

MASTER'S THESIS

Evaluating a 21st-Century Vernacular

*Performance and Applicability of Naturdorf Bärnau
(Germany), with Reference to the Vegetarian
Pavilions in Grugliasco (Italy)*



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di Torino**

Naturdorf Bärnau settlement

Illustration by Andreas Mann, c. 2024

The Climate Impact of the Building Sector

37% of global CO₂ emissions come from building operations and construction (UNEP, 2023).

This figure refers specifically to energy and process related CO₂ emissions. E.g, burning fossil fuels, power, heating buildings, and the industrial processes for making materials like cement and steel.

~50% of total emissions in new buildings is embodied carbon (WBCSD & ARUP, 2023)

Historically, when people talked about a building's environmental impact, they focused almost entirely on **operational energy** - the electricity and gas a building consumes while people live or work in it over decades, which made sense because buildings were poorly insulated and inefficient. Therefore, as buildings have become more energy efficient, the focus has shifted to **embodied carbon** emission.

Carbon neutrality frameworks (PAS 2060, ISO 14068-1) emphasise offsetting over reduction, leaving the **material dimension of construction** — where emissions are embedded before a building even operates — insufficiently addressed.

Vernacular architecture — historically rooted in local resources, climate response, and low-energy construction (Rudofsky, 1964; Oliver, 2006) — offers a relevant, evidence-based framework for rethinking the material basis of construction. Bocco and Habert (2024) reinterpret this for the 21st century through four principles tested in this thesis.

Aim and Research Questions



Aim: To critically assess the extent to which Naturdorf Bärnau aligns with the four principles of 21st Century Vernacular Architecture proposed by Bocco and Habert (2024).

- 1 To what extent does Naturdorf Bärnau align with the four principles of 21st Century Vernacular Architecture?
- 2 What are the embodied energy and embodied carbon profiles, including biogenic carbon storage?
- 3 To what extent do material sourcing patterns and financial flows contribute to regional economic retention?
- 4 Which design and construction strategies have the greatest influence on environmental performance?
- 5 How can the findings inform future vernacular and bio-based housing models?

Geographic and Territorial Context

Naturdorf Bärnau sits in the Upper Palatinate region of Bavaria, near the Czech border — a predominantly rural, peripheral landscape.

Yet it occupies a historically strategic position: the medieval Goldene Straße (Via Carolina) connected Luxembourg to Nürnberg to Prague and even Warsaw through this exact location, making Bärnau a centuries-old point of material, knowledge, and cultural exchange.

This dual identity, which is peripheral today and historically connected — is foundational to why the site was selected.

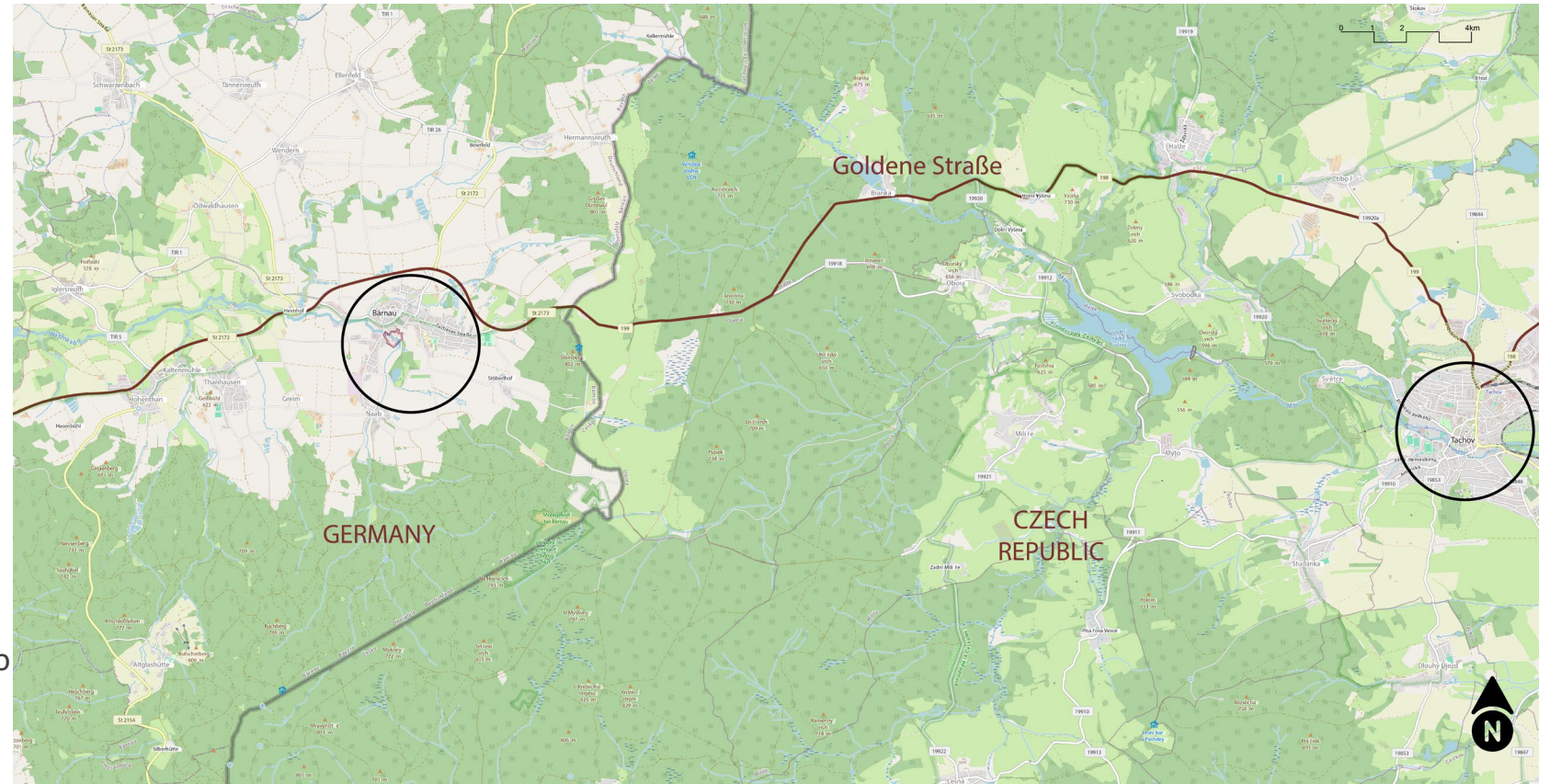


Figure 2: Regional location map - Bärnau & the Goldene Straße corridor

Source: Author's illustration based on Bärnau's archive and open street map.

