# On preserving decommissioned fossil fuel power plants as industrial heritage

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This study examines public attitudes toward the preservation of decommissioned fossil-fuel power
plants as industrial heritage, focusing on the As Pontes case in Spain. Survey data from local and
national populations were analyzed using Principal Component Analysis to reveal underlying opinion
structures. Results highlight a tension between heritage conservation and economic redevelopment,
emphasizing the importance of community perspectives in heritage policy and the contested nature of
post-industrial land-use decisions.

The International Committee for the Conservation of the Industrial Heritage's Nizhny Tagil Charter[1] underscores the importance of preserving industrial elements based on their "historical, technological, social, architectural or scientific value". While the charter does acknowledge social aspects, it implicitly suggests that industrial heritage provides a significant sense of identity per se: "industrial heritage has social value as part of the record of ordinary people's lives, and as such, it provides an important sense of identity". In consequence, industrial heritage is often framed as a near-universal value adjudicated by experts on technical, historical, and architectural grounds, overlooking how public perceptions (shaped by economic, political, and historical contingencies) render such status inherently contested.

Recent expert-driven assessments, such as that of Jato-Espino et al.[2], exemplify this approach by evaluating the decommissioned As Pontes coal-fired power plant based on expert opinions rather than community perspectives. Specifically, Jato-Espino et al. employ a Multi-Criteria Decision Analysis (MCDA) with 15 heritage experts, using seven criteria (importance in the electricity generation process, singularity, esthetics, ease of preservation, adaptability to new uses, sociocultural interest, work and technology testimony), and conclude that virtually the entire complex (including towers, chimney, boilers, and turbine hall) should be conserved as paramount heritage elements. While methodologically rigorous, such frameworks risk overlooking local concerns, particularly in regions where industrial sites are entwined with acute environmental conflicts as well as livelihoods. This study provides a direct counterpoint to Jato-Espino et al. by analyzing perceptions of the same industrial facility (the As Pontes power plant, Galicia, Spain) through the lens of public opinion.

As Pontes Power Plant was built in the 1970s as a classic mine-mouth plant, burning lignite from the adjacent open-pit mine. The plant and mine together employed roughly 3000 people during the period of maximum production in the late 1980s (the population by that time was approximately 13,000 inhabitants)[3]. By 1980, it burned around 14 million tons a year (about 45% of Spain's coal output) to feed four 350-MW units, making it the largest power station ever built in Spain. What set As Pontes apart was its location. Spain had roughly 14 similar coal plants, but most were sited in long-standing mining regions (Asturias, León, Palencia, or Huelva, see Fig. S1) where power generation extended existing coal economies. In contrast, As Pontes, in the province of A Coruña, Galicia, effectively redrew Spain's extractive map, becoming the country's leading coal center and a major hub of electricity production in a matter of one decade[4]. Comparable, though smaller or later-developing, cases include Cerceda (A Coruña, Galicia), Tineo (Asturias), and Teruel (Aragón). Unlike regions with long, incremental trajectories, these areas saw little to no coal extraction or power generation for most of the twentieth century, followed by rapid expansion after the 1970s.

In line with what the sociology of boomtown studies suggests[5–7], As Pontes power plant stands out for the deep social shifts it set in a remote rural setting[3,8]. The town's population nearly tripled between 1970 and 1985 as migration from across Spain surged. This influx sharpened divides between mining-company employees and longer-standing residents: company housing versus the traditional town, and company-sponsored events versus local festivities; creating distinct, sometimes conflicting identities[8,9]. From the 1990s, tightening environmental rules and falling coal demand reversed the demographic boom and pushed a gradual energy transition. The shift brought major adjustments: roughly 2000 early retirements, plus layoffs or relocations among workers in firms lured by tax incentives. After the mine closed in 2007, the power plant ran on imported coal. In 2018, the new elected socialist government launched the so-called Energy Transition Agreements, aiming to shut down all remaining plants by 2020. While this target was largely achieved, disruptions caused by the COVID-19 pandemic

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and the war in Ukraine extended operations at As Pontes plant until late 2023. The closure entailed dismissals or relocations for about 150 plant operators and ended coal-haul jobs for roughly 120 truck drivers, while threatening municipal revenues linked to the company's operations.

