing with a circular or rectangular cross-section, inside of which a belt ascends on one side and descends on the other, with buckets that lift the grain to the top (Figure 7b). These elevators have characteristics similar to those of silos in other countries, like Spain [38].

The conveyors consist of a square-section housing and a chain with crossbars that moves inside the housing, dragging the grain forward (Figure 7c,d). Grain is extracted from the cells at the bottom using manually operated gates that allow the grain to be unloaded onto a lower horizontal conveyor, which then returns the grain to one of the elevators to gain height so it can go through selection, bagging, or bulk dispatching, depending on what is needed (Figure 7e,f). Even these early silos are fitted with a pneumatic system for vacuuming up dust at points where dust is likely to be created, unlike Spanish silos of the 1950s and 1960s, which were rarely equipped with dust collection systems [38]. This system ends in an extractor and a settling cyclone where the larger particles settle out and are collected (Figure 7g).

Figure 7. (**a**) Reception hopper in silo in Aljustrel, Alentejo; (**b**) grain elevator and detail of elevator scoop in silo in Vila de Boím, Alentejo; (**c**) upper horizontal belt conveyor and loading tubes in silo in Pavia, Alentejo; (**d**) detail of drive chain and crossbars inside upper horizontal belt conveyor in silo in Mogadouro, North; (**e**) offloading tubes and lower horizontal belt conveyor in silo in Mértola, Alentejo; (**f**) external bulk offloading tube in silo in Portalegre, Alentejo; (**g**) dust collector in silo in Vale de Figueira, Centre; (**h**) underground horizontal conveyor from hopper to elevators in silo in Cuba, Alentejo; (**i**) control panel in silo in Ferreira do Alentejo, Alentejo; (**j**) temperature sensor controls in silo at Vale de Figueira, Centre; (**k**) aerial view of Trafaria silos, Lisbon; (**l**) detail of pneumatic unloader working in Trafaria silos, Lisbon; (**m**) online scale in Trafaria silos, Lisbon; (**n**) dispatch cells at Beato silos, Lisbon; (**o**) computerized control room in silo in Leixões, North; (**p**) computer terminal for haulers in Beato silos, Lisbon.

3.3.2. Silos from the 1970s

Silos built from the 1970s onwards can be grouped into two types based on what machinery is installed. First, there are silos built at various inland locations to receive and store grain. These silos have two or three rows of cells, with one or two cell elevators and one or two cleaning and weighing elevators, one to three upper horizontal conveyors for loading the cells, and one or two lower horizontal conveyors for emptying the cells, although grain can be released directly into a vehicle from the cells on the outer row. Branches carrying incoming grain to cells and outgoing grain from cells are opened by manually operated valves and, in some cases, automatic valves. Reception hoppers for grain arriving by both rail and road are located on the sides of the elevator tower; horizontal conveyors are thus required to carry the grain from the bottom of the hoppers to the elevators (Figure 7h). This machinery, which is used for both reception and dispatch, has a capacity of 120–360 t/h. These silos are more highly mechanised than those built decades earlier, and they can handle loading, unloading, cleaning, weighing, and even seed selection simultaneously. They can process large quantities of grain daily, all controlled from a control room on the ground storey of the silo [44,45] (CME, 1969; Sociedade de Construçoes Valura LDA, 1970) (Figure 7i). The majority of the EPAC network silos (80.5%) fall into this group. All these silos have an elevator in the elevator tower, and some of them have probes to monitor grain temperature (Figure 7j). Similarly, all of them have a 60 to 80 t, 14 to 16 m long weighbridge. Bringing railway facilities right up to silos proved to be a significant step forward for grain distribution in Europe, and in the 1970s and 1980s, rail became consolidated as one of the major means of transporting grain, according to Barciela [46]. This statement aligns with the findings of our study, which shows that 54.9% of the silos (all built in the 1970s) have rail reception and dispatch facilities. The function of this group of silos is the same as that of the 'transition and reserve' silos built for Spain's national network of silos and granaries: these silos collected grain from smaller silos and stored it until it could be marketed, and they were therefore located at sites with good road and rail connections [5,47].

3.3.3. Port Silos

The other type of silo built from the 1970s onwards is the port silo (Leixões (1978–1980), Beato (1958–1985), and Trafaria (1986)). Port silos are the largest-capacity silos: together, they account for 50% of the capacity of the entire EPAC network. Port silos are more highly mechanised because they receive grain from large-tonnage ships and need to unload quickly (Figure 7k). For this purpose, they have mechanical and/or pneumatic unloaders with capacities of up to 600 t/h apiece (Figure 7l). These devices are fully reversible and can be used for both unloading and loading. Silos of this type do not have machinery for cleaning and selecting grain; instead, they have automatic online scales for weighing grain and can receive and dispatch at the high rate of 1000–3000 t/h (Figure 7m). In these silos, the number of elevators ranges from 7 in Leixões to 14 in Trafaria, with three upper horizontal conveyors for loading cells in each module or group of cells built at the same time, and three to four lower conveyors for unloading cell groups. There are also 10 to 13 specific grain-dispatching cells apart from the storage cells; the dispatching cells are usually located above the lorry/train dispatch points (Figure 7n). In these silos, operations are fully automated and optimized and are all carried out from control rooms equipped with computer systems that reduce operation times for greater process efficiency (Figure 7o). Systems provide real-time information about the status of each cell, and supplier and customer management programs dispatch goods fully automatically through terminals identifying the hauler, the company, and the goods to be collected (Figure 7p). These silos have probes in each cell to monitor grain temperature continuously. It is worth noting that in over half of the silos, there is a fire protection system consisting of steel pipes with hose connections running from a reservoir at the top of the elevator tower. Additionally, 87% of the silos have a basket-type device for lowering an operator into grain cells.

3.4. Possibilities of Reuse for Portugal's Silos

Currently, just over half of the EPAC silos are being used for grain storage, but some of these silos are expected to become obsolete in the near future. The Portuguese state ought to be aware of the importance of these constructions for the country's strategic grain reserves. Portugal relies heavily on grain imports, and the international panorama has been adverse of late, with armed conflicts and the possibility of blocked marine trading routes. The EPAC silo network can hold enough grain to feed the country for more than nine months, though. To preserve that kind of autonomy, Portugal would be well advised to keep the network in good condition with a view to its strategic food reserve [48]. In Spain in 2017, the cost of getting an old silo running was estimated to be about EUR 6000 for silos in good condition and needing minor repairs and as much as EUR 115,000 for more run-down silos or silos requiring retrofitting to meet explosive atmosphere regulations, bearing in mind that such a proposal might also clash with European antitrust and free competition policies [28]. Furthermore, silos are part of the agro-industrial heritage of the cities and towns of Portugal, and their cultural value as sites of historical and cultural interest is inestimable. They ought to be protected from the dangers threatening them, especially neglect, decay and demolition. It is the government's duty to accord silos the same protection as is given to other parts of the country's heritage [49]. This proposal requires much deeper, more detailed groundwork, with an individual analysis of each silo and its context at all levels, to see how each silo can be protected and, at the same time, imbued with new life and made useful again.