Why Bärnau? A History of Exchange



Figure 3: Goldene Straße trade route map - Medieval Bavaria–Bohemia trade routes

Source: Naturdorf Bärnau's panel.

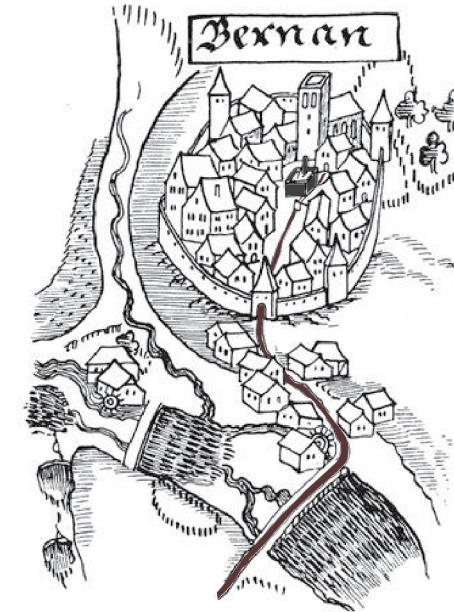


Figure 4: Town of Bärnau, historic illustration - Button Town Bärnau

Source: Bärnau City Archives (with author's illustration)

Established in the 14th century under Emperor Charles IV, the Goldene Straße was a major political and economic corridor — not just for goods, but for the exchange of construction knowledge and craftsmanship across Central Europe (Wolters, 2015).

This contributed to a hybrid architectural culture, where timber, clay, and stone were pragmatic responses to climate and resource availability — not stylistic choices. This is the cultural and material logic Naturdorf Bärnau extends today.

The Geschichtspark Bärnau-Tachov



Figure 5: Geschichtspark aerial / reconstructed buildings - Experimental archaeology site

Source: https://www.kreis-tir.de/buergerservice/aktuelles/detail/via-carolina-goldene-strasse-ev-erhaelt-600000-euro-zur-staerkung-des-geschichtspark-baernau-tachov?utm_



Figure 6: Experimental archaeology site

Source: Naturdorf Bärnau's photo archive.



Figure 7: Experimental archaeology site

Source: Naturdorf Bärnau's photo archive.

An open-air museum and research site reconstructing settlement typologies through **full-scale experimental archaeology** — buildings are constructed, inhabited, and maintained using historically informed techniques (Reynolds, 1999).

This reframes vernacular architecture as a **dynamic, evolving system** of knowledge, not a fixed historical artefact.

Naturdorf Bärnau, located adjacent to the park, directly extends this experimental logic into the realm of modern, inhabited construction — the critical bridge justifying its selection as a case study.

Landscape, Ecology, and the Green Belt



Figure 8: European Green Belt corridor map - Former Iron Curtain ecological corridor

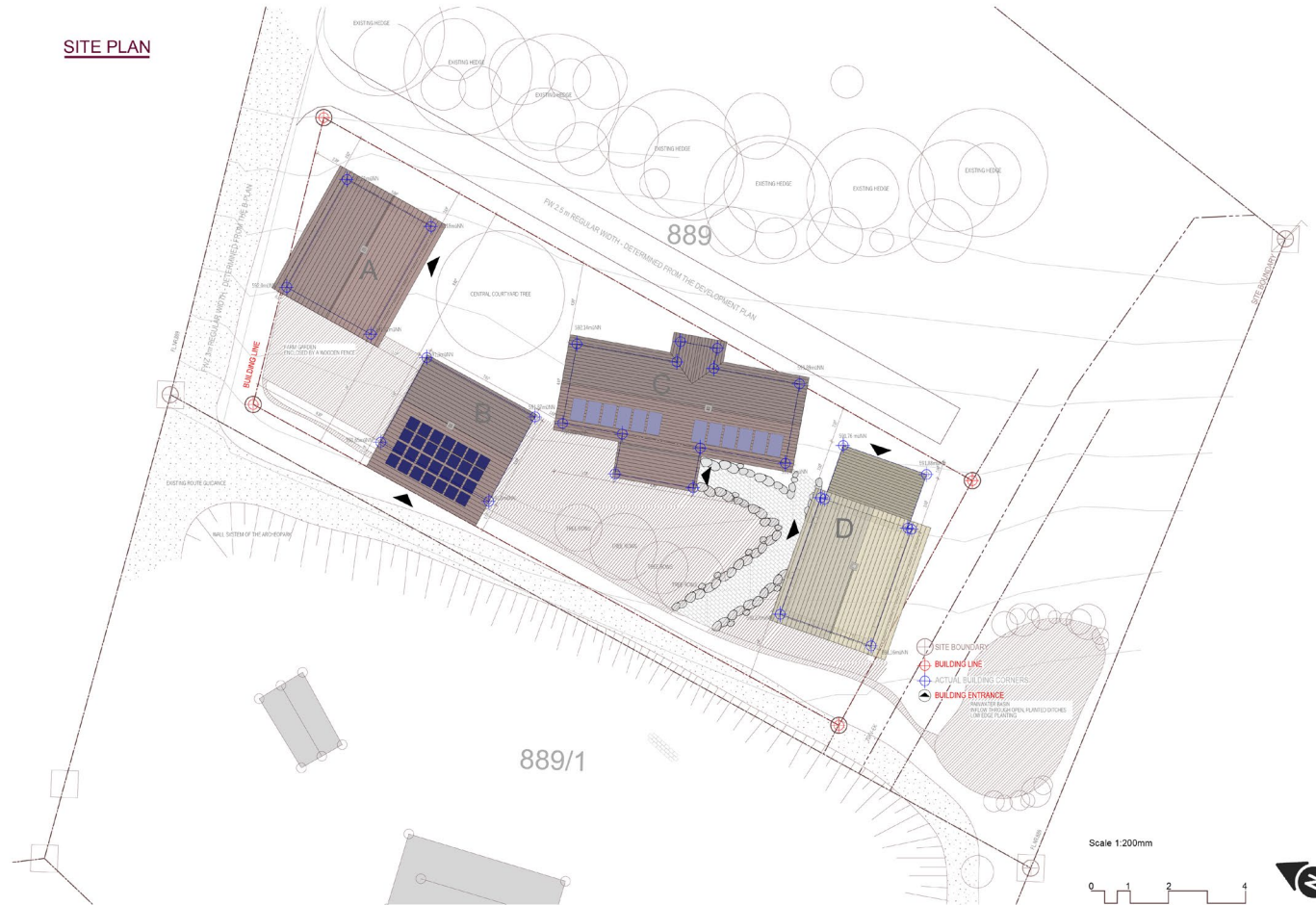
Source: Naturdorf Bärnau's photo archive