In this context, our study draws on a survey conducted shortly after the plant's closure among residents of the municipality where the power plant is located. Respondents rated on a scale from 0 to 10 their interest in preserving the power plant as industrial heritage (heritage conservation), as well as two more alternative post-closure uses: reindustrialization (demolishing existing structures to facilitate new industrial projects) and renaturalization (removing infrastructure and restoring the original natural habitat). To enable comparisons with other mining areas and the broader population, we extended the survey to a nationally representative sample of Spanish citizens, asking the same question regarding all coal power plants decommissioned in recent years.

As Pontes is the only case in which reindustrialization scores higher than heritage conservation and renaturalization (Fig. 4). Moreover, the structure of attitudes shows a markedly sharper internal divergence in As Pontes than either nationally or in long-standing mining regions. In As Pontes, stronger support for reindustrialization tends to coincide with weaker support for preservation and the reverse. These results align with recent research highlighting how community members often hold diverse opinions on cultural heritage representation, influenced by their sociocultural contexts, making a unified narrative challenging to establish[10–15]. A good example is Mukherjee and Banerji[10], who documents clear mismatches between expert framings and community meanings in industrial heritage, reinforcing the case for inclusive, community-centered approaches. In Spain, Ruiz Ballesteros and Hernández Ramírez's[13] study of Andalusia is illustrative: despite a deep mining legacy, some towns show weak identification with mining, while top-down heritage projects increase acute local conflict and tensions between "us" (townspeople) and "them" (miners). Finally, a recent study published in the *Spanish Journal of Sociology*[16], based on a content analysis of news media, confirms the existence of discursive conflicts over potential land uses after plant closures in the Spanish former coal mining areas, including the case at hand, As Pontes.

Building on this, our study is, to our knowledge, the first to examine public perceptions specifically of decommissioned coal power plants across multiple scales (local, mining regions, national). A concept especially useful to unpack the complexity of our results is "difficult" or "painful" heritage, that is, heritage linked to painful or morally troubling pasts. It highlights how the same industrial structures can evoke pride and nostalgia for some, yet loss, shame, or resentment for others, depending on lived histories and power relations[17–19]. In As Pontes, which trajectory is marked by a combination of boom and bust, identity conflicts, and environmental impacts, this lens helps explain why preferences for reindustrialization, renaturalization, or conservation cluster with different constituencies despite referring to the very same site.

By directly contrasting our findings with Jato-Espino et al., this study situates itself within the field of Critical Heritage Studies (CHS)[20–22]. Heritage Science has traditionally been dominated by experts in engineering, archeology, history, architecture, and art history. This critical perspective advocates for an intellectual openness that incorporates disciplines such as sociology, anthropology, cultural geography, and political science. It emphasizes the need to democratize heritage by integrating the perspectives of affected communities and recognizing that heritage should emerge from a subjective political negotiation of identity, place, and memory.

## Methods

### Survey design and data collection
The survey was conducted between May and June 2024 as part of a wider project on energy transition in Spain[23]. It targeted two distinct groups: residents of As Pontes ($n = 162$) and a nationally representative sample of Spanish citizens ($n = 1002$). Because As Pontes has a small population (~10,000) and limited telephone coverage, phone interviews were not feasible. We therefore conducted on-street surveys, using predefined routes

that covered multiple neighborhoods and key public spaces to maximize spatial representativeness. In contrast, the national sample was surveyed using Computer-Assisted Telephone Interviewing (CATI).

Data were weighted based on demographic criteria (gender, age, and occupation) using iterative proportional fitting to align with census benchmarks. The estimated margin of error is approximately 7.5% for the As Pontes municipality sample, 3.91% for the Spanish population sample, and 14.45% for the contiguous Asturias–León–Palencia area sample, here considered as population with a greater historical exposure to the coal and energy industry; all calculated at a 95% confidence level.

