ANALES de Edificación

Received: 17/03/2024
Accepted:23/04/2024

Anales de Edificación
Vol. 10, Nº1, 54-65 (2025)
ISSN: 2444-1309
DOI: 10.20868/ade.2025.5401

Estudio energético para la rehabilitación de la antigua Abadía de Salas de Bureba (Burgos) para uso residencial. Caso de estudio

Energy study for the rehabilitation of the old Abbey of Salas de Bureba (Burgos) for residential use. Case study

Raúl Briones-Llorente[a]; Juan María Hidalgo-Betanzos[b]; Paula Montoya Saiz[c]; Imanol Ruiz de Vergara Ruiz de Azúa[b]; Gabriel Rubio-Pérez[a]; Natalia Muñoz-Rujas[a]; Fernando Aguilar Romero[a]

[a] Grupo de Investigación en Ingeniería Energética (iENERGÍA), Departamento de Matemáticas y Computación, Universidad de Burgos, Facultad de Ciencias, Plaza Misael Bañuelos, s/n, 09001 Burgos, España, rbriones@ubu.es, grubio@ubu.es, nmrujas@ubu.es, faguilar@ubu.es

[b] Grupo de Investigación Energética en la Edificación (ENEDI), Departamento de Ingeniería Energética, Universidad del País Vasco UPV/EHU, Escuela de Ingeniería de Bilbao, Plaza Ingeniero Torres Quevedo 1, 48013 Bilbao, España, juanmaria.hidalgo@ehu.eus,

Resumen-- **La rehabilitación de edificios es clave para luchar contra el cambio climático y ofrece oportunidades para fijar población en el medio rural, revalorizar su patrimonio y ayudar a descongestionar las ciudades. Además, tiene un menor impacto ambiental que la nueva construcción. Con esta contribución, se presenta el estudio energético para la rehabilitación de la antigua Abadía de Salas de Bureba, situada en el Valle de Caderechas, al Norte de Burgos. El objetivo es devolver el edificio a su estado original, por lo que la mayoría de las fachadas no se van a poder aislar. Se ha realizado una simulación energética en detalle y se han analizado todas las opciones viables, aplicando mejoras pasivas combinadas con la instalación de energías renovables. Este proyecto, cuya ejecución ya ha comenzado, ha obtenido una calificación energética doble A, lo ha permitido que opte a las ayudas del Programa PREE 5000.**

Palabras clave— Eficiencia energética; patrimonio; rehabilitación; reto demográfico.

Abstract— **The renovation of buildings is key to the fight against climate change and offers opportunities to fix the population in rural areas, revalue their heritage and help decongest cities. In addition, it has a lower environmental impact than new construction. With this contribution, the energy study for the rehabilitation of the old Abbey of Salas de Bureba, located in the Caderechas Valley, north of Burgos, is presented. The aim is to return the building to its original state, so most of the facades will not be able to be insulated. A detailed energy simulation has been conducted and all viable options have been analysed, applying passive improvements combined with the installation of renewable energies. This project, whose implementation has already begun, has obtained a double A energy rating, which has allowed it to apply for aid from the PREE 5000 Programme.**

Index Terms— Energy efficiency; heritage; rehabilitation; demographic challenge.

I. INTRODUCTION

In this first section, the building is presented to understand its historical and architectural importance, the pathologies of the current state and the scope of the intervention.

A. Historical description of the building

The first reference to the Abbey of Salas de Bureba is made by Emiliano Nebreda (Nebreda Perdiguero, 2016), who states that: "attached to its northern gable (that of the church) is

R.B.L, G.R.P., N.M.R., and F.A.R. are associate professor at Departamento de Mátemáticas in Faculty of Science, University of Burgos. J.H.B. and I.R.deV. are associate professor at Energy Engineering Department at Universidad del País Vasco. P.M.S. is assistant professor at Energy Engineering Department at Universidad del País Vasco.

Fig. 1 and 2: Views of the building, and of the Tower. (Source: Paula Montoya Saiz)

preserved the building of an old palace, which previously housed a Benedictine abbey, which tradition maintains was founded by King Recesvin in the year 666."

It appears in some chronicles as the year of the foundation of an abbey of Benedictine nuns in Salas in the year 966: "in the year 966 a Benedictine monastery was founded in this municipality that was not united to Oña until 1011, as stated in the founding document of the Oniense abbey, signed by Count Don Sancho and his wife Doña Urraca, his daughter Tigridia was abbess. In 1067 Don Sancho II donated a serna in Salas to the monastery and in 1085, Pedro Díaz donated a fifth of his property in the town to his parish church. Two years later he granted the Cathedral of Burgos the church of Santa María, deciding to bury him in it" (Fundación Santa María la Real, 2019), and already with a historical and documented character, it is cited: "the foundation by D. Pedro Díaz in 1087 of the abbey of Salas de Bureba, added to the Cathedral of Burgos" (Serrano 1935).

This detail of "added to the Cathedral of Burgos" is important and we find in the archive of the Cabildo numerous entries about the abbey of Salas or its abbots, although they do not provide information on its construction or subsequent modifications (Cabildo Burgos 1556). It is possible that the first monastery of Benedictine nuns founded in the 7th or 10th century was transformed into a men's abbey in the 11th century.

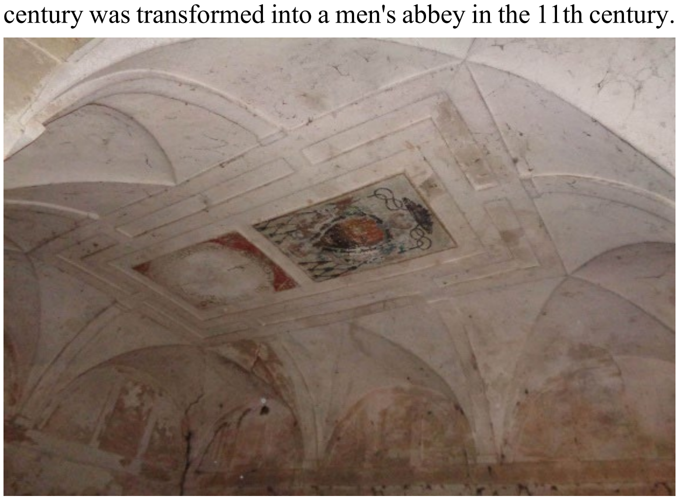

Fig. 3: Partitioned vaults over the main staircase. (Source: Imanol Ruiz de Vergara Ruiz de Azúa)

In the records we only find abbots from that date, or perhaps Lupián de Zapata invented an earlier monastery, annexed to that of Oña by Count Sancho García (967-1017), to justify and make the rights of Oña (founded in 1011) prevail over those of the Cathedral.