Few repurposing proposals have been submitted, primarily due to the high cost of refurbishing structures like these. Unlike other agro-industrial constructions like flour mills and public slaughterhouses, whose open-plan, single-storey distribution makes them ideal candidates for conversion into museums, cultural centres, and similar venues [50–52], silos are uncomfortably tall and are divided into numerous small cells [28]. Some innovative projects for silo reuse have nevertheless emerged in Portugal [53]. For example, in the Vila Boím silo, all walls inside the ground floor and the attached warehouse have been removed, creating an open-plan meeting place for an energy drink company's promotions and events. Funding was 100% private (Figure 8a,b). The Instituto Lusíada de Cultura (Lusíada Institute of Culture) has been working since 2020 to refurbish an agricultural cooperative's silo in Santa Catarina da Fonte do Bispo, in the municipality of Tavira in the Algarve region, to create Museo Zer0, the first digital art museum in Portugal and Europe. The silo will be transformed to house artists in residence, who will remain there for two or three months at a time to create and prepare their own art shows. The project has used EU Interreg funding [54] (Figure 8c). The Braganza silo will be transformed into the future Museum of the Portuguese Language after a public investment of nearly EUR 11 million. This is the most ambitious Portuguese silo repurposing project yet: the upper gallery and all internal cell walls have been removed, leaving just the outer walls standing. The indoor space has then been reorganised into floors of varying heights, creating a totally different new building. The work was carried out with the economic cooperation of local, national and European institutions. It is hoped that this will have a significant impact on the region both economically and culturally (Figure 8d). There are also other proposals farther from completion, such as the transformation of the Mértola silo into a biological station with a EUR 4.5 million investment linked to the Universidade do Porto (University of Porto) [55]. Another innovative proposal is to create a 'Route of the Silos' in the Alentejo region to showcase and capitalise on silos as a means of attracting population and economic resources to rural areas [12]. In some cases, silos have served as canvases for outdoor murals, as seen in the silo in Agra do Heroísmo on Terceira Island in the Azores (Figure 8e).

Figure 8. Examples of reused silos. (**a**,**b**) Before and after refurbishment of silo in Vila de Boím, Alentejo; (**c**) 3D view of Museo Zer0 in Catarina da Fonte do Bispo, Algarve; (**d**) 3D view of future museum in Braganza, North; (**e**) Silo in Angra do Heroísmo, Isla Terceira, Azores; (**f**) 'Titans' project, silo in Herencia, Spain.

Other countries, like Spain, have seen many ambitious attempts to weave silos into the surrounding urban fabric and give fresh lustre to their value [56]. Several such proposals have been completed. For example, in Fuentes de Andalucía, Sevilla, a silo now holds a museum on its ground storey and a viewing platform on its roof. This project received an award from the Fundación de Patrimonio Industrial de Andalucía (Industrial Heritage of Andalusia Foundation) in 2014 [57]. In Pozoblanco, Córdoba, a more ambitious proposal called for a silo to be integrated into a new building containing a theatre with over 800 seats [58]. The silo in Alcaracejos, Córdoba, has been made over into a spa resort. Where grain was once stored, massages are now given using oils from the local olive trees. The silo in Belorado, Burgos, was transformed into the Museo Internacional de Radiocomunicación

Inocencio Bocanegra (Inocencio Bocanegra International Radiocommunication Museum) in 2013 [59]. In the Spanish province of Ciudad Real, ten silos were painted as part of the 'Titanes' project to promote the social integration of people with disabilities through art, transforming the landscape of La Mancha [60] (Figure 8f). In Italy, the silo at Livorno harbour has been transformed into an event venue, and the port silo in Genoa, known as Silo Hennebique, is being converted into a cruise terminal, hotel, student residence, and multicultural space with an investment of EUR 130 million [61]. In Moscow, the silo known as 'Tank 41′ has been made into a theatre [62], and in Oslo, Norway, a silo has been transformed into the Grünerløkka student quarters [63]. These are some examples of successful silo refurbishment projects. There have also been cases of silo demolition; the silo in Vila Viçosa was demolished over 30 years ago, and the silo at Funchal harbour on the island of Madeira was knocked down in a renovation of the port and Avenida Sá Carneiro. Although government authorities are not very inclined to invest heavily in repurposing silos, there is a growing trend towards unconventional tourism based on ethnographic and industrial assets (old mills, oil mills, wineries, mining structures, etc.). These abandoned, purposeless buildings are being turned into assets, part of the cultural heritage with great potential to enhance the value of their home territory [24,64]. Great contributions to these efforts have been made by organisations like ICOMOS (International Council on Monuments and Sites), which is associated with UNESCO [65]; DOCOCOMO (Documentation and Conservation of buildings, sites and neighbourhoods of the Modern Movement) [66], an organisation inspired by the work of ICOMOS; and associations like ERIH (European Route of Industrial Heritage), which fosters industrial heritage tourism and currently represents over 1800 places in Europe [67]. There is also increasing social awareness in favour of reusing existing buildings instead of constructing new ones for a smaller carbon footprint [63,68–71].

Based on the data in Supplementary Materials Table S2, over half of the EPAC silos are located in towns with more than 10,000 inhabitants. Their reuse could become a cultural and economic resource for the town and a new opportunity for the future. In socioeconomic terms, these towns can be grouped into two categories. The first group consists of towns with over 10,000 inhabitants (including five cities with over 50,000 inhabitants) and a stable or slightly growing population, with occasional exceptions. These towns are well connected by roads, and some even have railway connections (in the case of islands, ports and airports). They engage in an array of economic activities covering the primary, secondary, and tertiary sectors and have a municipal budget of several million euros. For these cities, it is recommended to invest public funds to transform abandoned silos into tourist attractions, venues for cultural activities and sports, business premises, government offices, and public housing [36]. Researchers in Spain included villages with more than 2000 inhabitants in this group, but in Portugal, towns with less than 10,000 inhabitants are mostly losing population and have poor connections [28]. The second group consists of 14 towns and villages with fewer than 10,000 inhabitants, experiencing negative or very negative population trends. These towns are mostly poorly connected and have an economy based mainly on the primary sector. Therefore, public investment cannot be recommended. However, private entrepreneurial initiatives may still be a possibility, as seen in the cases of the silos in Vila de Boím, Portalegre, and Santa Catarina da Fonte do Bispo, Faro.