The central question asked respondents for their views on post-closure land uses for power plant sites. The exact wording is given in quotation marks below. Each item was rated independently on a 0–10 scale (non-exclusive), so respondents could endorse more than one option. To minimize order effects, item order was randomized at the respondent level—an option shown first for one respondent could appear second or third for another.

"For the sites of coal-fired power plants that have ceased operations, several potential new uses have been proposed, such as new industrial projects, habitat restoration, or cultural and tourism projects. Please rate how appealing you find the following options on a scale from 0 to 10:
  a. Demolishing the existing structures to facilitate the creation of new industrial projects [Reindustrialization].
  b. Tearing down the structures and restoring the original natural habitat as much as possible [Renaturalization].
  c. Preserving the installations as much as possible and repurposing them for alternative uses, such as museums, tourism, educational activities, or research [Heritage conservation]."

### Missing data procedures
We found 74 and 5 respondents with missing answers in some of the items in the National and As Pontes samples, respectively. To avoid listwise deletion and loss of power, we imputed these values using subset-level weighted means: within each analysis group (e.g., Spain, historic mining areas, As Pontes), after excluding cases with missing weights, empty cells were replaced by that group's weighted mean for the corresponding item (clamped to the 0–10 scale). This increases N while preserving group-specific opinion structure.

### Principal component analysis
We analyzed the structure of public opinion with Principal Component Analysis (PCA)[24–26]. PCA condenses correlated survey standardized items (each has mean 0 and standard deviation 1) into a small number of uncorrelated axes (components) that capture the main directions of variation. Each component is a weighted combination of the original items. Items that tend to move together receive loadings with the same sign, and items that move in opposite directions load with opposite signs. For instance, if a given component exhibits loadings of 0.78 for option a, −0.65 for option b, and −0.10 for option c, it reads as a contrast between option a and option b because they pull in opposite directions. This approach fits our question because disagreements are not always visible in raw averages, whereas PCA reveals the underlying bundles of agreement and opposition.

Our results are presented in biplots (one of each of the subgroups) (Fig. 1). In them we can read the loadings (shown as arrows): arrow direction indicates alignment with each component; the angle between arrows approximates correlations (acute = positive, ~90° = weak/none, obtuse = trade-off) and arrow length indicates how well an item is represented in the two-component display.

### Component evaluation and rotation
To determine whether a component is statistically significant (that is, whether it reflects a real cleavage in opinions), we use two criteria. First, we consider the percentage of variance it explains (reported in brackets in Fig. 1). Second, we examine its eigenvalue (Fig. 2), which is the sum of the squared loadings for a given component. Following Kaiser normalization
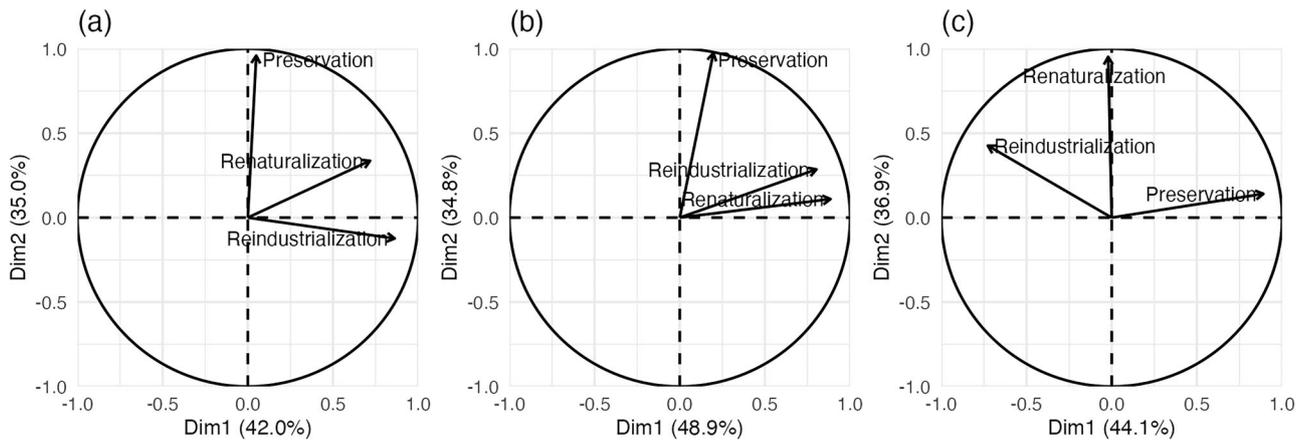
**Fig. 1 | PCA correlation-circle biplots with varimax rotation of post-industrial land-use preferences. a** Spain, **b** Asturias/León/Palencia, **c** As Pontes. Axes (Dim1, Dim2) show % variance explained. Vectors are loadings (length = strength;