Bärnau sits within the European Green Belt — a 12,500 km transboundary ecological corridor along the former Iron Curtain, characterised by high biodiversity and minimal development (Terry et al., 2006).

Building here requires reduced soil disturbance, limited transport, and reversible construction — constraints that align directly with vernacular building logic rather than imposing new ones.

Ecological protection and vernacular material logic converge structurally at this site — environmental sensitivity, material locality, and cultural continuity are interconnected, not separate design considerations.

The Naturdorf Bärnau Project



Four holiday homes (A–D), built with the same techniques and core materials, adjacent to the Geschichtspark. Conceived as a **long-term experiment** translating historical reconstruction into contemporary, inhabited residential design. The site functioned as a practical training ground, where craft techniques were taught and rehearsed by voluntary groups during construction.

Figure 9: Site plan, Buildings A–D + shared areas - Scale 1:200

Source: Author's drawing

Scope of Analysis: Focus on Building D



Figure 10: Building D at completed state

Source: Photo from site visit – captured by Redina

Why a single-building focus?

- First completed** of the four houses — full as-built documentation available
- Material clarity** and representativeness within the settlement's typological logic
- Enables analytical precision** for LCA, material quantification, and construction detailing
- Single-unit case study approach** (Yin, 2018) — depth and traceability prioritised over breadth

Testing a 21st-Century Vernacular

Bocco and Habert (2024) propose four criteria for a contemporary vernacular architecture. This thesis tests their applicability through Building D.



01

Local Resources

Materials sourced, manufactured, and processed within a defined regional radius



02

Low Environmental Footprint

Quantified through Life Cycle Assessment of embodied and biogenic carbon



03

Contemporary User Expectations

Verified thermal performance against German GEG 2020 regulatory standards



04

Affordability to Local Communities

Reproducibility within a regionally anchored skill and material economy

Comparative Case Studies

Three reference projects situate Naturdorf Bärnau within a broader field of contemporary vernacular reinterpretation, leading into its selection as the central case.



METI Handmade School

Bangladesh

Earth, bamboo & straw; participatory construction embedding economic value locally (Heringer, 2006)

Figure 11: <https://archello.com/project/handmade-school-in-bangladesh>



Strawbale & Timber

Valdichiana, Italy

Timber frame + strawbale infill (GREB method); hybrid systems meeting modern structural standards

Figure 12: La Valdichiana archive and project documentation.
https://www.lavaldichiana.it/casa-di-paglia-valdichiana-martin-steiger/?utm_



Vegetarian Pavilions

Grugliasco, Italy

Research-scale prototypes (straw, hemp, earth) — author's direct site participation

Figure 13: Author's photo from site participation

These projects span the spectrum from research-scale experimentation to real-scale application — Naturdorf Bärnau occupies the hybrid, transitional position between them.