The current building, new abbey, palace, rectory, or priest's house, of classicist (Renaissance) style, seems to have been built by the impulse of D. Andrés del Castillo Pesquera, Abbot of Salas, dignity of the Cathedral of Burgos and patron of the Monastery of La Merced, in the last years of the sixteenth or early seventeenth century. between 1581 (Archivo Histórico de la Catedral de Burgos 1581), when he took possession of the abbey, and 1610, (Blanco Díaz 1948), the year of his death.

B. Current state of the building

The building, also known as "Casa del Cura", is located on a central promontory of the municipality next to the Church of Santa María. The preliminary historical analysis shows an old abbey-collegiate church of monumental size, with two rectangular squares and two levels of semicircular arches, possibly intended to be completed in a square cloister (Fig. 1). At the meeting of the two bodies, a tower with openings (Fig. 2), possibly for rectangular bells, a second level is raised above the access level. The building is decorated with three coats of arms where we find the cardinal's hood and cord, the best preserved being that of the impost line of the Tower.

The construction was made with compact sandstone ashlar masonry with exterior walls between 0.60 meters and 1.00 meters thick, probably with two locked leaves leaving the carved ashlar on the outside and masonry on the inside joined with cyclopean concrete as mortar.

The building has two bays: the interior one forms the body of the cloister gallery of 3.20 meters wide, whose arches were blinded with varied materials throughout its history. The second and fourth openings form arches to brace both bays. On the façade you can see the voussoirs in corbel to link with the bodies that would close the cloister. Behind a wall 1.00 meters thick, the interior bay is a spacious open nave about 5.00 meters wide, only cut by some partitions made of adobe or rough masonry.

On the north side of the main bay is the large main staircase

Fig. 4 and 5: Wood structure of the roofs and interior of the Tower. (Source: Paula Montoya Saiz)

that communicates with the upper floor by means of a stone staircase of three sections. The double-height space is covered with a structure of triangular vaults in the form of false lunettes, as can be seen in Fig. 3.

There is another wooden staircase of little historical or constructive value that was made for the conditioning of the body where the priest's house was located for many years. There were bedrooms and bathrooms and rooms with an irregular and unoriginal layout.

The slab structure is made of solid wood joists without beams with an upper entablature to support the flooring on the first floor.

It is estimated that the roof is built on four sides with solid wood beams, the covering element is completed with pairs and shingles on which are tiles placed in the traditional style, without receiving. There is no clear truss system, and a precarious structure has been built to support the inclined beams, as can be seen in Figs. 4 and 5.

The west end has an unfinished roof with a lattice wall element, as if it had intended to extend the building on that side, as can be seen in Fig. 6.

The architect who drafted the Rehabilitation Project, Paula Montoya Saiz, has made several visits to the building to conduct a detailed survey of the property, a photographic report, and an analysis of the most pressing pathologies of construction. The main pathologies detected are the following:

- The foundation is the extension of the walls themselves to the pavement, and does not seem to present any problem, except for settlements around the Torreón.
- Deteriorated construction of the slabs, although it seems that the supports are in good condition, which generates a serious threat of collapse of the roof structure, the bell tower and part of the interior slabs.
- Lack of resistance capacity and rigidity in some of the existing slabs due to the addition of masonry on it and, in general, for current regulatory requirements.
- Severe damage to the roof, where the loss of the tiles has caused the collapse of some areas of the roof, under the roof and first floor, allowing the permanent passage of rainwater and generating dampness in the walls. In July 2022, the roof structure of the Tower collapsed.
- Cracks in the south and west façades, due to the deterioration of the factories that have not been able to withstand the existing thrusts.
- Alternations in the openings of the façade and some of the interior, totally or partially blocked with masonry, brick, or rammed earth, as well as with added metal carpentry. The openings in the façade of the upper body of the Tower have been vandalised and the voussoirs of the arches behind the central openings have been removed.
- Cracks and deterioration of the vaults of the main stairwell and in some of the lintels of large interior openings.

The historical relevance of the building is undoubted, due to the cultural and religious significance that for several centuries has completed the urban layout of Salas de Bureba. The environment cannot be understood without the union between the Church and this Abbey, which give each other meaning and which were most likely the origin and support for the construction of the human community that developed under its protection.

The architectural value of the building is very remarkable, due to its entity within the historical trace of the municipality and although the construction solutions used are simple and absent of ornamental elements, the proportions of the construction and the Tower or bell tower make it an exceptionally beautiful Castilian architectural ensemble.

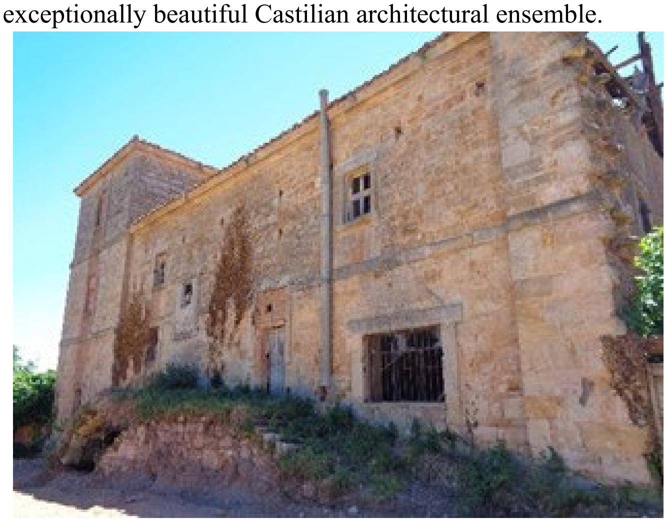

Fig. 6: North façade with tower and west end. (Source: Imanol Ruiz de Vergara Ruiz de Azúa)

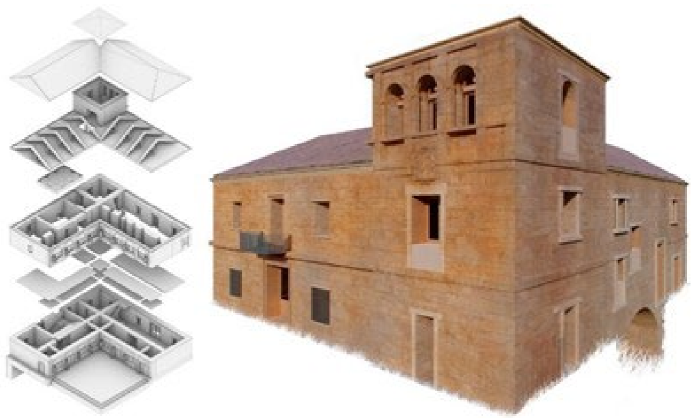

Fig. 7 and 8: 3D models of the building in its rehabilitated state, and state of the works in the North-South wing. (Source: Paula Montoya Saiz)

For all these reasons, and although it does not have explicit protection by the Heritage of the Autonomous Community of Castilla y León, it has been considered essential to preserve the values of the building and its indivisible presence in the memory of Salas de Bureba.