angle = association (acute positive, ~90° weak, opposite negative); opposing vs. aligned indicate divergence vs. complementarity. The circle marks the maximum possible correlation.

**Fig. 2 | Scree plots of eigenvalues for post-industrial land-use preferences across survey samples.** Each panel shows the first three components with the Kaiser criterion threshold (eigenvalue = 1, dashed line). Samples include the national population (**a**), historical mining provinces (**b**, **f**), As Pontes (**e**), and A Coruña and Teruel provinces with and without 150-km expansions around power plants (**c**, **d**, **g**, **h**).
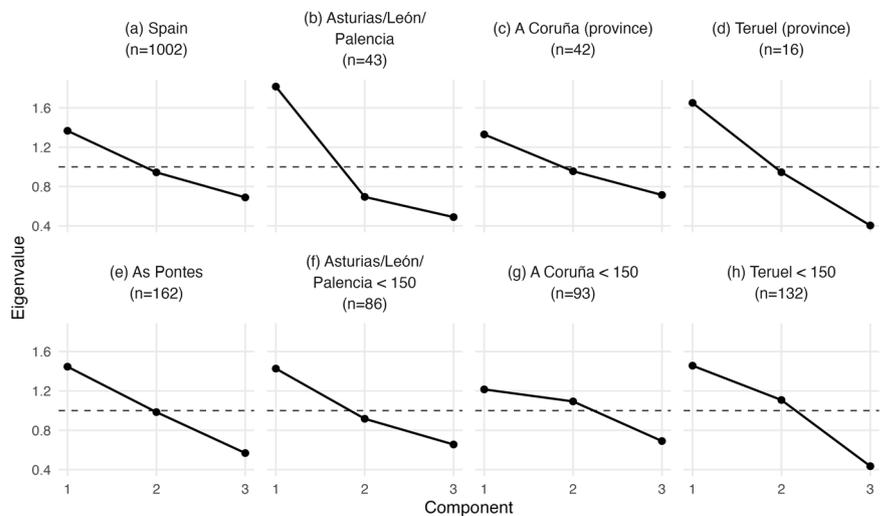


criterion[27], a component is typically treated as a substantive if its eigenvalue exceeds 1, which means it captures more variation than any single item. We then verify how many components exhibit an eigenvalue greater than 1 for each of our subgroups (As Pontes municipality, historical mining provinces, and the national population) and interpret the loading patterns for the heritage context. With only three items at most three components exist, and typically only one is clearly interpretable in practice. A second component can still be informative. The fact that two items load with the same sign on the first component does not prevent them from pointing in opposite directions on the second component. That second axis can thus reveal a secondary tension that is not visible in raw averages.

One limitation of PCA is that items often load on several components, which makes the axes hard to interpret. We therefore apply a varimax rotation[28] to achieve simple structure, so each item loads strongly on one component and only weakly on the others. It is important to note that the rotation does not change the total variance explained or the communalities, but helps to observe at a glance whether preferences behave like trade-offs or like complementary tendencies.

## Results

In As Pontes municipality, the first principal component (represented on the horizontal axis) explains nearly half of the variance, highlighting a stark divide between heritage conservation on one side and reindustrialization and renaturalization on the other (panel "c" in Fig. 1). This polarization

suggests that economic concerns strongly shape local perceptions, with reindustrialization emerging as the dominant preference. However, the second principal component shows that opposition to conservation does not translate into a single redevelopment choice: among respondents who deprioritize conservation, support splits between reindustrialization and renaturalization, indicating the debate is not strictly binary but structured around competing, yet non-mutually-exclusive, visions of economic and environmental transformation. Consistent with this, the scree plot (Fig. 2) places PC2 close to the Kaiser threshold, so two factors are defensible in As Pontes (one capturing the conservation vs. redevelopment divide, the other differentiating the two redevelopment paths).