Timber Frame: The Structural Backbone

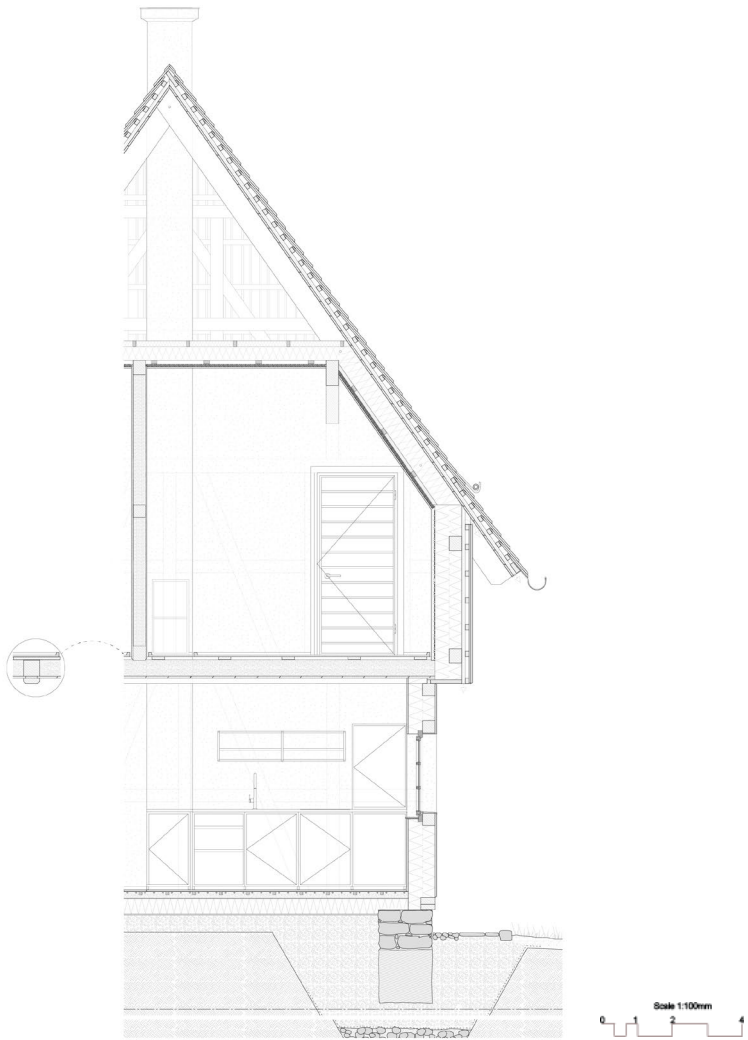


Figure 14: Cross section, timber frame + assembly - Scale 1:100 (Author's drawing)

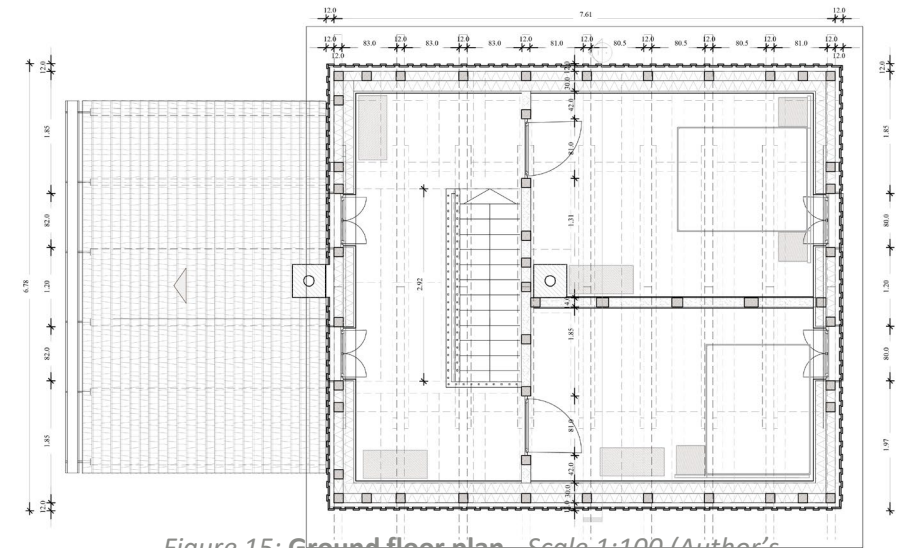


Figure 15: Ground floor plan - Scale 1:100 (Author's drawing)

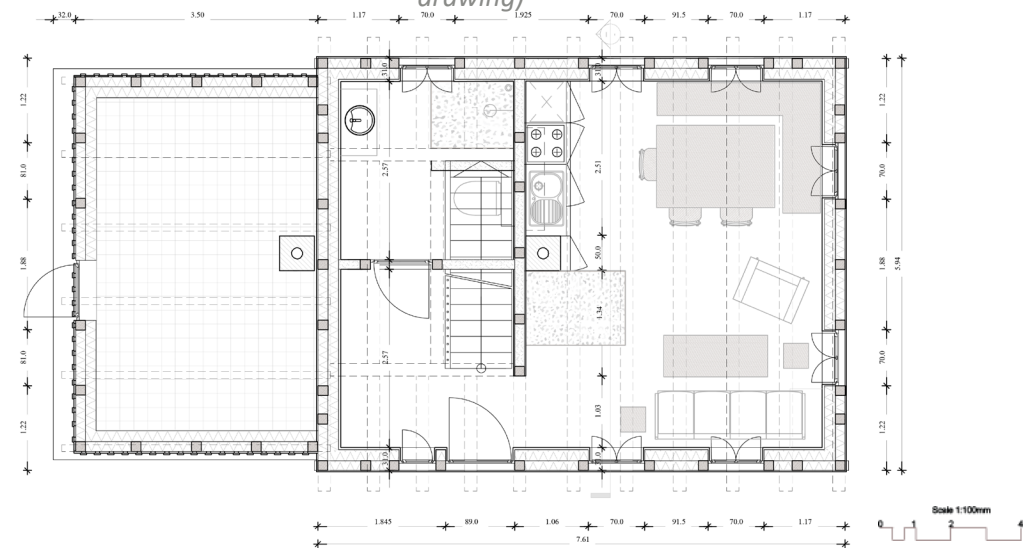


Figure 16: First floor plan - Scale 1:100 (Author's drawing)

Wall and Roof Assemblies

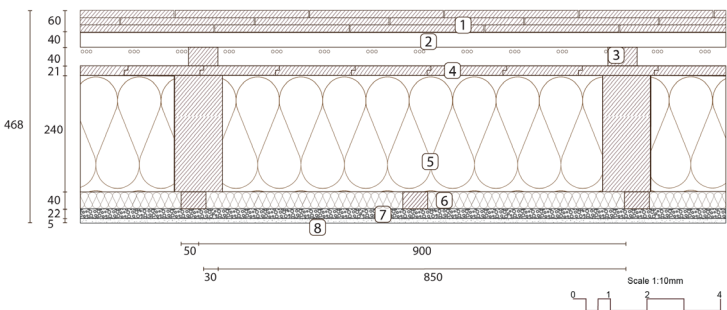


Figure 17: Warm roof callout - Scale 1:100 (Author's drawing)

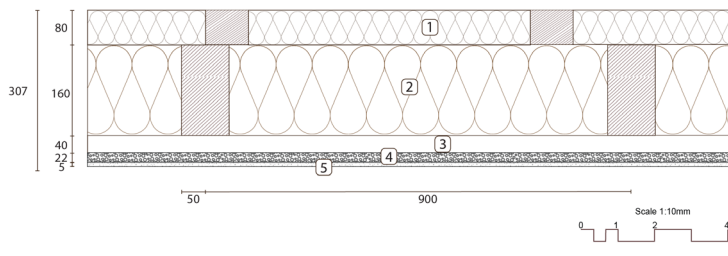


Figure 18: Cold roof callout - Scale 1:10 (Author's drawing)