4. Conclusions

The methodology used by Fernández-Fernández et al. (2023) [24] in Spain to characterise silos and granaries in the secondary network in Castile and Leon, Spain, was adapted for the EPAC silo network in Portugal and used to inventory the EPAC silos and evaluate potential alternatives for their reuse. Adaptation meant taking account of the Portuguese network's unique features, such as its great uniformity of categories (as opposed to the 20 categories of Spanish silos) and the existence of high-capacity, highly mechanised, highly automated port silos (as opposed to the non-existence of port silos in Spain). As a result, a number of variables of no interest were eliminated, and other variables (such as the number of rows of internal cells and the existence of a lift or thermometric sensors) were added.

Although planned in the 1930s, the EPAC silo network was mainly built and used in the 1970s. Its usage declined after the liberalisation of the wheat market and Portugal's accession to the European Economic Community (EEC). Silos are still present in many villages across Portugal and form part of the rural landscape. The silos in the EPAC network are located in 30 towns, primarily in the country's biggest grain-producing regions, especially the Alentejo region, which has the largest number of silos and the greatest storage capacity. Altogether, 31 silos were built for the EPAC network, with a total capacity of 841,100 t, much larger than originally proposed. Most of these silos were enlarged in the 1970s and early 1980s.

Currently, over half of the silos are leased to agricultural cooperatives or private companies. The number of unused silos is expected to increase in the coming years as lease contracts expire because not all tenants may choose to renew. EPAC silos exhibit a range of design and construction characteristics. The first silo, built in 1938 in Mértola, consists of two rows of square cells raised above the ground, constructed with reinforced brick and concrete pillars, with a capacity of 4500 t. In 1952, the first silo with circular cells was constructed in Angra do Heroísmo, with a capacity of 11,000 t. In the 1950s and 1960s, several more silos were built with diverse capacities and designs. From the 1970s onwards, silos were designed with circular cells grouped into two or three rows, with the intercell space used for storage. These silos are taller and have larger capacities, ranging from 6000 to 35,000 t. Their cells are built out of reinforced concrete. Most silos have an elevator tower at one end and a flat or sloping roof. The facades are made of reinforced concrete, mostly painted white.

The technological development of EPAC silos may be divided into various stages. Early silos (those built up to the 1960s) were equipped with vertical elevators that carried grain through tubes to storage cells. Shorter elevators were also used for cleaning and selecting grain. These silos had pneumatic systems to collect dust and extract coarse particles. From the 1970s onwards, two types of silos were built. First, there were reception and storage silos located at inland sites. They were highly mechanised and could perform operations such as loading, unloading, cleaning, weighing, and seed selection. These silos had elevators, horizontal conveyors, and probes to monitor grain temperature. Second, there were port silos designed to unload grain quickly from large vessels. These silos had larger capacities and were outfitted with mechanical or pneumatic unloaders, automatic weighing scales, and automated control systems. They did not have machinery for grain cleaning and selection, but they were equipped with real-time information systems and management programs for cargo dispatch.

The possibility of repurposing silos is now being explored since several silos are expected to fall into disuse by 2030–2035. Unlike other agro-industrial buildings, silos present challenges due to their height and design. However, some innovative initiatives have been proposed, such as converting silos into event venues, museums, or biological stations or creating a silo-based tourist route in the Alentejo region. Other countries, like Spain, have put together successful refurbishment projects, transforming silos into museums, theatres, spas, and homes. While some authorities may be reluctant to invest in repurposing silos, there is a growing interest in utilising existing structures and promoting tourism based on the country's cultural and industrial heritage, to which organisations like ICOMOS, DOCOCOMO, and ERIH are actively contributing. Through reuse, silos could become cultural and economic resources for cities and towns, particularly those with stable populations, good connections, and a well-rounded array of business activities. In short, this research can be considered the first step towards inventorying, documenting, informing about, and enhancing the value of abandoned silos in the defunct EPAC network, as well as raising awareness about the neglected state of some of these properties. Further studies can delve into specific refurbishment proposals for EPAC network silos.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16052116/s1, Table S1: Information collected from the silos in Portugal's EPAC network; Table S2: Indicators for 30 towns in Portugal, sites of 31 silos.

Author Contributions: All authors contributed to the concept and design, acquisition, analysis, interpretation of data and drafting of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data is contained within the article and Supplementary Materials.