C. *Rehabilitation project objective*

This Rehabilitation Project, in addition to restoring the building's structural integrity and giving it a new functionality linked to private residential use, aims to achieve optimal levels of energy efficiency, considering the limitation of not being able to insulate most of the façade panels, not even from the inside. Thus, passive improvements will be applied following the criteria of: (i) no deterioration, (ii) flexibility, and (iii) repair of damages, of the DB-HE Energy Saving of the Technical Building Code (MITMA 2022).

The scope of the first phase of intervention, currently underway, is structural consolidation and consists of:

- Preliminary actions: perimeter fencing and installation of shoring, scaffolding and other auxiliary means for initial work and detailed study of pathologies.
- Replacement of the roof: dismantling of tiles, shingles, and purlins. Lifting and removal of wooden beams, cleaning of supports at the top of walls. Securing cornice parts. Reconstruction of the roof structure with wooden trusses. Execution of new roof skirts using sandwich panel with thermal insulation, waterproofing and ventilated tile with an aged finish. Gutters are not foreseen, but the traditional system of overflowing the cantilevered tile and the cornice as a drip is reproduced.
- Bracing of wall crowning elements (if necessary).
- Dismantling of demolished or dilapidated floor slabs. They will be rebuilt with wooden joists like the existing ones, and thermal insulation will be placed on all the floors of the building.
- Tied with wall elements, lintels, and arches, with special attention to the openings of the Tower, the condition of which will be unknown until access can be safely achieved.
- Cleaning and recovery of façades, restoring the coats of arms and recovering those areas where the ashlars are in the worst condition.
- Recovery of the stately staircase by replacing the corner pieces with stone like the existing one and the ceiling of false plaster lunettes.
- Elimination of elements inappropriate to the original construction, such as partitions or blinding of arches and openings.
- Dismantling of the auxiliary wooden staircase, which was built in the 50s to adapt the priest's house and was executed in untreated rough wood, which has led to an inexorable deterioration, currently in a ruinous state.
- Renovation of the exterior carpentry with new high-performance ones, with wooden frames and high thermal insulation glazing.

This project, the implementation of which has already begun, has obtained a double A energy rating, which has allowed it to qualify for aid from the PREE 5000 Programme (MITERD 2021). Fig. 7 and 8 show two 3D simulations with the structure and appearance of the building once rehabilitated, as well as the status of the works at the end of 2022.

II. METHODS

In this second section, the methods applied, and variables considered both for the energy study of the current building and for the decision-making towards the most suitable energy improvement for the rehabilitation project of the Abbey of Salas de Bureba are presented. The results and their discussion are presented in the next section.

A. *Constraints of the energy rehabilitation project*

As this is the project for the rehabilitation of an existing building from the 17th century, compliance with the requirements of the DB-HE Energy Saving of the Technical Building Code (MITMA 2022) presents difficulties in preserving the architectural and historical essence of the building. However, the provisions of Section IV Criteria for application in existing buildings of the DB-HE Introduction have been considered:

- Criterion 1. Non-worsening: The thermal qualities of those elements that are not going to be intervened due to historical conservation criteria will not be reduced, as is the case of the exterior and interior sandstone walls, and the floor of the main staircase. The restoration work, reintegration of volumes, replacement of mortars and sealing of cracks will improve its thermal performance. The rest of the elements of the thermal envelope will be intervened and the DB-HE requirements will be met.

- Criterion 2. Flexibility: Solutions will be adopted that allow the highest degree of compliance with the DB-HE, considering that the building is in the assumption of having a recognized historical or architectural value, and that other standardized solutions such as the insulation of its stone walls would unacceptably alter its character or appearance, even if it were done for its interior.
- Criterion 3. Repair of damage: All restoration and reconstruction work will be aimed at remedying the damage observed in relation to the scope of the DB-HE. This project involves the renovation of an existing building, in which more than 25% of the thermal envelope is intervened, and the air conditioning and domestic hot water production (DHW) systems are changed.

B. Energy simulation of the building

First, a detailed energy simulation of the building in its current state has been conducted to determine its thermal behaviour. The calculations are made hourly for a year, obtaining energy demands, energy consumption and CO2 emissions, both global and by services. In addition, it has been possible to calculate the thermal transmittance values of the enclosures and partitions. The thermal transmittance of the frames and glazing of the openings, the solar factor of the glazing and the air permeability of each opening have also been characterized and evaluated.

Subsequently, new energy simulations have been developed to evaluate the different possible measures to improve the energy efficiency of the building, studying functionally, technically, and economically viable solutions. The selected passive measures and the new installation for heating and DHW will be described in subsequent subsections.

Fig. 9: Location plan of the building. (Source: Cadastre)

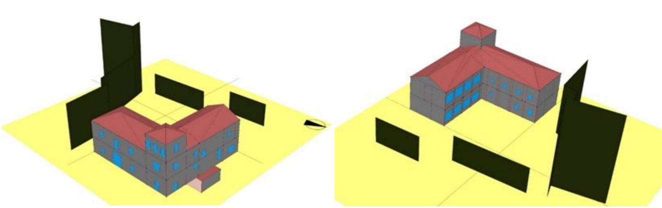

Fig. 10 and 11, Northeast and southwest view of the 3D model in current state.. (Source: Raúl Briones Llorente)

To conduct all these dynamic energy simulations on an hourly basis, the Unified Tool LIDER-CALENER (HULC) software (MITMA 2022) has been used, which has been provided by the Ministry of Transport, Mobility and Urban Agenda of the Government of Spain to verify compliance with the DB-HE. Likewise, this computer program is a Document Recognized by the Ministry for the Ecological Transition and the Demographic Challenge of the Government of Spain as one of the General Options to conduct the Energy Certification of Buildings. In this way, the results obtained serve both to conduct a detailed energy study, and to justify compliance with the Energy Regulations in force in Spain when conducting the project for the execution of the rehabilitation of this building.