Warm roof

- ① 60 mm larch shingles (20mm x3 layers)
- ② 40 mm battens 4/6
- ③ 40 mm counter battens 4/6
- ④ 21 mm tongue/groove formwork
- ⑤ 240 mm premium sheep wool insulation
- ⑥ 40 mm optimal sheep wool insulation
- ⑦ 22 mm Claytec clay building board
- ⑧ 5 mm Clay plaster on jute mesh

468 mm

Cold roof

- ① 80 mm sheep wool
- ② 160 mm sheep wool
- ③ 40 mm air layer counter battens 4/6
- ④ 22 mm Claytec clay building board
- ⑤ 5 mm Clay plaster on jute mesh

307 mm

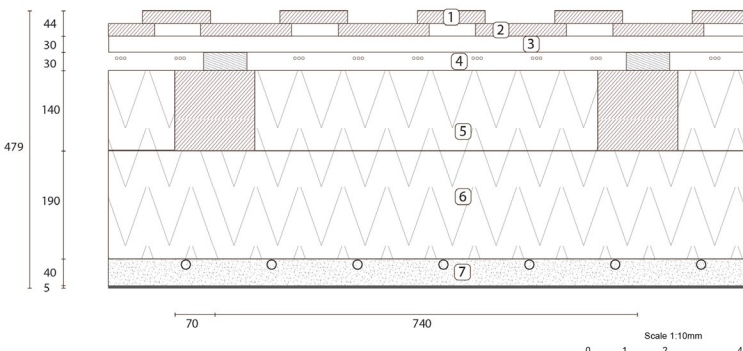


Figure 19: Upper-floor wall callout - Scale 1:100 (Author's drawing)

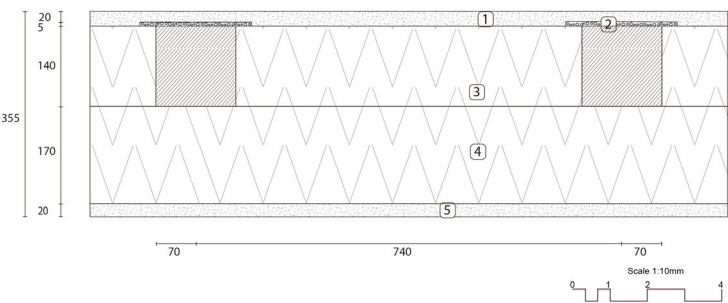


Figure 20: Ground-floor wall callout - Scale 1:10 (Author's drawing)

Exterior wall, upper floor

- ① 22 mm spruce wood panels
- ② 22 mm spruce wood panels
- ③ 30 mm battens 3/6
- ④ 30 mm rear ventilation layer 3/6
- ⑤ 140 mm hemp lime
- ⑥ 190 mm hemp lime
- ⑦ 40 mm clay plaster (basecoat)
- ⑧ 5 mm clay plaster (topcoat)

479 mm

Exterior wall, ground floor

- ① 20 mm lime render (exterior)
- ② 5 mm reed mats (on timbers)
- ③ 140 mm hemp lime
- ④ 170 mm hemp lime
- ⑤ 20 mm clay plaster (interior)

355 mm

Both wall types use hemp-lime infill (upper floor: 140mm + 190mm; ground floor: 140mm + 170mm) — the difference is the exterior finish: ventilated timber cladding upstairs, lime render at ground level. Both roof configurations use sheep wool as the sole insulation, fully bio-based and reversible.

Floor Assemblies: Acoustics, Mass, Moisture

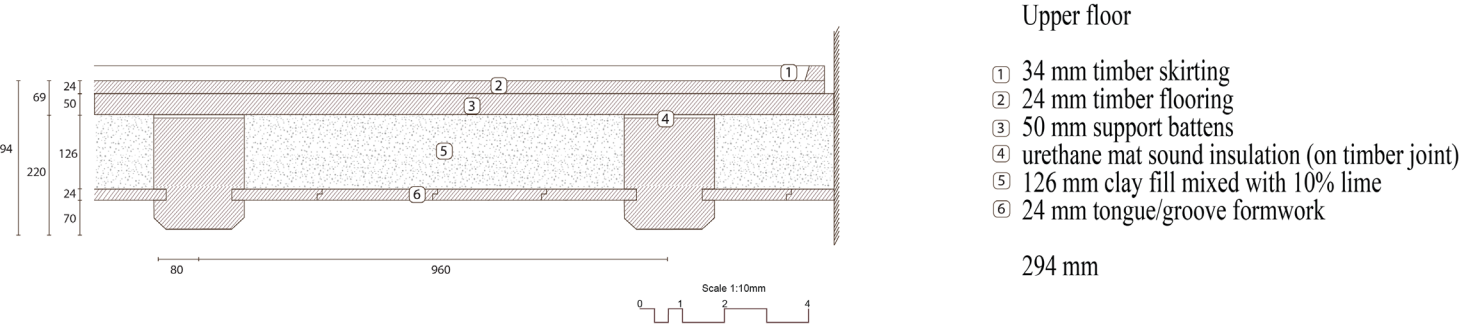


Figure 21: Upper floor detail (joists, clay-lime fill) - Scale 1:100 (Author's drawing)

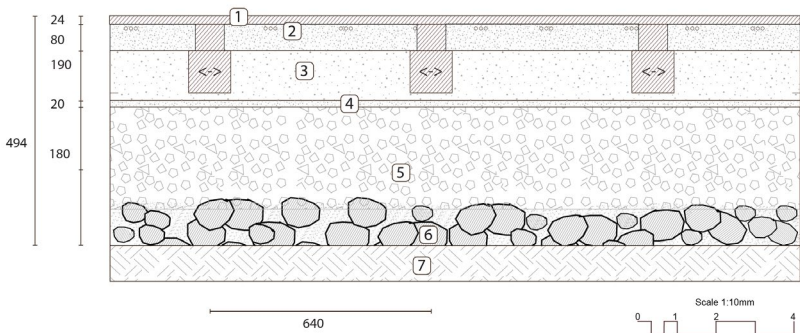


Figure 22: Ground-floor details - Scale 1:100 (Author's drawing)