Acknowledgments: The authors would like to express their gratitude for the hearty cooperation of the companies, cooperatives, and other entities that lease or own the silos and the invaluable cooperation of the municipal chambers of the territories where the silos are located.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Teague, W.D. *Flour for Man's Bread: A History of Milling*; Minnesota Archive Editions; University of Minnesota Press: New York, NY, USA, 2007.
2. Pereira, J.L. Contribución fiscal del partido de Cáceres durante el siglo XVI: Alcabalas y tercias. *Norba. Rev. Arte Geogr. E Hist.* **1980**, *1*, 71–72. Available online: http://hdl.handle.net/10662/810 (accessed on 8 January 2024).
3. Banham, R. A Concrete Atlantis. In *US Building and European Modern Architecture*; MIT Press: Cambridge, MA, USA, 1989.
4. Salido, J. El almacenamiento de cereal en los establecimientos rurales hispanorromanos. In *Horréa d'Hispanie et de la Méditerranée Romaine*; Arce, J., Goffaux, B., Eds.; Casa de Velázquez: Madrid, Spain, 2011; pp. 127–141.
5. Fernández-Fernández, M.V. Catalogación de Las Unidades de Almacenamiento Vertical de Cereales de la Red Básica de Castilla Y León, Propuesta de Una Nueva Clasificación Y Posibilidades de Reutilización. Master's Thesis, University de León, León, Spain, 2016.
6. DG. Lei de 15 de Julio de 1889. Diário do Governo n.º 156/1889 de 16 de Julho.
7. DG. Decreto de 29 de Agosto de 1889. Diário do Governo n.º 198/1889 de 4 de Setiembre.
8. DG. Lei de 14 de Julio de 1899. Diário do Governo n.º 156/1899 de 15 de Julho.
9. Amaral, L. Política e economia: O Estado Novo, os latifundiários alentejanos e os antecedentes da EPAC. *Anal. Soc.* **1996**, *31*, 465–486.
10. Ribeiro, I.; Diniz, A. Celeiro Epac. A Paisagem Industrial de Évora. *Sci. Antiq.* **2019**, *2*, 153–176.
11. Reis, J. "Lei da Fome": As origens do proteccionismo cerealífero (1889–1914). *Análise Soc.* **1979**, *15*, 745–793.
12. Alves, J.A. Arquiteturas do Trigo: Espaços de Silagem no Alentejo, do Século XIX à Atualidade. Master's Thesis, Universidade de Évora, Évora, Portugal, 2016. Available online: http://hdl.handle.net/10174/19745 (accessed on 8 January 2024).
13. Pais, J.M. Elementos para a história do fascismo nos campos: A campanha do trigo: 1928–1938 (I). *Análise Soc.* **1976**, *12*, 401–473.
14. Machado, J.; Valadas, A.M.; Ferrerira, J.; Marques, M.F.; Gameiro, M.M. Elementos para a história do fascismo nos campos: A «Campanha do Trigo»: 1928–1938 (II). *Análise Soc.* **1978**, *14*, 321–389.
15. Pratas, A.M. Arquitectura e Memoria. Proposta de Reabilitaçao das Moagens de Mértola. Master's Thesis, Universidade de Coimbra, Coimbra, Portugal, 2018.
16. FNPT. *Federação Nacional de Produtores de Trigo: XXV Aniversario*; Federação Nacional de Produtores de Trigo: Lisboa, Portugal, 1958.
17. Galvão, J.M. *A Campanha do Trigo: Comemoração do seu Trigésimo Aniversário: Discurso Proferido na Inauguração do Marco Comemorativo em Agua de Peixes-Viana do Alentejo em 28/12/59*; Minerva Commercial: Beja, Portugal, 1960.
18. Lucena, M. Salazar, a «fórmula» da agricultura portuguesa e a intervençao estatal no sector primario. *Análise Soc.* **1991**, *26*, 97–206. Available online: https://www.jstor.org/stable/41010848 (accessed on 8 January 2024).
19. Palomares, S.; Viscomi, P.; Quintas, A. La patrimonalización rural del sur ibérico. 4rth international congress for heritage education and socialisation in rural áreas. *Zalamea Serena Descomunal. Rev. Iberoam. Patrim. Y Comunidad* **2016**, *1*, 187–200.
20. Mayer, R. *Estabelecimento de Silos Para Trigo em Portugal: Relatório Apresentado à Federação Nacional dos Produtores de Trigo*; Tipográfica, S., Ed.; Livraria Castro e Silva: Lisbon, Portugal, 1938.
21. Lyttelton, A. *Liberal and Fascist Italy: Short Oxford History of Italy: 1900–1945*; Davis, J.A., Ed.; Oxford University Press: Oxford, UK, 2002.
22. Clough, S.B. *The Economic History of Modern Italy*; Columbia University Press: New York, NY, USA, 1964.
23. Ferreira-Lopes, P.; Mateo, C.; Landi, S. La Historia y Fundamentos de la Construcción de la Red Nacional de Silos Mediante un Análisis Comparativo Entre España, Italia y Portugal. In Proceedings of the XII Congreso Nacional y Cuarto Congreso Internacional Hispanoamericono de Historia de la Construcción, Mieres, Spain, 4–8 October 2022.