C. Climatic data of Salas de Bureba

The building is in the town of Salas de Bureba, belonging to the Caderechas Valley, north of Burgos. It has an altitude of 636 m above sea level, so it corresponds to the E1 climate zone, in accordance with the provisions of Annex B Climatic zones of the DB-HE. These climate data are incorporated into the HULC software, and are the ones used in this study.

D. Geometry of the building in its current state

The building is "L" shaped, with two wings of a semi-cloister, which has a tower at its junction. The Ground Floor, First and Lower Deck have a constructed area of 411.00 m2 each, and the building has a maximum height of 14.00 m. Fig. 9 shows the location plan of the Cadastral File.

E. Construction characteristics of the building in its current state

To know the main construction characteristics of the building to conduct its energy simulation, data have been obtained on the composition of the elements of the thermal envelope, as well as the previous partitions. To this end, the document of the Execution Project for the Rehabilitation of the Old Abbey of Salas de Bureba, prepared by the Architect Paula Montoya Saiz, has been examined. In addition, *on-site* visits have been carried out to collect data and check. In addition, some thermal images have been taken to look for discontinuities in the constructed panels, using a FLIR E75 camera.

The Database of Opaque and Semi-Transparent Enclosures of the building has been created with HULC, composing all of them layer by layer, and choosing the materials most like those existing in the building. The HULC software database contains the Catalogue of Construction Elements (CEC) (Ministerio de Fomento, 2011), which is a Recognized Document of the CTE. The performance resulting from the building enclosures and partitions in their current state is far from the requirements of the CTE DB-HE, as discussed below in section 3.1.

Glazing has been chosen from the HULC Database for all types of doors or windows:

- 4 mm Single glazing.
- Thermal transmittance: Ug = 5,70 W/m2K.
- Solar factor: g = 0,85.

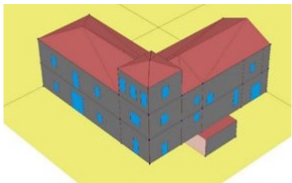
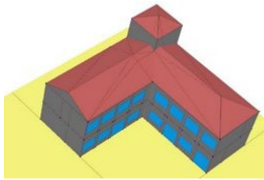

Fig. 12 and 13. Northeast and southwest view of the 3D model after intervention. (Source: Raúl Briones Llorente)

The frames have also been chosen from the HULC Database for all types of door or window:

- Upright frame made of medium-high density wood.
- Thermal transmittance: $U_f = 2{,}20$ W/m^{2}K.

According to Table 3.1.3.a-HE1 Air Permeability Limit Value of Thermal Envelope Voids, $Q_{100,lim}$ [m^3/h·m^2] del DB HE-1, following permeabilities are estimated:

- 60 m^3 / h×m2, a 100 Pa, for doors, according to a default value of HULC (Class 3 according to the UNE-EN 12207:2017 Standard) (AENOR, 2017).
- 50 m3 / h×m^2, a 100 Pa, for windows (Class 1 according to the UNE-EN 12207:2017 Standard).

The total solar energy transmittance of glazing with mobile shading device activated has been calculated in accordance with Table 12 – Total Transmittance of Solar Energy of Openings for Different Moving Shading Devices ($g_{gl;sh,wi}$), from Document DA DB – HE/1 – Calculation of the characteristic parameters of the envelope (MITMA, 2020):

- The openings have simple glazing and interior protection device with pastel-coloured curtains: $g_{gl;sh,wi} = 0{,}59$.

All the frame fractions of the doors and windows have been calculated one by one.

For all thermal bridges, those models that most closely resemble the construction reality of the building have been chosen from the models listed in the HULC Database.

Regarding the absorptivity of the exterior enclosures, the following have been considered:

- Medium brown colour for all facades: $\alpha = 0.75$.
- Medium red colour for sloping roofs with ceramic tiles: $\alpha = 0.80$.
- Medium brown colour for all exterior joinery: $\alpha = 0.75$.

F. Operational conditions of the building in its current state

The existing spaces in the building have been classified for their geometric definition in HULC, into non-habitable spaces and conditioned living spaces, according to the DB-HE:

Profile of use of living spaces: Residential.

Profile of use of non-habitable spaces: Watertightness level 5.

Table 8 is used. Rate of air renewal between non-habitable spaces and the exterior, from the Document DA DB HE-1 Calculation of characteristic parameters of the envelope, to determine the level of tightness of non-habitable spaces, considered level 5, which implies a high rate of air renewal.

G. Installation of heating and domestic hot water in the building in its current state

The building has a mixed system for heating and DHW, which only serves the rooms that made up the Casa del Cura, located on the First Floor:

- Sanitary supply temperature: 60 ºC.
- Heating supply temperature: 80 °C.

According to the DB-HE, Annex F DHW Reference Demand, the reference demand for private residential use is obtained by considering 28 litres/(× person's day) at 60 ºC.

According to DB HE-4, Table a-Appendix F. Minimum occupancy values calculated in private residential use, the number of people occupying the dwelling is related to the number of bedrooms. In this building: 1 bedroom ⇒ for 1.5 people.

The total daily DHW consumption for the building, in litres/(day × person), is: 1.5 people × [28 litres/(day × person)] = 42 litres/day.

As it is an individual installation, no centralization factor is applied, and the operating temperature for DHW is 60 ºC.

The building has a DHW storage unit with the following characteristics:

- Tank volume: 50 litres.
- Loss coefficient, AU: 1 W/ºC.
- High tank setpoint temperature: 80 ºC.
- Low tank setpoint temperature: 60 ºC.

The building has a standard combi boiler for heating and DHW with the following features:

- Total capacity: 20 kW.
- Nominal throughput (PCI-based): 0.85.
- Energy type: diesel.

The building's air-conditioned living rooms have heating circuits for hot water radiators. Given the characteristics of the building and based on experiences in previous works in installations of that time, the terminal units have been estimated with an installed power of 100 W/m2 of usable area.

To size the boiler, the total installed power has been increased by a factor of 1.15 to consider possible distribution losses: 11.69 kW × 1.15 = 13.44 ⇒ 20.00 kW.

H. Geometry of the building in its refurbished state

The building, as it could not be otherwise, will maintain its volumes and geometry, as well as its orientation. The geometric differences will be in the interior, with a new redistribution of spaces according to the new needs for private residential use, throughout the built area. Also, the original geometry of the openings in the façades will be recovered. All these changes are reflected in Figs 12 and 13, which show two views of the 3D modelling of the building in its refurbished state, made again with HULC.