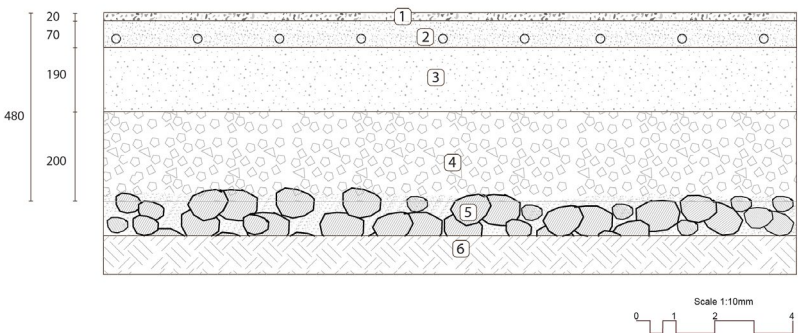


Figure 23: Ground-floor entrance details- Scale 1:10 (Author's drawing)

Upper floor combines timber joists with clay-lime fill (126mm) for acoustic damping and thermal mass. **Ground floor** uses 190mm bound biochar insulation over a gravel capillary break — passive moisture control without synthetic membranes.

Elevations

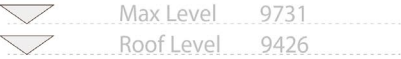


Figure 24: South elevation - Scale 1:100 (Author's drawing)

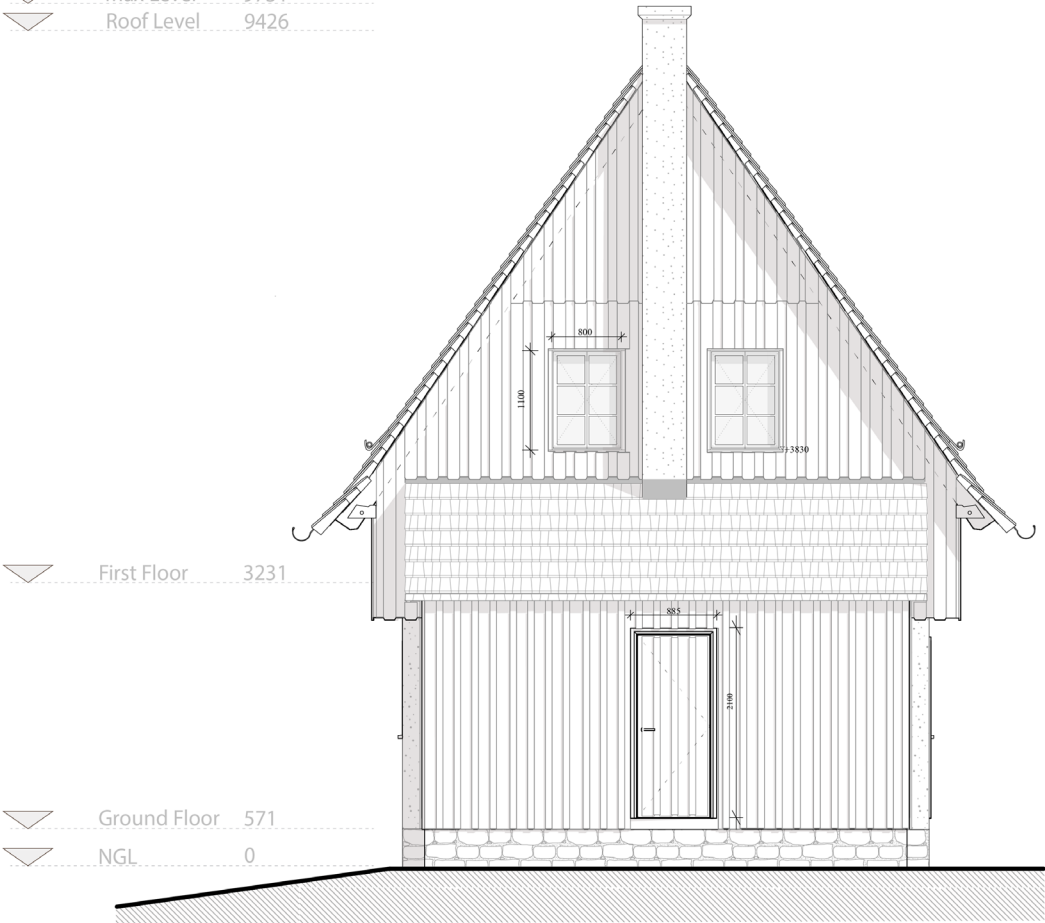
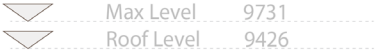


Figure 25: West elevation - Scale 1:10 (Author's drawing)

Intermediate floors combine timber joists with clay-lime fill (126mm) for acoustic damping and thermal mass. **Ground floor** uses 190mm bound biochar insulation over a gravel capillary break — passive moisture control without synthetic membranes.

Assessment Framework



Life Cycle Assessment

ISO 14040 and EN 15978, modules A1–A4, ÖKOBAUDAT (2024-I) database



Climate Impact

EN 15804+A2, IPCC characterisation factors, results in kgCO₂e



Biogenic Carbon

Assessed separately per EN 16449, static –1/+1 approach applied following Hoxha et al., (2020)



Thermal Performance

U-value calculations via u-wert.net, benchmarked against GEG 2020 Neubau

Module A5 (on-site construction) excluded due to unavailable contractor records — declared as a study limitation.