24. Fernández-Fernández, M.V.; Marcelo, V.; Valenciano, J.B.; González-Fernández, A.B. Characterisation of the National Network of Silos and Granaries in Castilla y León, Spain: A Case Study. *Sustainability* **2023**, *15*, 3755. [CrossRef]
25. Palmeiro, A. Postais Ilustradros: UM Olhar Sobre os Silos do Distrito de Portalegre. In Proceedings of the III Seminário de I&DT, Centro Interdisciplinar de Investigação e Inovação, Instituto Politécnico de Portalegre, Portalegre, Portugal, 6–7 December 2012.
26. DRE. Decreto-Lei 663/76 de 4 agosto de 1976, Institui as Empresas Públicas Empresa Pública do Abastecimento de Cereais (EPAC) e Instituto dos Cereais, E.P. (ICEP), e Aprova os Respectivos Estatutos. Diário da República (Portugal) n.º 181/1976. Série I de 1976-08-04. Available online: https://dre.tretas.org/dre/111961/decreto-lei-663-76-de-4-de-agosto (accessed on 8 January 2024).
27. EPAC. História. Available online: https://epac-comercial.webnode.pt/historia/ (accessed on 8 January 2024).
28. Fernández-Fernández, M.V.; Marcelo, V.; Valenciano, J.B.; López, F.J. History, construction characteristics and possible reuse of Spain's network of silos and granaries. *Land Use Policy* **2017**, *63*, 298–311. [CrossRef]
29. DRE. Decreto-Lei 26/91 de 11 de Janeiro, Transforma A Empresa Pública de Abastecimento de Cereais (EPAC) em Sociedade Anónima. Diário da República (Portugal) n.º 9/1991, Série I-A de 1991-01-11, 175-180. Available online: https://dre.pt/dre/detalhe/decreto-lei/26-693841 (accessed on 8 January 2024).
30. DRE. Decreto-Lei 572-A/99 de 29 de Dezembro, Determina a Dissolução e Regula a Liquidação da EPAC—Empresa Para Agroalimentação e Cereais, S.A. Diário da República (Portugal) n.º 301/1999, 1º Suplemento, Série I-A de 1999-12-29, 2-3. Available online: https://data.dre.pt/eli/dec-lei/572-a/1999/12/29/p/dre/pt/html (accessed on 8 January 2024).
31. DRE. Decreto-Lei nº 188/2001 de 25 de Junho, Regula o Processo de Liquidação da SILOPOR—Empresa de Silos Portuários, S.A., e Estabelece um Conjunto de Regras Sobre a Concessão da Actividade da Empresa. Diário da República (Portugal) n.º 145/2001, Série I-A de 2001-06-25. Available online: https://dre.tretas.org/dre/142331/decreto-lei-188-2001-de-25-de-junho (accessed on 8 January 2024).
32. Vaquero, M. Innovation in times of autarky: The construction of the wheat silos in Fascist Italy. *Fabrikart* **2011**, *10*, 264–277.
33. Verde, P. Representaçao Tipológica Através da Fotografía Silos no Alentejo, Partindo da Obra de Bernd e Hila Becher. Master's Thesis, Universidade de Evora, Evora, Portugal, 2010.
34. Maurílio, F. As arquiteturas do cereal em Évora. In *Património Industrial Ibero-Americano: Recentes Abordagens*; Palomares, S., Quintas, A., de Lima, F., Viscomi, P., Eds.; Biblioteca Estudos & Colóquios, Universidad de Evora: Évora, Portugal, 2020; Serie e-books nº 22; Available online: https://books.openedition.org/cidehus/13907#text (accessed on 8 January 2024).
35. Benito, P. Patrimonio industrial y cultura del territorio. *Boletín Asoc. Geogr. Esp.* **2002**, *34*, 213–227.
36. Mateo, C. Red Nacional de Silos y Graneros de España. In Proceedings of the III International Venue of the Agriculture and Food Production Section of TICCIH, Nogent-sur-Seine, France, 20–22 October 2011.
37. Fernández-Fernández, M.V.; Marcelo, V.; Valenciano, J.B.; Boto, J. Catalogación de los silos pertenecientes a la red española de silos y graneros en Castilla y León. In Proceedings of the IX Congreso Ibérico de Agroengenharia, Braganza, Portugal, 4–6 September 2017.
38. Fernández-Fernández, M.V.; Marcelo, V.; Valenciano, J.B.; López, F.J.; Pastrana, P. Spain's national network of silos and granaries: Architectural and technological change over time. *Span. J. Agric. Res.* **2020**, *18*, e0205. [CrossRef]
39. Han, S.; Zhang, H. Progress and Prospects in Industrial Heritage Reconstruction and Reuse Research during the Past Five Years: Review and Outlook. *Land* **2022**, *11*, 2119. [CrossRef]
40. Giuliani, F.; De Falco, A.; Landi, S.; Bevilacqua, M.G.; Santini, L.; Pecori, S. Reusing grain silos from the 1930s in Italy. A multi-criteria decision analysis for the case of Arezzo. *J. Cult. Herit.* **2018**, *29*, 145–159. [CrossRef]
41. Salamanca, D.; Mateo, C.; Moreno, M.; Rodríguez, L.; Alarcón, A. *Red Nacional de Silos. Integración en la Realidad Urbana Andaluza y su Reutilización Para Nuevas Tipologías*; Junta de Andalucía: Sevilla, Spain, 2011; pp. 45–50. Available online: https://ws132.juntadeandalucia.es/publicaciones/Proyectosdeinvestigacion/45_Red%20Nacional%20de%20Silos/RNSG_tomo%201.pdf (accessed on 8 January 2024).
42. Marcelo, V.; Valenciano, J.B.; López, J.; Pastrana, P. The D5 Silo of Manganeses of the Lampreana (Zamora): History, construction characteristics and technology. In Proceedings of the European Conference on Agricultural Engineering AgEng2021, Évora, Portugal, 4–8 July 2021; Volume 2. Available online: https://www.corpuspublishers.com/assets/articles/aart-v2-21-1028.pdf (accessed on 8 January 2024).
43. Azcárate, C.A. *Catedrales Olvidadas, La Red Nacional de Silos en España 1949–1990*, T6 ed.; Ministerio de Medio Ambiente y Medio Rural y Marino: Madrid, Spain, 2009.
44. CME. *Parecer de Construção de um Silo Para 20000 Toneladas na Horta das Figueiras em Évora*; Acessível no Divisão de Gestão Urbanística da Câmara Municipal de Évora: Évora, Portugal, 1969.
45. Sociedade de Construções Valura LDA. *Memória Descritiva de Silos Para 20000 Toneladas em Évora*; Acessível no Divisão de Gestão Urbanística da Câmara Municipal de Évora: Évora, Portugal, 1970.
46. Barciela, C.F. La modernización de la agricultura y la política agraria. *Papeles Econ. Esp.* **1997**, *73*, 112–133.
47. Moreno, A. Un análisis tecnológico sobre la red nacional de silos y graneros desde la ingeniería industrial en el ámbito agrario: ¿con qué maquinaria y cómo funcionaban? In Proceedings of the I Jornadas de Patrimonio Industrial Agrario: Silos a Debate, Badajoz, Spain, 26–28 September 2014.
48. Instituto Nacional de Estatística Portugal. Estatística Agrícolas 2022. Available online: https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=620831430&PUBLICACOESmodo=2 (accessed on 21 February 2024).