I. Constructive characteristics of the building in its refurbished state

HULC has modified the Database of Opaque and Semi-Transparent Enclosures of the building, recomposing layer by layer all those that are going to receive some type of thermal insulation or change in the rehabilitation. The layer-by-layer composition of the enclosures and partitions is shown below, indicating their main thermophysical properties. First, those that are preserved without additional insulation in Tables 1-3, as well as those that are new or modified in Tables 4-10.

New glazing has been defined for all types of door or window:

- Low-emissive double glazing, with solar control and outdoor safety: 4+4be/14Ar/6cs mm.
- Thermal transmittance: Ug = 1.10 W/m2K.
- Solar factor: g = 0,19.

In the same way, the new frames have been defined for all types of door or window:

- Upright frame made of American cedar wood, with a density of 490 kg/m3.
- Thermal transmittance: Uf = 1,15 W/m2K.
- Thickness: 80 mm.

According to Table 3.1.3.a-HE1 Air Permeability Limit Value of Thermal Envelope Voids, $Q_{100,lim}$ [$m^3/h·m^2$] del DB HE-1, the following permeabilities are estimated with the data provided by the manufacturers:

- 60 m^3 / h×m^2, a 100 Pa, for doors, according to a default value of HULC (Class 3 according to the UNE-EN 12207:2017 Standard).
- 3 m3 / h×m^2, a 100 Pa, for windows (Class 4 according to the UNE-EN 12207:2017 Standard).

The total solar energy transmittance of glazing with mobile shading device activated has been calculated in accordance with Table 12 – Total Transmittance of Solar Energy of Openings for Different Moving Shading Devices ($g_{gl;sh,wi}$), of the Document DA DB – HE/1 – Calculation of the characteristic parameters of the envelope:

- The openings have low-emissive glazing and sun protection device opaque interiors made of dark-toned wood: $g_{gl;sh,wi}$ = 0,51.

All door and window frame fractions have been recalculated one by one.

All the thermal bridges have been redefined, choosing among the models that appear in the HULC Database, those that most closely resemble the new construction reality of the Execution Project for the Rehabilitation of the Building.

TABLE I
FAÇADE AND INTERIOR PARTITION WALL THROUGHOUT THE BUILDING OF 100 CM

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m²)	Specific heat (J/Kg·K)	Thermal resistance (m²K/W)
Sandstone Factory	0,30	3,000	2.400	1.000	---
Sand and gravel filling	0,40	2,000	1.450	1.050	---
Sandstone	0,30	3,000	2.400	1.000	---

TABLE II
FAÇADE AND INTERIOR PARTITION WALL THROUGHOUT THE BUILDING OF 100 CM

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m²)	Specific heat (J/Kg·K)	Thermal resistance (m²K/W)
Soil	0,50	0,520	2.000	1.840	---

TABLE III
FLOOR OF THE MAIN STAIRCASE ON THE GROUND FLOOR

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m²)	Specific heat (J/Kg·K)	Thermal resistance (m²K/W)
Sandstone	0,40	3,000	2.400	1.000	---

TABLE IV
FAÇADE AND INTERIOR PARTITION WALL THROUGHOUT THE BUILDING OF 100 CM

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m²)	Specific heat (J/Kg·K)	Thermal resistance (m²K/W)
Ceramic tile	0,02	1,000	2.000	800	---
Horizontal slightly ventilated air chamber	0,05	---	---	---	0,080
Low-density polyethylene sheet	0,001	0,330	920	2.200	---
Medium density coniferous wood board	0,02	0,150	480	1.600	---
Mineral wool insulation	0,16	0,031	40	1.000	---
Medium density coniferous wood board	0,02	0,150	480	1.600	---

TABLE V
GROUND FLOOR WITHOUT THE MAIN STAIRCASE

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m²)	Specific heat (J/Kg·K)	Thermal resistance (m²K/W)
Stoneware slab flooring	0,01	2,300	2.500	1.000	---
Cement mortar	0,04	0,550	1.125	1.000	---
Expanded polystyrene insulation	0,08	0,038	30	1.000	---
Reinforced concrete	0,05	2,300	2.400	1.000	---
Polypropylene	0,005	0,220	910	1.800	---
Horizontal unvented air chamber	0,015	---	---	---	0,340
Mass concrete screed	0,15	1,650	2.150	1.000	---
Gravel	0,20	2,000	1.450	1.050	---

TABLE VI
FLOOR OF THE FIRST FLOOR WITHOUT THE MAIN STAIRCASE AND THE TOWER

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m^2)	Specific heat (J/Kg·K)	Thermal resistance (m^{2}K/W)
Stoneware slab flooring	0,01	2,300	2.500	1.000	---
Cement mortar	0,04	0,550	1.125	1.000	---
Expanded polystyrene insulation	0,08	0,038	30	1.000	---
Medium density coniferous wood board	0,02	0,150	480	1.600	---

TABLE VII
UNDER-ROOF FLOOR

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m^2)	Specific heat (J/Kg·K)	Thermal resistance (m^{2}K/W)
Cement mortar	0,04	0,550	1.125	1.000	---
Expanded polystyrene insulation	0,08	0,038	30	1.000	---
Medium density coniferous wood board	0,02	0,150	480	1.600	---

TABLE VIII
FAÇADE WALL THROUGHOUT THE BUILDING OF 80 CM CLADDING

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m^2)	Specific heat (J/Kg·K)	Thermal resistance (m^{2}K/W)
Stoneware slab flooring	0,01	2,300	2.500	1.000	---
Cement mortar	0,04	0,550	1.125	1.000	---
Expanded polystyrene insulation	0,08	0,038	30	1.000	---
Reinforced concrete	0,05	2,300	2.400	1.000	---
Polypropylene	0,005	0,220	910	1.800	---
Horizontal unvented air chamber	0,015	---	---	---	0,340
Mass concrete screed	0,15	1,650	2.150	1.000	---
Gravel	0,20	2,000	1.450	1.050	---

TABLE IX
FAÇADE WALL THROUGHOUT THE BUILDING OF 80 CM CLADDING

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m^2)	Specific heat (J/Kg·K)	Thermal resistance (m^{2}K/W)
Sandstone	0,30	3,000	2.400	1.000	---
Cement mortar	0,01	0,550	1.125	1.000	---
Mineral wool insulation	0,16	0,031	40	1.000	---
Low-density polyethylene	0,001	0,330	920	2.200	---
Triple Hollow Brick Masonry	0,10	0,427	920	1.000	---
Plaster trimming and plastering	0,015	0,400	900	1.000	---

TABLE X
LIGHTWEIGHT PARTITION WALL THROUGHOUT THE BUILDING

Material	Thickness (m)	Conductivity (W/m·K)	Density (Kg/m^2)	Specific heat (J/Kg·K)	Thermal resistance (m^{2}K/W)
Double drywall pane	0,028	0,250	825	1.000	---
Mineral wool insulation	0,04	0,031	40	1.000	---
Double drywall pane	0,028	0,250	825	1.000	---

J. Operational conditions of the building in its refurbished state

The new spaces of the refurbished building have been classified for their geometric definition in HULC, into non-habitable spaces and conditioned living spaces, according to the DB-HE:

- Profile of use of living spaces: Residential.
- Profile of use of non-habitable spaces: Watertightness level 3.