In contrast, at the national level, the Spanish population exhibits a more balanced structure (panel "a" in Fig. 1). The first component (42% variance explained) suggests broad similarity in opinions, with responses generally favorable toward all alternatives, albeit with differences in intensity and nuance. The second component captures some opposition between conservation and reindustrialization, but much less than in As Pontes. This is mirrored in the eigenvalues: PC1 > 1 and PC2 hovers around 1 (Fig. 2), implying a strong general factor with, at most, a borderline second (i.e., milder tensions rather than hard splits).

Notably, this pattern tightens in the historical mining provinces (Asturias/León/Palencia) (panel "b" in Fig. 1). Here, the first component explains an even greater share of variance and all three options align in the same general direction. Crucially, the eigenvalue profile shows PC1 well

**Fig. 3 | PCA correlation-circle biplots with varimax rotation of post-industrial land-use preferences across mining provinces. a** A Coruña (province), **b** A Coruña + respondents ≤150 km from power plants, **c** Asturias/León/Palencia, **d** Asturias/León/Palencia + respondents ≤150 km from power plants, **e** Teruel (province), **f** Teruel + respondents ≤150 km from power plants. Axes (Dim1, Dim2) show % variance explained. Vectors are loadings (length = strength; angle = association (acute positive, ~90° weak, opposite negative); opposing vs. aligned indicate divergence vs. complementarity. The circle marks the maximum possible correlation.
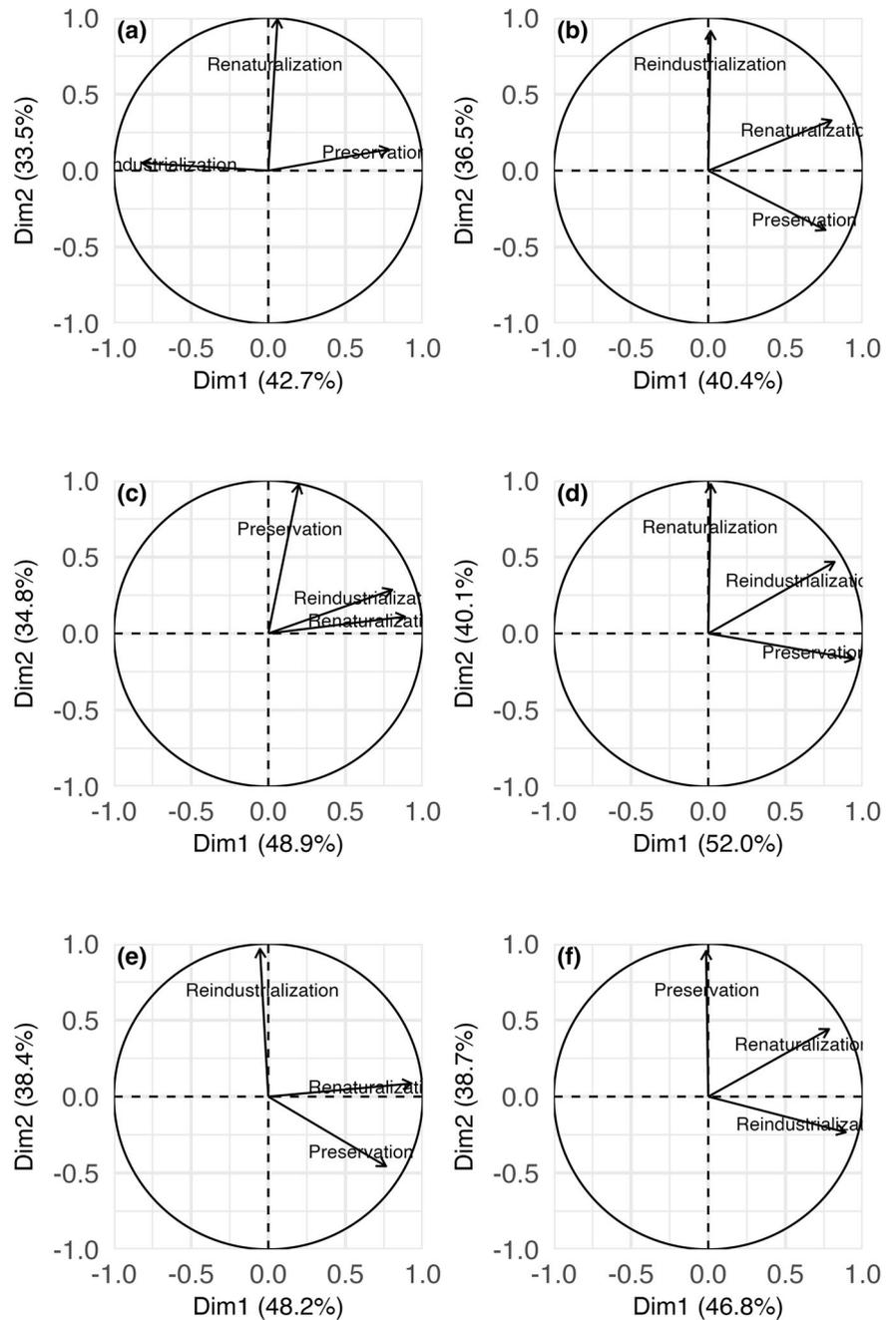