49. The Declaration of Amsterdam—1975. Available online: https://www.icomos.org/en/and/169-the-declaration-of-amsterdam (accessed on 21 February 2024).
50. Pardo, C.J. El patrimonio industrial en España: Análisis turístico y significado territorial de algunos proyectos de recuperación. *Boletín Asoc. Geogr. Esp.* **2010**, *53*, 239–264.
51. Fuentes, J.M.; López-Sánchez, M.; García, A.I.; Ayuga, F. Public abattoirs in Spain: History, construction characteristics and the possibility of their reuse. *J. Cult. Herit.* **2015**, *16*, 632–639. [CrossRef]
52. Fuentes, J.M.; García, A.I.; Ayuga, E.; Ayuga, F. The development of the flour-milling industry in Spain: Analysis of its historical evolution and architectural legacy. *J. Hist. Geogr.* **2011**, *37*, 232–241. [CrossRef]
53. Matoso, R. Visita a antigos espaços industriais—Antigos Celeiros da Epac e Antiga Fábrica de escolha de sementes de trigo. In *Ciclo de Conferências «Cultura, Espaço Público e Desenvolvimento—Que Opções Para uma Política Cultural Transformadora»*; Universidade de Évora: Évora, Portugal, 2014; pp. 33–36.
54. MZ. Museo Zer0. Available online: https://www.museu0.pt/ (accessed on 8 January 2024).
55. Radiopax. Mértola: Antigos Celeiros da EPAC vão Transformar-se numa Estação Biológica. Available online: https://www.radiopax.com/mertola-antigos-celeiros-da-epac-vao-transformar-se-numa-estacao-biologica/ (accessed on 8 January 2024).
56. Aguilar, E.; Merino, D.; Migens, M. Cultura, políticas de desarrollo y turismo rural en el ámbito de la globalización. *Horiz. Antropol.* **2003**, *20*, 161–183. [CrossRef]
57. FUPIA. Se fallan los Premios Fundación Patrimonio Industrial de Andalucía. Fundación Patrimonio Industrial de Andalucía. Available online: http://www.fupia.es (accessed on 8 January 2024).
58. Junta de Andalucía. *Informe Final, Año 2006, Sobre el Expediente POZ/2004/SIL Sobre La Actuación Completa en el Silo de Pozoblanco Iniciado en 2004*; Junta de Andalucía, Consejería de Agricultura, Pesca y Desarrollo Rural: Sevilla, Spain, 2006.
59. MIRIB. Museo Internacional de Radiotransmisión Inocencio Bocanegra. Available online: https://www.museobocanegra.com/ (accessed on 8 January 2024).
60. Titanes. Arte Público e Inclusión Social. Available online: https://iamtitanes.com/ (accessed on 8 January 2024).
61. Comune di Genova. Bando Pubblico per la Ristrutturazione e la Gestione del Silos Hennebique. Available online: https://www.portsofgenoa.com/it/archivio-notizie/item/1357-hennebique.html (accessed on 8 January 2024).
62. Río, A.S.; Blanco, S. La tempestad en el silo: Reutilización de un almacén de grano para representaciones teatrales. In *Espacios Industriales Abandonados. Gestión del Patrimonio y Medio Ambiente*, 15th ed.; Colección: Los ojos de la memoria; INCUNA, CICEES, Miguel, A., Eds.; Álvarez Areces: Gijón, Spain, 2015; pp. 433–440.
63. Salazar, A. Del Trigo al Hombre. Rehabilitar el Silo. Master's Thesis, Máster en Intervención Sostenible en el Medio Construido, Escuela Técnica Superior de Arquitectura del Vallès, Universidad politécnica de Cataluña, Barcelona, Spain, 2015.
64. Laumain, X.; López, A.; Moreno, J.; Sánchez, D. Turismo Como Desencadenante de la Recuperación de Patrimonio Industrial. In Proceedings of the III Jornadas de Patrimonio Industrial Activo, Murcia, Spain, 15–16 November 2013.
65. ICOMOS (International Council on Monuments and Sites). Available online: https://www.icomos.org/en#:~:text=International%20Council%20on%20Monuments%20and%20Sites,-Print (accessed on 21 February 2024).
66. DOCOCOMO (Documentation and Conservation of Buildings, Sites and Neighbourhoods of the Modern Movement). Available online: https://docomomo.com/ (accessed on 21 February 2024).
67. ERIH (European Route of Industrial Heritage). Available online: https://www.erih.net/ (accessed on 21 February 2024).
68. García, A.I.; Ayuga, F. Reuse of abandoned buildings and the rural landscape: The situation in Spain. *Trans. ASABE* **2007**, *50*, 1383–1394. [CrossRef]
69. Fuentes, J.M. Methodological bases for documenting and reusing vernacular farm architecture. *J. Cult. Herit.* **2010**, *11*, 119–129. [CrossRef]
70. Fuentes, J.M.; Gallego, E.; García, A.I.; Ayuga, F. New uses for old traditional farm buildings: The case of the underground wine cellars in Spain. *Land Use Policy* **2010**, *27*, 738–748. [CrossRef]
71. Cano, M.; Garzón, E.; Sanchez-Soto, P.J. Historic preservation, GIS, & rural development: The case of Almería province, Spain. *Appl. Geogr.* **2013**, *42*, 34–47. [CrossRef]

Supplementary Materials. Table S1.—Information collected from the silos in Portugal´s EPAC network.

Region	District	Town/Village	Geolocation	Year construction	Extension year	Ownership	Use	State of conservation	Category	Capacity (t)	Height (m)	Ground plan	Roof shape	Tower position	No. of storage cells	No. of rows of cells	No. of rows of internal cells	Shape of cells	Cell dimensions (m)	Façade types	Constr. Mat.	Receiving machinery cap. (t/h)	No. elevators	Nº upper storey horizontal conveyors	Nº down storey horizontal conveyors	Firefighting system	Lift	Thermometric sensors	Railway	Lorry weighbridge (t)	Railway weighbridge (t)
Alentejo	Beja	Aljustrel	37°52'47.0"N 8°09'25.7"W	1970	1973/78	LC	GS	1	CF	14,500	37.5	S	F	FT	43	3	2	C	5.4	SII	RC	120	2	2	2	N	Y	N	N	30	
Alentejo	Beja	Inside Beja	38°01'18.2"N 7°51'38.2"W	1961		LC	WU	2	CF	15,000	45.0	S	2	FT	28	3	2	C	6.3	SII	RC	240	3	3	2	Y	Y	N	N	30	
Alentejo	Beja	Outside Beja	38°01'55.6"N 7°52'15.5"W	1977	1981	PS	GS	1	CF	26,500	70.0	S	2	FT	48	3	2	C	7.0	SII	RC	360	3	3	2	Y	Y	N	Y	60+100	200
Alentejo	Beja	Cuba	38°09'57.5"N 7°53'49.4"W	1973	1980	LC	GS	1	CF	23,500	42.5	S	F	FT	35	2	1	C	6.5	SIII	RC	120	2	2	1	N	Y	N	Y	50	200
Alentejo	Beja	Ferreira do Alentejo	38°03'44.9"N 8°07'10.8"W	1973	1976	LC	GS	1	CF	23,500	44.1	S	F	FT	32	2	1	C	6.5	SIII	RC	120	2	2	1	Y	Y	N	N	60	
Alentejo	Beja	Mertola	37°38'12.5"N 7°39'39.2"W	1938		PS	WU	2	R	4,500	37.5	S	F	ST	17	2		S	2.3	ST	RB	120	2	2	1	N	N	N	N	50	
Alentejo	Beja	Moura	38°08'10.3"N 7°26'47.4"W	1974		LC	GS	1	R	10,000	43.2	S	F	FT	17	2	1	C	6.5	SII	RC	120	2	2	1	N	Y	N	N	30+60	
Alentejo	Beja	Serpa	37°56'49.8"N 7°36'16.0"W	1974	1980	LC	GS	1	CF	19,000	44.1	S	F	FT	32	2	1	C	6.5	SIII	RC	120	2	2	1	Y	Y	N	N	30+60	
Alentejo	Evora	Estremoz	38°50'36.9"N 7°34'50.5"W	1973	1979	PS	WU	2	CF	16,000	43.4	L	2	FT	29	2	1	C	6.5	SII	RC	120	2	4	2	Y	Y	N	N	50	
Alentejo	Evora	Evora	38°33'40.1"N 7°54'29.3"W	1971	1976	LC	GS	1	CF	23,000	45.1	S	V	FT	38	3	2	C	6.3	SI	RC	240	4	2	2	N	Y	N	Y	60	200
Alentejo	Evora	Pavia	38°52'43.0"N 8°01'00.6"W	1976	1979	PS	WU	2	CF	18,000	45.4	S	2	FT	29	2	1	C	6.5	SII	RC	120	2	2	1	Y	Y	N	Y	60	200
Alentejo	Evora	Reguengos de Monsaraz	38°25'25.6"N 7°32'31.3"W	1976	1979	LC	GS	1	CF	35,000	43.2	S	2	FT	41	2	1	C	6.5	SII	RC	120	2	2	1	Y	Y	N	Y	60	200
Alentejo	Evora	Vila Viçosa	38°46'45.8"N 7°25'34.0"W	1973			WU	4	R	2,300																			Y		
Alentejo	Portalegre	Alter do Chão	39°12'03.1"N 7°39'21.0"W	1969		LC	GS	1	R	8,000	37.5	S	F	FT	14	2	1	C	5.5	SI	RC	120	2	1	1	N	N	N	N	50	
Alentejo	Portalegre	Elvas	38°53'44.6"N 7°08'18.1"W	1970		LC	GS	1	CF	15,000	47.0	S	2	FT	28	3	2	C	6.5	SII	RC	240	2	2	1	Y	Y	N	Y	80	200
Alentejo	Portalegre	Fronteira	39°02'50.6"N 7°38'36.9"W	1973	1979	LC	GS	1	R	16,000	43.2	S	2	FT	29	2	1	C	6.5	SII	RC	120	2	2	1	Y	Y	N	Y	30+80	200