Table 8 is used. Rate of air renewal between non-habitable spaces and the exterior, from the Document DA DB HE-1 Calculation of characteristic parameters of the envelope, to recalculate the level of tightness of new non-habitable spaces, considered level 3.

K. Installation of heating and domestic hot water in the building in its refurbished state

The building will have a new mixed system for heating and DHW:

- Sanitary supply temperature: 55 ºC.
- Heating supply temperature: 40 °C.

According to the DB-HE, Annex F DHW Reference Demand, the reference demand for private residential use is obtained by considering 28 litres/(× person's day) at 60 ºC.

According to DB HE-4, Table a-Appendix F. Minimum occupancy values calculated in private residential use, the number of people occupying the dwelling is related to the number of bedrooms. In this building: 5 bedrooms ⇒ 7 people.

The total daily DHW consumption for the building, in

TABLE XI
FAÇADE WALL THROUGHOUT THE BUILDING OF 80 CM CLADDING

Name	Thermal transmittance (W/m²·K)			Compliance
	Closing	Table 3.1.1.a	Table 3.2	
Pitched roof	2,68	0.33	2.400	1.000
Pitched roof **Under-roof floor**	2,68 2,91 1.53	0,33	---	NO
Cellar Floor	0,85	---	---	---
Floor PB stairs	2,91	0,59	---	NO
Soil PB	0,80	0,59	---	NO
Wall 100 cm	1,75	0,37	---	NO
Wall 80 cm	2,13	0,37	---	NO
Wall 60 cm	2,70	0,37	---	NO
First Tower Ground	2,91	---	1,00	NO
Wall_100_cm	1,75	---	1,00	NO
Wall_60_cm	2,70	---	1,00	NO
Lightweight partition wall	2,21	---	1,00	NO
Hollow	≤ 5,11	1,80	---	NO
Glazing	5,70	---	---	---
Frame	0,85	---	---	---

litres/(day × person), is: 7 people × [28 litres/(day × person)] = 196 litres/day.

As it is an individual installation, no centralization factor is applied, and the operating temperature for the a.c.s. is 60 ºC.

The building will have a domestic hot water storage unit with the following characteristics:

- Tank volume: 200 litres.
- Loss coefficient, AU: 1 W/ºC.
- High tank setpoint temperature: 60 ºC.
- Low tank setpoint temperature: 50 ºC.

The building will have a combi condensing boiler for low-temperature heating and DHW with the following characteristics:

- Total capacity: 45 kW.
- Nominal throughput (PCI based): 0.98.
- Energy type: densified biomass (pellets).

The building's air-conditioned living rooms will have low-temperature hot water underfloor heating circuits. After the rehabilitation, an installed power of 75 W/m2 has been estimated.

To size the boiler, the total installed power has been increased by a factor of 1.15 to consider possible distribution losses: 37.78 kW × 1.15 = 43.45 kW ⇒ 45.00 kW.

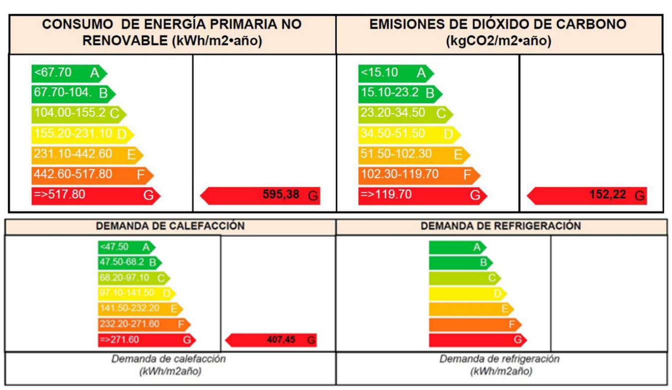

Fig. 14: Energy Performance Certificate of the building in its current state. (Source: Raúl Briones Llorente)

III. Results and discussion

This section shows the results obtained after conducting the detailed energy simulations of the building, first in its initial state, and then, in the renovated state proposed for the Execution Project for the Rehabilitation of the Abbey of Salas de Bureba, including the best energy improvement measures chosen and exposed in the previous section.

A. Results of the energy study of the building in its current state

The building in its current state is exempt from complying with the DB-HE. However, and for information purposes, to know the current qualities, the thermal transmittances of the enclosures and interior partitions have been compared in Table 11 with the requirements of Table 3.1.1.a – HE1 Limit values of thermal transmittance, Ulim [W/m²K] and Table 3.2 – HE1, both belonging to the DB HE-1.

It can be seen, as expected, that no enclosure or partition complies with the limitations of thermal transmittances.

The values of the thermal transmittance of the roof on a non-habitable sloping space in the lower roof have been calculated based on the HULC results for the roof of the First Floor and for the sloping skirt and using the Document DA DB – HE / 1 – Calculation of the characteristic parameters of the envelope.

Regarding the annual hourly calculations, Fig. 14 shows the results obtained when conducting the Energy Performance Certificate of the Building in its current state:

- Non-renewable primary energy consumption: 595.38 kWh/m2 year (Class G).
- CO2 emissions: 152.22 kgCO2/m2 year (Class G).
- Heating demand: 407.45 kWh/m^2 year (Class G).
- Cooling demand: 0.85 kWh/m^2 year (not assessable).