above 1 while PC2 falls below 1, meaning only one factor is extracted by the Kaiser criterion (Fig. 2). Substantively, that points to low overt conflict: attitudes cohere along a single consensus axis rather than separating into competing camps. Compared with As Pontes (where a second, substantively meaningful axis still surfaces), the mining areas display greater convergence on how to use post-industrial land.

**Robustness and additional results**

This study has two main limitations. First, mode effects are possible: in As Pontes, data were collected face-to-face on the street, whereas in the other areas, telephone interviews were used. The survey-methods literature shows that mode can affect measurement (e.g., social desirability, coverage, non-response), creating comparability biases across areas[29–31]. Second, the initial sample size for the historical mining provinces (Asturias, León, and Palencia) was small, which increases sampling error and makes both means and the PCA less stable.

To mitigate both issues, we expanded the analytical frame to a 150-km radius around the power plants in each province, increasing N at the cost of reduced alignment with actual geographic exposure. We defined the 150-km radius in two steps. First, for each respondent, we computed the distance from the centroid of their municipality of residence to the nearest power plant. Second, we retained for analysis only respondents whose municipality lay within 150 km of any plant in the focal area. For example, in A Coruña we included municipalities located <150 km from either As Pontes or Meirama (see Fig. S1) After expansion, each province reached not less than 84 completes (see N per sample in Fig. 4), exceeding the minimum rules of thumb of 5–10 respondents per variable and falling within ranges that simulation evidence deems adequate when communalities are moderate/high and the structure is simple[32–34]. In our subsamples, communalities are indeed moderate to high (h² ≈ 0.64–0.99) (See Fig. S2), which supports model stability at these Ns.