Alentejo	Portalegre	Portalegre	39°11'58.7"N 7°27'47.3"W	1978		PS	WU	2	CF	10,000	45.5	S	2	FT	17	2	1	C	6.5	SII	RC	120	2	2	1	Y	Y	N	Y	60	200
Alentejo	Portalegre	Vila de Boim	38°51'43.8"N 7°16'22.0"W	1964		PC	R	3	R	4,000	40.0	S	F	CT	14	3		S	2.0	ST	RB	100	2	1	1	N	N	N	N	30	
Algarve	Faro	Santa Catarina da Fonte do Bispo	37°09'13.8"N 7°47'07.4"W	1958		LI	R	3	R	1,300	18.0	S	F	FT	14	2	1	C	3.6	SII	RC	50	2	1	1	N	N	N	N	50	Sur
Azores	Punta Delgada	Punta Delgada	37°44'43.6"N 25°39'03.4"W	1972	1978	PC	GS	1	R	34,000	45.0	S	F	FT	61	3	2	C	6.0	SII	RC	120	3	4	4	Y	Y	N	N	60	
Azores	Angra do Heroismo	Angra do Heroismo	38°39'17.0"N 27°12'46.3"W	1953	1975	PS	WU	1	R	21,000	40.0	S	F	FT	35	3, 2	2, 1	C	6.5	SII	RC	120	3	3	3	Y	Y	N	N	60	
Centro	Castelo Branco	Alcains	39°55'12.4"N 7°26'09.1"W	1977		PS	WU	2	CF	10,000	37.5	S	2	FT	17	2	1	C	6.0	SI	RC	120	2	2	1	Y	Y	N	Y	60+80	200
Centro	Leiria	Caldas de Rainha	39°24'08.6"N 9°08'21.7"W	1959		PS	WU	2	R	6,500	32.0	S	F	FT	18	3	2	C	5.5	SI	RC	120	2	2	1	N	N	N	Y	50	200
Centro	Santarem	Vale de Figueria	39°18'59.4"N 8°37'43.5"W	1977	1979	LPS	GS	1	CF	24,000	37.0	S	2	FT, IT	34	2	1	C	6.0	SII, SIII	RC	120	4	2	1	Y	Y	Y	Y	60+100	200
Lisboa	Lisboa	Beato	38°44'06.3"N 9°06'09.8"W	1958	1962/75/85	LPS	GS	1	P	120,000	65.0	S	2	FT, IT	128	3	2	C	7-13	SII, SIII	RC	1,000	13	8	9	N	Y	Y	Y	70+2x100	200
Lisboa	Lisboa	Vila Franca de Xira	38°57'47.8"N 8°59'02.3"W	1956		PC	WU	2	R	6,500	33.0	S	F	FT	11	2	1	C	6.0	SI	RC	120	2	1	1	N	N	N	Y	30	200
Lisboa	Setubal	Caparica e Trafaria	38°40'21.9"N 9°14'15.9"W	1986		LPS	GS	1	P	200,000	60.0	S	2	CT	114	4, 3	3, 2	C	8-10	SIII	RC	3,000	14	10	8	N	Y	Y	N	5x 100	
Madeira	Funchalñ	Funchal	32°38'33.6"N 16°55'00.1"W	1984		PS	WU	4	P	16,000	47.0	S	F	FT	21	3	2	C	6.0	SII	RC	240	3	3	3	Y	Y	N	N	60	
Norte	Braganza	Braganza	41°48'01.1"N 6°46'13.2"W	1973	1978	M	R	3	CF	12,000	37.7	S	F	FT	20	2	1	C	6.5	SIII	RC	120	2	2	1	Y	Y	N	Y	80	200
Norte	Braganza	Mogadouro	41°20'02.2"N 6°39'02.7"W	1973		PS	WU	2	R	6,000	37.5	S	F	FT	11	2	1	C	6.5	SIII	RC	120	2	1	1	N	Y	N	Y	80	200
Norte	Oporto	Leixoes. Matosinhos	41°12'00.3"N 8°40'54.3"W	1978	1980	LPS	GS	1	P	100,000	60.0	S	F-2	FT	76	3	2	C	8.0	SII	RC	1,000	5	3	3	N	Y	Y	Y	2x 100	200

Geolocation: coordinates ETRS 89 Use 30. Ownership: PS: Portuguese state; LC: lease to cooperative; LPC: lease to private company; LI: lease to institute; PC: private company; M: municipality Use: GS: grain storage: R: reused; WU: without use. State of conservation: 1: in use; 2: abandoned and poor condition; 3: rehabilitated; 4: demolish. Category: R: regional; CF: concentration or final; P: Port. Ground plan: S: square; L: L-shape. Roof shape: F: flat roof; 2: gable roof; F-2: flat and gable roof; V: vaulted roof. Tower position: FT: front tower; ST: side tower; CT: corner tower; IT: interior tower. Form of cells: CI: circular; S: Square. Façade types: ST: straight; SI: semicircular type I: Consisting of straight façade, semi-circular façade and straight façade; SII: semicircular type II: Consisting of semi-circular façade and straight façade; SIII: semicircular type III: Consisting of semi-circular façade only. Cell construction material: RB: reinforced brick; RC: reinforced concrete. Railway: Y: exist; N: does not exist. Firefighting system: Y: exist; N: does not exist. Lift: Y: exist; N: does not exist. Thermometric sensors: Y: exist; N: does not exist.