Carbon Intensity by Life Cycle Stage

267.60

kgCO₂e / m² (A1–A4)

Below the 310–350 kgCO₂e/m² average reported
for Northern European residential building
(One Click LCA, 2021)

Total A1–A4 = 20,508.19 kgCO₂e

A1–A3 Production



19,718.39 kgCO₂e (96.15%)

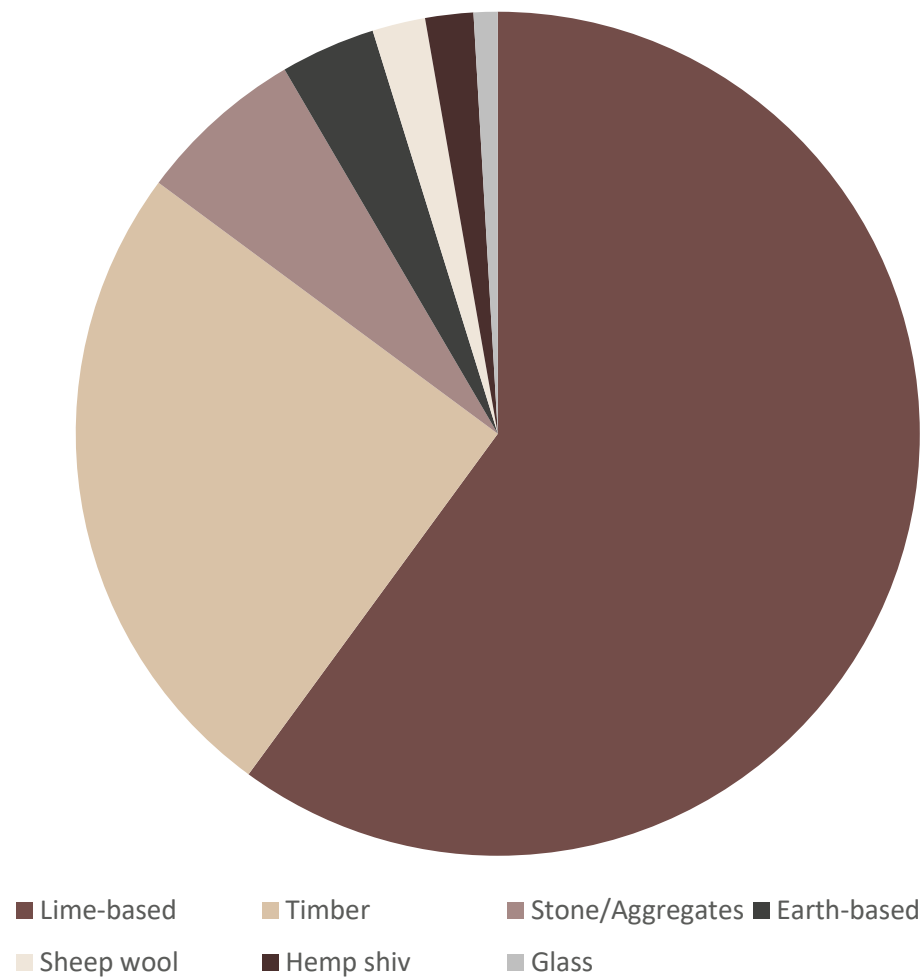
A4 Transport



789.80 kgCO₂e (3.85%)

Geographically concentrated sourcing keeps transport impact minimal — confirming the project's local-resources principle.

Material Contribution (A1–A3)



Lime is the dominant impact driver

60.05% of A1–A3 emissions comes from lime-based assemblies — structural foundations, render, plaster, and screed — despite a low share of overall building weight.

Timber at 25.08% is the largest single material volume — but also the structural backbone enabling biogenic carbon storage.

Sheep wool and hemp shiv combined contribute under 4% to fossil emissions, while serving as primary thermal insulation.

A Carbon-Storing Building

- 33,947.9

kgCO₂ stored

Timber, sheep wool, and hemp shiv biogenic carbon

20,508.19

kgCO₂e fossil (A1–A4)

Total embodied emissions across production and transport

–13,439.68

kgCO₂e GWPnet

Static –1/+1 approach (Hoxha et al., 2020) — carbon-negative across A1–A4

Biogenic carbon is reported separately, not deducted from fossil totals, per EN 15804 and EN 16449 — this figure is informative, not a certified carbon-negative claim.

Meeting Regulatory Comfort Standards

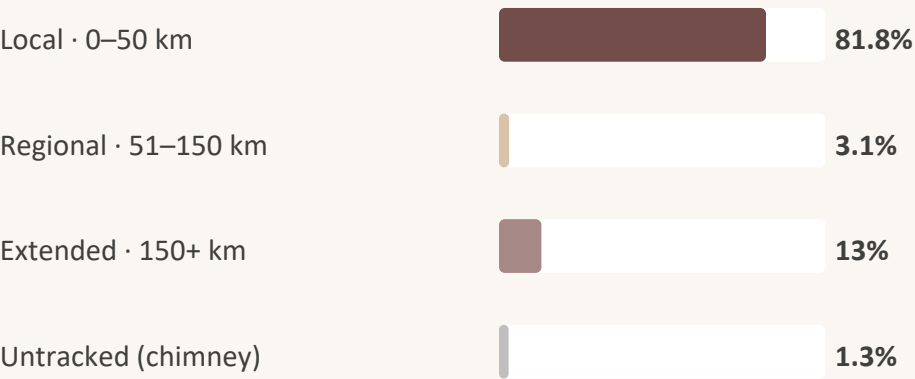
All primary envelope assemblies comply with GEG 2020 Neubau thresholds — using bio-based insulation exclusively, without synthetic substitutes.

ASSEMBLY	U-VALUE (W/m²K)	GEG 2020 THRESHOLD	
Warm roof (sheep wool, 240+40mm)	0.15	< 0.16	✓
Cold roof (sheep wool, 80+160mm)	0.16	< 0.16	✓
Upper floor wall (hemp-lime, timber clad)	0.20	< 0.22	✓
Ground floor wall (hemp-lime, lime render)	0.22	< 0.22	✓
Main ground floor (charcoal-lime)	0.20	< 0.28	✓

Both wall types incorporate radiant heating within the clay-lime plaster — heating integrated within the building fabric itself, not as a separate mechanical system.