**Fig. 4 | Mean weighted responses for three post-industrial land-use options. a** Spain, **b** Asturias/León/Palencia, **c** A Coruña (province), **d** Teruel (province), **e** As Pontes, **f** Asturias/León/Palencia + respondents ≤150 km from power plants, **g** A Coruña + respondents ≤150 km from power plants, **h** Teruel + respondents ≤150 km from power plants ≤150 km. Data are weighted by gender, age, and occupation to match census benchmarks.
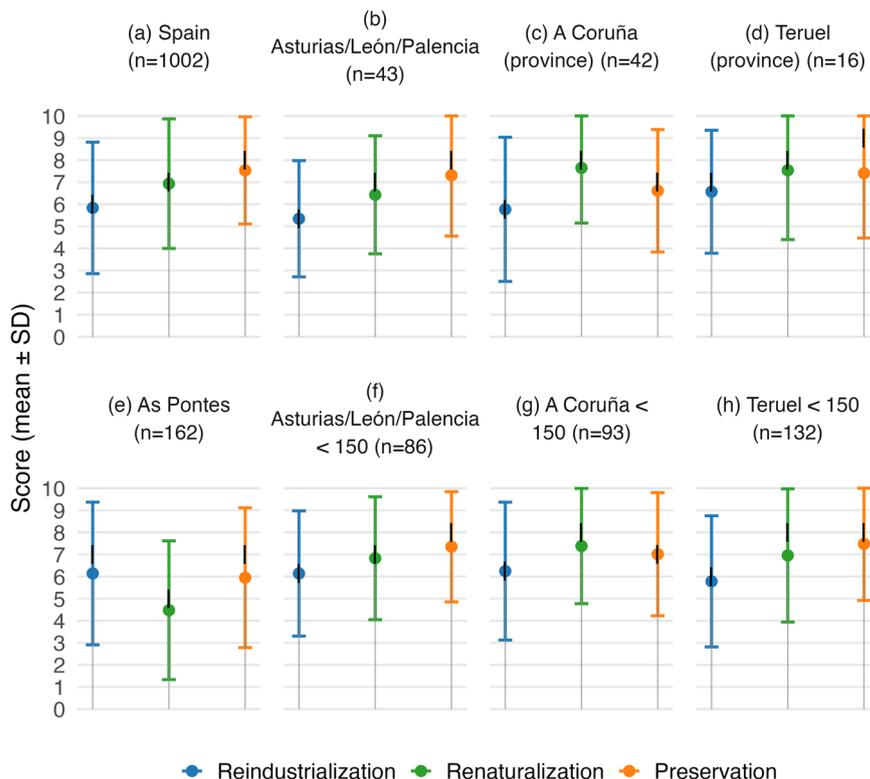


Beyond boosting N, this threshold is also plausible on environmental and perceptual grounds: tall stacks and gas plumes ($SO_2$, $NO_x$, particulates) can generate visible and measurable impacts over tens (and in some cases more than a hundred) kilometers, depending on topography and prevailing winds[35]. Historical complaints support this radius; for instance, municipalities in Castellón (Valencian Community) filed actions in the late 1980s alleging acid-rain damage from the Andorra (Teruel) plant[36].

With the 150-km expansion, in the case of the historical mining area (Asturias/León/Palencia), the opinion structure is substantively unchanged (see Fig. 3). The preservation–reindustrialization tension even diminishes as both load positively and more collinearly on Dim1. In turn, Renaturalization becomes the main contrasting pole on Dim2; however, PC2's eigenvalue hovers around (but does not clearly exceed) the Kaiser threshold, so this vertical split is only modestly supported and does not constitute a new cleavage.

To rule out a mode effect (face-to-face in As Pontes vs. telephone elsewhere), we triangulated with exclusively telephone samples in provinces comparable in proximity and energy trajectory. In A Coruña (where As Pontes is located and where the Meirama power plant with a similar history also operated) we would expect similar patterns because of territorial exposure and shared industrial memory. Indeed, both at the provincial level and in the 150-km radius area around the power plants, we observe the same kind of discrepancy between reindustrialization and preservation, albeit considerably less intense in the 150-km area around the power plants. The contrast reappears in Teruel, another case of relatively recent mining: the vectors for reindustrialization and preservation lie in opposite sectors (angle >90°), and the tension persists even in the 150-km area ($n \approx 120$), though attenuated. Importantly, in A Coruña's ≤150-km sample a secondary tension emerges on Dim2, which splits renaturalization and preservation (opposite signs) while both remain broadly aligned on Dim1; this is consistent with a two-factor structure (PC2 > 1) and indicates a trade-off between ecological restoration and heritage reuse distinct from the main redevelopment dimension.

Regarding the estimated means (Fig. 4), As Pontes stands out even comparing with the expanded provincial samples: it is the only sample in which reindustrialization ranks first. By contrast (and as in Teruel) both A Coruña (province) and its ≤150-km area share a different but related feature: preservation never tops the ranking. Together, these patterns indicate preference structures tilted toward redevelopment/renaturalization over heritage conservation in these areas.