The Old Abbey of Salas de Bureba, in its current state, even though it only has a conditioned living area of 148.29 m2 that groups the spaces on the First Floor destined to the Casa del Cura, presents a bad energy performance, which is not

TABLE XI
FAÇADE WALL THROUGHOUT THE BUILDING OF 80 CM CLADDING

Name	Thermal transmittance ($W/m^2 \cdot K$)			Compliance
	Closing	Table 3.1.1.a	Table 3.2	
Pitched roof	0,18	0,33	---	YES
Pitched roof	0,18 0,21	0,33	---	YES
Floor under cover	0,40			
Soil PB	0,34	0,59	---	YES
Wall 80 cm cladding	0,17	0,37	---	YES
Cladding wall	0,17	0,37	---	YES
First Tower Ground	0,40	---	1,00	YES
Lightweight partition wall	0,59	---	1,00	YES
Hollow	≤ 1,25	1,80	---	YES
Glazing	1,10	---	---	---
Frame	1,15	---	---	---

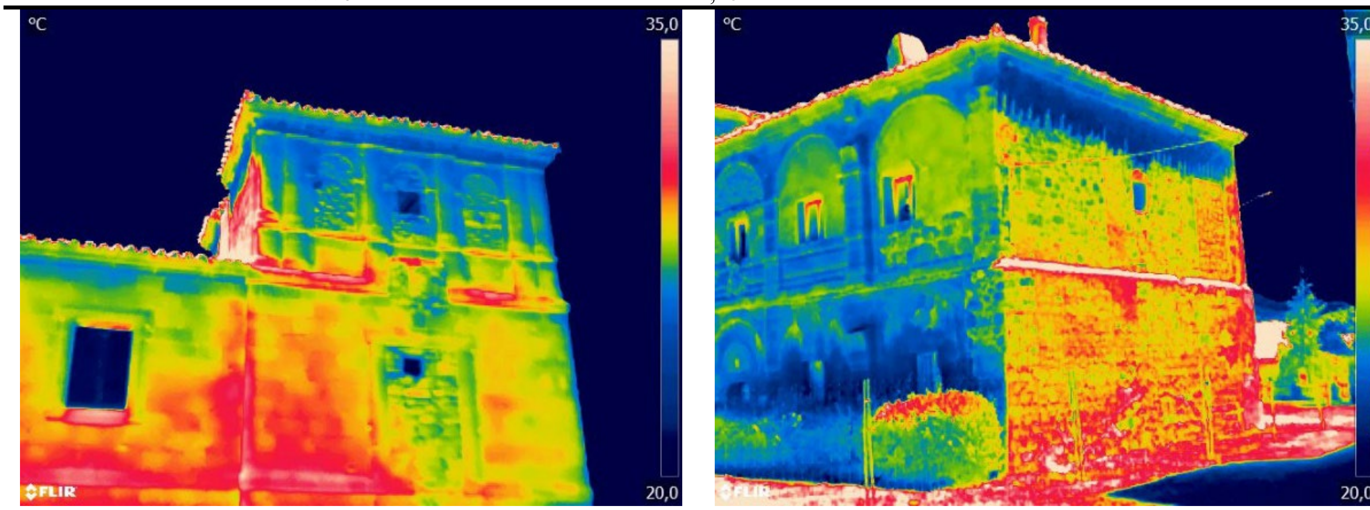

Fig. 15: Infrared thermographs of the Tower and the South body in their current state. (Source: Imanol Ruiz de Vergara Ruiz de Azúa)

surprising considering the deficient construction characteristics described.

It must be noticed that the high values for heating supply, in terms of energy demand, non-renewable primary energy consumption and CO2 emissions. They are coherent, as the heating system has an inefficient boiler, fuelled by oil.

Considering the climatic conditions, with a long and severe winter and a summer of mild temperatures, the HULC software does not consider the values related to cooling, as they are insignificant compared to those for heating.

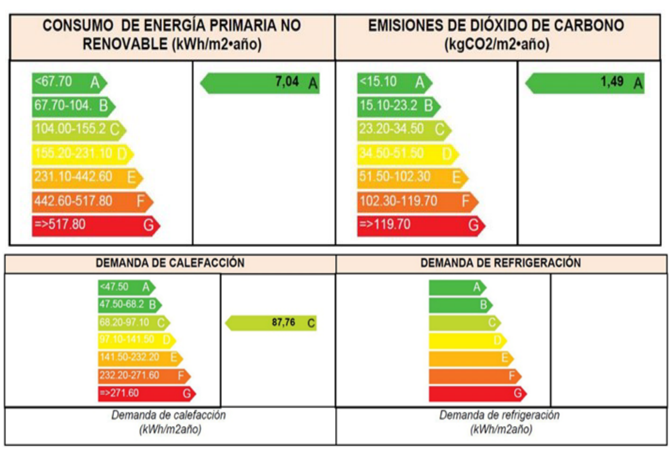

Fig. 14: Energy Performance Certificate of the building in its current state. (Source: Raúl Briones Llorente)

The HULC software also provides values for the supply of DHW, even if they do not appear on the labels shown above. In any case, they are also insignificant in relation to those of heating:

- Non-renewable primary energy consumption: 11.79 kWh/m^2year (Class B).
- CO2 emissions: 3.11 kgCO2/m2year (Class C).
- DHW demand: 8.50 kWh/m^2year.

By means of the thermographic study (Fig. 15) the reading of the composition of the walls is improved, the location of blinded or modified panels in distinct phases of the building. It also helps to visualize the solar capture of the walls and their high thermal inertia

B. Results of the energy study of the building in its refurbished state and savings achieved

As the building is for private residential use, but is not a new construction, but is an existing building that is going to undergo a major intervention in more than 25% of its thermal envelope, only the enclosures and interior partitions in which intervention is carried out are subject to the limitations of Table 3.1.1.a - HE1 Thermal transmittance limit values, Ulim [W/m²K] of the DB HE-1.

The thermal transmittance of the interior partitions shall not exceed the value of Table 3.2 - HE1 of the DB HE-1, depending on the use assigned to the different units of use that they delimit. In this project, this requirement affects all the interior partitions that are replaced, and not the interior sandstone walls that are only restored.

It can be clearly seen in Table 12 that all the proposed enclosures comply with the limitations of thermal transmittance, except for those in which no intervention is going to be conducted, and which would be exempt.

The values of the thermal transmittance of the roof on a non-habitable attic space on the lower roof have been recalculated based on the new HULC results for the roof of the First Floor and for the sloping skirt and using Document DA DB – HE / 1 – Calculation of the characteristic parameters of the envelope. Regarding the annual hourly calculations, Fig. 16 shows the results obtained when conducting the Energy Performance Certificate of the Building in its refurbished state:

- Non-renewable primary energy consumption: 7.04 kWh/m^{2}year (Class A).
- CO2 emissions: 1.49 kgCO2/m^{2}year (Class A).
- Heating demand: 87.76 kWh/m^{2}year (Class C).
- Cooling demand: 0.08 kWh/m^{2}year (not assessable)

The Old Abbey of Salas de Bureba, in its restored state, goes from having a conditioned living area of 148.29 m^2 (Casa del Cura), to 967.89 m^2.. Despite a five-fold increase in the number of conditioned spaces, the energy performance of the overall building has improved significantly.