Sourcing by Weight and by Material

By total weight (232.3 t)



Materials within each tier:

- Local (0–50km):**
Timber (11–20km), lime (28km), granite (18km), aggregates (28–35km), glass (30km), clay boards (45km), clay — on site (0km)
- Regional (51–150km):**
Sheep wool — Austria (96km), charcoal (90km), timber window frames (120km), larch shingles (140km), pozzolana (28km dist.)
- Extended (150+km):**
Hemp shives (220km raw material source, 700km origin)

By number of categories (n=17)

Local · 0–50km	10 categories	59%
Regional · 51–150km	6 categories	35%
Extended · 150+km	1 category (hemp shives)	6%

Note: figures differ from the weight-based breakdown because category count treats all 17 materials equally, while weight is dominated by high-mass items like timber, lime, and aggregates.

Notable exception: Pozzolana/trass is sourced regionally (28km distribution) but its manufacturer is 230km away — illustrating the limits of simple transport accounting.

Affordability to Local Communities

What does "affordability" mean here? Bocco and Habert's framework goes beyond upfront construction cost. Affordability is understood as the capacity of a building to remain accessible — to build, maintain, and adapt — throughout its entire service life.

Affordability of skills and knowledge Timber framing, lime rendering, clay plastering, and hemp-lime casting all draw on craft traditions with deep roots in Central Europe. Any regional carpenter, plasterer, or mason can build, repair, or modify these assemblies. No proprietary systems, certified specialists, or imported components are required. Therefore, the knowledge to work on this building exists locally and does not disappear.

Affordability over time through reversibility Dry and semi-dry construction techniques mean materials can be separated, repaired, or recast without demolishing the whole assembly. A degraded hemp-lime panel is recast. A failing timber joint is replaced. This allows incremental maintenance rather than costly wholesale replacement, keeping the building affordable as it ages.

An honest limitation was that Upfront construction costs at Naturdorf Bärnau were high, due to its experimental nature and learning-by-doing process. However, the material and skill logic positions this approach to become more affordable as craft knowledge scales and regional supply chains mature.

From Pavilion to Permanent Dwelling

Reflections from the Vegetarian Pavilions in Grugliasco, Italy, observed during the author's internship, contextualise the transferability of vernacular principles.



Figure 26: Grugliasco wall assembly

Source: Author's image from site participation



Figure 27: Naturdorf field photo

Source: Onetz.de photo archive



Figure 28: Naturdorf interior

Source: Author's image from site visit

Grugliasco Pavilions

Experimental, temporary structures — hypothesis-testing under controlled, non-regulatory conditions.



Naturdorf Bärnau

Permanent, inhabited dwelling — confirmed performance meeting regulatory thresholds and durability requirements.

Scope and Boundary Conditions

● **Module A5 excluded**

On-site construction impacts excluded due to unavailable contractor records. Comparable case studies found A5 contributing up to 20% of total A1–A5 carbon — figures here are a conservative minimum.

● **Single-building assessment**

Findings are specific to Building D; the three companion houses share techniques but were not independently assessed.

● **No post-occupancy data**

Thermal performance is verified through calculation, not yet validated through monitored occupancy.

● **Financial flows partially addressed**

Supplier-level procurement records were unavailable; regional economic retention is evidenced geographically, not financially.

CONCLUSION

A Performance-Driven Reinterpretation

Building D demonstrates that all four criteria of a 21st-century vernacular **are jointly achievable** under real construction conditions — not as a stylistic revival, but as a measurable, performance-driven approach to material intelligence.

267.60

kgCO₂e/m²

below regional benchmarks

33,947.9

kgCO₂ stored

biogenic carbon

81.8%

by weight

sourced within 50 km

100%

GEG 2020

envelope compliance

Thank you.

Key References

Bocco Guarneri, A. and Habert, G. (2024) 'New vernacular construction: Environmental awareness and territorial inclusivity', IOP Conference Series: Earth and Environmental Science, 1363, 012114. doi: 10.1088/1755-1315/1363/1/012114.

Hoxha, E., Passer, A., Saade, M. R. M., Trigaux, D., Shuttleworth, A., Pittau, F., Allacker, K., & Habert, G. (2020). Biogenic carbon in buildings: a critical overview of LCA methods. *Buildings and Cities*, 1(1), 504–524.

Mazelli, R. and Bocco, A. (2025) 'The Hidden Journey of Construction Materials: Insights from Experimental Pavilions of Vegetarian Architecture in Northern Italy', IOP Conference Series: Earth and Environmental Science, 1536, 012041. doi: 10.1088/1755-1315/1536/1/012041.

Mazelli, R., Iroagbalachi, P. C., Mann, A., Stassi, F., & Bocco, A. (in press). Verification of the applicability of the 'Vernacular Architecture of the 21st century' concept: the Naturdorf Bärnau. *Proceedings of WSBE 2026, IOP Conf. Ser.: Earth Environ. Sci.*

Isolena Naturfaservliese GmbH. (2024). Environmental Product Declaration: Sheep's wool insulation (BAU-EPD-Isolena-2024-1).

One Click LCA Ltd. (2021). *Embodied Carbon Benchmarks for European Buildings*. Helsinki: One Click LCA Ltd. Available at: <https://oneclicklca.com/resources/ebooks/embodied-carbon-benchmarks-for-european-buildings> (Accessed: 3 July 2026).

United Nations Environment Programme (UNEP) (2023) 2023 Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. Nairobi: UNEP.

World Business Council for Sustainable Development (WBCSD) and ARUP (2023) Net-Zero Buildings: Halving Construction Emissions Today. Geneva: World Business Council for Sustainable Development. Available at: <https://www.wbcd.org> (Accessed: 28 October 2025).

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods*. 6th edn. Sage Publications.