Supplementary Materials. Table S2.- Indicators for 30 villages in Portugal, sites of 31 silos.

Region	District	Village	Population	Demographic pattern	Annual village budget (€)	Economic activity	Land communications	Distance to major urban centre (km)
Alentejo	Beja	Aljustrel	8,879	-1	37,481,577	1	N	Beja 37, Evora 96, Faro 130, Lisboa 164
Alentejo	Beja	Beja	33,401	0	40,540,647	1, 3	N, T	Evora 80, Faro 147, Lisboa 176
Alentejo	Beja	Cuba	4,378	-1	7,979,609	1, 3	P	Beja 20, Evora 67, Faro 166, Lisboa 177
Alentejo	Beja	Ferreira do Alentejo	7,686	-1	20,053,091	1, 3	N	Beja 24, Evora 74, Faro 149, Lisboa 153
Alentejo	Beja	Mertola	8,712	-2	19,041,908	1, 3	P	Beja 53, Ayamonte 67, Huelva 114, Faro 117, Lisboa 234
Alentejo	Beja	Moura	13,259	-2	35,095,085	1, 3	N	Beja 52, Evora 78, Sevilla 185, Faro 203, Lisboa 209
Alentejo	Beja	Serpa	13,764	-1	27,762,400	1, 2, 3	N	Beja 28, Evora 102, Faro 166, Sevilla 203, Lisboa 203
Alentejo	Evora	Estremoz	13,683	-1	20,169,328	1, 2, 3	N, M	Elvas 43, Evora 47, Badajoz 72, Beja 125, Lisboa 171
Alentejo	Evora	Evora	53,591	0	49,824,915	2, 3	N, M, T	Beja 80, Badajoz 101, Lisboa 134
Alentejo	Evora	Pavia	932	-1	2,400,674	1	N	Evora 38, Elvas 91, Badajoz 104, Lisboa 143
Alentejo	Evora	Reguengos de Monsaraz	9,871	-1	14,241,037	1	N, T	Evora 39, Badajoz 99, Lisboa 170
Alentejo	Evora	Vila Viçosa	8,871	0	11,672,154	1, 2, 3	N	Elvas 31, Badajoz 58, Evora 63, Lisboa 187
Alentejo	Portalegre	Alter do Chão	3,044	-1	9,481,442	1	N	Elvas 62, Evora 93, Badajoz 79, Lisboa 195
Alentejo	Portalegre	Elvas	20,753	0	30,828,796	1, 2, 3	N, M, T	Badajoz 20, Evora 84, Lisboa 208
Alentejo	Portalegre	Fronteira	2,858	-2	5,303,650	1	N	Elvas 53, Evora 74, Badajoz 77, Lisboa 180
Alentejo	Portalegre	Portalegre	22,341	-1	27,666,431	1, 2, 3	N, M, T	Elvas 58, Badajoz 68, Evora 103, Caceres 128, Lisboa 227
Alentejo	Portalegre	Vila de Boim	2,109	-1	3,132,941	1,	N, M	Elvas 10, Badajoz 33, Evora 73, Lisboa 197
Algarve	Faro	Santa Catarina da Fonte do Bispo	2,085	1	2,506,847	1, 3	N, M	Faro 26, Albufeira 54, Lagoa 73, Lagos 104
Azores	Punta Delgada	Punta Delgada	67,287	1	38,215,821	1, 2, 3	N, M, Port, Airport	Flights to many European capitals especially between April and October. Port of call for cruise ships.
Azores	Angra do heroismo	Angra do Heroismo	35,402	0	26,291,101	1, 2, 3	N, M, Port, Airport	Flights to many European capitals especially between April and October.
Centro	Castelo Branco	Alcains	4,615		4,943,975	2, 3	N, M, T	Castelo Branco 12, Guarda 89, Coimbra 148, Lisboa 230
Centro	Leiria	Caldas de Rainha	50,917	0	36,864,045	2, 3	N, M, T	Santarem 56, Lisboa 93, Entrocamento 91
Centro	Santarem	Vale de Figueria	1,294	-1	982,151	1	P	Santarem 12, Entroncamento 29, Lisboa 91
Lisboa	Lisboa	Beato	14,241	0	33,927,384	2, 3	N, M, T, Port	Lisboa 5, Santarem 79, Evora 132
Lisboa	Lisboa	Vila Franca de Xira	137,540	1	78,891,043	2, 3	N, M, T	Lisboa 35, Santarem 51, Entroncamento 87
Lisboa	Setubal	Trafaria	26,357	0	146,545,738	1, 2, 3	P, Port	Lisboa 16, Evora 134, Badajoz 227
Madeira	Funchal	Funchal	105,795	1	104,080,116	2, 3	N, M, Port, Airport	Flights to many European capitals especially between April and October. Port of call for cruise ships.
Norte	Braganza	Braganza	34,582	0	46,148,600	1,2, 3	N, M,	Zamora 103, Vila Real 118, Oporto 207, Braga 217
Norte	Braganza	Mogadouro	8,304	-2	10,985,000	1	N, M	Braganza 74, Mirandela 78, Zamora 101, Vila Real 125, Salamanca 133
Norte	Oporto	Matosinhos	172,577	0	133,272,282	2, 3	N, M, T	Oporto 9, Braga 59, Viana do Castelo 70

Demographic pattern: -2: significant decline; -1: slight decline; 0: stable; 1: slight rise; 2: significant rise. Economic activity: 1: primary sector; 2: secondary sector; 3: tertiary sector. Land communication: P: poor; N: national road; M: motorway; T: railway