It can be noticed that the 78.46% decrease in heating demand, from 407.45 kWh/m^2 year to just 87.76 kWh/m^{2}year. This is directly due to the significant improvement of the thermal envelope.

Non-renewable primary energy consumption has decreased by 98.82%, from 595.38 kWh/m^2 year to just 7.04 kWh/m^{2}year. This is due to the combined effect of the improvement of the thermal envelope to lower the heating demand, and the change of the mixed system for heating and DHW, for a more efficient one that uses a fuel of renewable origin.

CO2 emissions have decreased by 99.02%, from 152.22 kgCO2/m^2 year to just 1.49 kgCO_2/m2year. The two causes of this significant reduction are the same as those set out in the previous paragraph.

The HULC software still does not consider the values for cooling, as they are insignificant compared to those for heating.

The new values for the supply of DHW, although they do not appear on the labels, would be as follows, but they are still insignificant in relation to those for heating:

- Non-renewable primary energy consumption: 0.38 kWh/m^2 year (Class A).
- CO2 emissions: 0.08 kgCO2/m2 year (Class A).
- DHW demand: 4.43 kWh/m^2 year.

The satisfactory results obtained in improving energy efficiency for the rehabilitation of the Old Abbey of Salas de Bureba have made it possible for this project to be included in the 2022 call of the PREE 5000 Energy Rehabilitation Program for existing buildings in municipalities with demographic challenges.

Specifically, the eligible action for existing complete buildings (Option A) is divided into two clearly differentiated typologies: Improvement of the energy efficiency of the thermal envelope (Typology 1), and Improvement of energy efficiency and renewable energies in thermal heating, air conditioning, ventilation and DHW installations (Typology 2), specifically, in subsection 2.3 Substitution of conventional energy by biomass in thermal installations. Thus, between both typologies, aid has been requested that represents 75% of the total amount of material execution of the energy improvement works of the building

IV. Conclusions

The old Abbey of Salas de Bureba, known locally as the "House of the Priest", is a magnificent representative of the religious/civil architecture of the Caderechas Valley and an exponent of the value of coexistence between the clergy and the inhabitants of the town over the centuries. Therefore, it is essential to preserve it to prevent its disappearance.

A complete restoration is being undertaken, adapting the building to a private residential use with current standards, but maintaining the original architectural richness, and with a focus on energy efficiency and sustainability during its life cycle.

A detailed energy simulation of the building in its current state has been conducted to know its thermal behaviour, calculating on an hourly basis for the period of one year, the energy demands, energy consumption and CO2 emissions, global and separately, for heating, cooling, and domestic hot water. The thermal behaviour of each element of the thermal envelope and the interior partitions has also been characterised in detail.

Measures to improve the building's energy efficiency have been evaluated, studying functionally, technically, and economically viable solutions. The passive measures selected are based on the addition of thermal insulation in the opaque elements of the envelope, minus the walls, and on the placement of new high-efficiency joinery. A new installation for heating and domestic hot water has also been designed, with a low-temperature boiler fuelled by biomass.

The building had a G energy rating, both for non-renewable primary energy consumption, for CO2 emissions and for heating demand. An A rating has been achieved in the first two indicators and a C in the third. The savings obtained are 98.82%, 99.02% and 78.46%, respectively.

These satisfactory results have made it possible for this project to be included in the 2022 call of the PREE 5000 Programme, being eligible for aid that represents 75% of the total amount of material execution of the building's energy improvement works.

AKNOWLEDGEMENTS

To Mr. Rubén Ganzo Pérez, Technical Architect at Ganzo Arquitectura Técnica Eficiente (www.arquitecturaganzo.es), for the information work and processing of the grants of the PREE 5000 Program.

To the Thermal Area of the Basque Government's Building Quality Control Laboratory, for their collaboration, for providing infrared thermography equipment and their knowledge in building characterisation, energy audits and rehabilitation

REFERENCES

AENOR, Ventanas y puertas. Permeabilidad al aire. Clasificación. https://www.une.org/encuentra-tu-norma/busca-tu-norma/norma?c=N0058081, 2017 (acceso 26 febrero 2023).

Archivo Histórico de la Catedral de Burgos, Copia auténtica. Ante Juan Bautista Hernández, notario. Posesión otorgada por el Cabildo de la Catedral de Burgos, Burgos, 1581, Referencia: RR – 63, Unidad Documental: 20 – 34, Folios: 20 – 21.

A. Blanco Diaz, Adición a los libros impresos burgaleses: Proyección de recuerdos de la primera mitad del siglo XVII : [02] (continuación), Editorial de la Diputación Provincial de Burgos, Burgos, 1948.

Cabildo Catedralicio de Burgos, Acta de reunión del 21 de enero de 1556. (sin acceso).Fundación Santa María la Real, Románico digital. Salas de Bureba. https://www.romanicodigital.com/sites/default/files/pdfs/files/burgos_SALAS_DE_BUREBA.pdf, 2019 (acceso 7 marzo 2023).

Ministerio de Transportes, Movilidad y Agenda Urbana del Gobierno de España, Documento Básico de Ahorro de Energía (DB-HE) del Código Técnico de la Edificación (CTE). https://www.codigotecnico.org/DocumentosCTE/AhorroEnergia.html, 2022 (acceso 21 febrero 2023).

Ministerio para la Transición Ecológica y el Reto Demográfico del Gobierno de España, Programa PREE 5000 de rehabilitación energética para edificios existentes en municipios de reto demográfico. https://www.idae.es/ayudas-y-financiacion/para-la-rehabilitacion-de-edificios/programa-pree-5000-rehabilitacion, 2021 (acceso 21 febrero 2023).

Ministerio de Transportes, Movilidad y Agenda Urbana del Gobierno de España, Herramienta Unificada LIDER-CALNER (HULC). https://www.codigotecnico.org/Programas/HerramientaUnificadaLIDERCALENER.html, 2022 (acceso 25 febrero 2023).

Ministerio de Fomento del Gobierno de España, Catálogo de Elementos Constructivos (CEC). https://itec.cat/cec/Pages/BusquedaSC.aspx, 2011 (acceso 26 febrero 2023).

Ministerio de Transportes, Movilidad y Agenda Urbana del Gobierno de España, DA DB – HE / 1 – Cálculo de los parámetros característicos de la envolvente. https://www.codigotecnico.org/DocumentosCTE/AhorroEnergia.html, 2020 (acceso 26 febrero 2023).