## Discussion

This study examined whether decommissioned coal power plants, exemplified by As Pontes, are perceived by surrounding communities as heritage assets to be preserved or as spaces more appropriately devoted to redevelopment or ecological restoration. The aim was to contrast expert-led assessments of heritage value with public opinion, capturing the perspectives of those directly affected by the closure of these facilities.

Our results highlight the contested nature of industrial heritage and challenge the assumption that sites like the As Pontes power plant hold intrinsic historical value. While expert-driven studies such as Jato-Espino et al. justify preservation based on material heritage conservation and historical significance, the public opinion data presented here suggest that local communities do not necessarily align with those visions. The polarization observed in As Pontes indicates that heritage recognition is perceived in opposition to redevelopment. In contrast, in historical mining regions and for the Spanish population overall, polarization disappears, reflecting a broader acceptance of multiple post-industrial land-use strategies. In these contexts, heritage conservation, renaturalization, and reindustrialization are not seen as mutually exclusive but rather as complementary.

One plausible interpretation is rooted in the notion of difficult heritage. Industrial infrastructure can elicit ambivalence rather than shared recognition, carrying unresolved economic, environmental, and social meanings. In long-established mining regions, industrial landscapes are embedded in local identity; by contrast, the rapid rise and decline of As Pontes has hindered the consolidation of a stable heritage narrative. As a result, the power plant is perceived predominantly through the lens of economic survival, underscoring that industrial heritage is not merely historical or architectural, but inseparable from contemporary livelihoods.

Our results are more consistent with Critical Heritage Studies[20–22], which emphasize that heritage is not fixed but socially negotiated, and with empirical work in Spain and abroad showing divergences between expert framings and community perspectives[8–11].

One unexpected result is that preservation is not the top option in any of the newer coal regions (Teruel, A Coruña), i.e., those developed in the 1970s through capital-intensive, large-scale opencast mining. This suggests that rapid, externally driven energy projects leave weaker cultural anchors than the gradual industrialization of older, labor-intensive underground coalfields, raising questions about the durability of heritage claims in "boomtown" contexts. As Niver and Doyon[37] work on US coal regions illustrates, contrasting technological and organizational regimes (underground Appalachian mines versus western surface operations) foster different cultures and attachments. Efforts to recognize and preserve such infrastructures as heritage elsewhere must therefore begin from a clear, context-specific understanding of these historical sociotechnical differences.

Taken together, our findings imply that policies addressing contested industrial heritage should move beyond expert adjudication and adopt plural, negotiated approaches. Preservation, renaturalization, and redevelopment should be framed not as exclusive alternatives but as competing claims to be balanced through participatory decision-making that acknowledges ambivalence and conflict.

Like any survey-based study, our analysis has limitations. First, differences in data collection mode (face-to-face in As Pontes, telephone elsewhere) may introduce comparability biases, although triangulation with additional provinces mitigates this concern. Second, the relatively small sample sizes in historical mining regions increase margins of error and reduce stability in factor solutions, even though post-expansion Ns fall within accepted thresholds for PCA when communalities are high. A further limitation is the mismatch in geographic scale. The As Pontes survey was conducted at the municipal level—directly in the community affected by the plant's closure—whereas the "historic mining regions" are analyzed at the provincial scale, and many respondents there may not reside in municipalities directly affected, implying lower exposure to the phenomenon. This differential exposure could attenuate contrasts across groups. Nevertheless, the fact difference persists when comparing those provinces with the province where As Pontes is located (A Coruña) lends support to our conclusions. Finally, our focus on three options (reindustrialization, renaturalization, and preservation) necessarily simplifies the broader spectrum of possible post-industrial futures. Future research should examine how attitudes evolve as redevelopment plans unfold, explore additional post-industrial alternatives, and assess whether participatory governance models can mitigate conflict and foster more inclusive heritage outcomes.

## Data availability

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## Author contributions

X.P.S.: Conceptualization, methodology, formal analysis, investigation, resources, writing—original draft, writing—review and editing, visualization. M.G.D.: Methodology, formal analysis, and review. A.A.D.: Resources and review. A.S.H.: Resources and review.

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## Additional information

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