Energy Retrofit Documentation
Dual-Buffer Architecture, HRV, Controls, Funding

Project: 1972 Mid-Terrace House

October 27, 2025

Contents

Chapter 1

Abbreviations

- AWHP — air-to-water heat pump
- DHW — domestic hot water
- FriWa — fresh-water station (instantaneous DHW via plate heat exchanger)
- UFH — underfloor heating
- HRV — heat recovery ventilation
- PHE — plate heat exchanger
- PV — photovoltaics
- HA — Home Assistant (open-source automation)
- HP — heat pump
- COP — coefficient of performance
- SoC — state of charge (battery)
- SPD — surge protective device
- ATS — automatic transfer switch
- EEE — Energie-Effizienz-Experte (energy-efficiency expert)
- EH — Efficiency House standard (e.g., EH 85)
- DIN — Deutsches Institut für Normung (German standards)
- EN — European Norm (standards)
- KfW — Kreditanstalt für Wiederaufbau (German development bank)
- BAFA — Bundesamt für Wirtschaft und Ausfuhrkontrolle
- BEG — Bundesförderung für effiziente Gebäude
- iSFP — individueller Sanierungsfahrplan (individual retrofit roadmap)
- BzA — Bestätigung zum Antrag (confirmation before application)
- BnD — Bestätigung nach Durchführung (confirmation after completion)
- VDI — Verein Deutscher Ingenieure (Association of German Engineers)
- WMZ — heat meter (Wärmemengenzähler)
- RCD — residual current device
- MCB — miniature circuit breaker
- RLA — return-lift valve (keeps stove return $\geq$ 60°C)
- TAS — thermal discharge safety (valve)

Chapter 2

Project Overview

Chapter 3

Project Overview

- Building: Mid-terrace house (Reihenmittelhaus), 113 m^2, built 1972, EG + DG + cellar.
- Occupancy: 3 persons.
- Current energy (2023):
- Space heat: 9,824 kWh/yr (87 kWh/m^2·yr), district heating.
- Domestic hot water (DHW): 16.86 m^3 water (≈881 kWh/yr thermal, $\Delta T \approx 45$ K).
- Electricity: 2,671 kWh/yr.
- Goals:
- Achieve Effizienzhaus 85 + Erneuerbare-Energien-Klasse (≥65- Strong photovoltaics (PV) self-consumption; resilience with battery and critical-loads subpanel.
- Efficient, simple-to-operate system with safe controls and clean commissioning.
- Gentle hydronic cooling without AC (UFH cooling with dew-point protection).

3.1 Key Design Decisions

- Dual-buffer system:
- DHW heating buffer (200–300 L) always hot (55–60°C), supplies FriWa (no potable storage).
- Heating/Cooling buffer (800–1,000 L) hot in winter, cold in summer (16–18°C target for night charging).
- Heat source: Reversible air-to-water heat pump (AWHP, R290), monovalent for design heat load; wood stove with back-boiler as comfort/backup.
- Distribution: Water-based underfloor heating (UFH) in main zones; no fan-coils, no AC.
- Ventilation: Decentralized single-room heat recovery ventilation (HRV) units (6–8 total), DIN 1946-6 compliant.
- Controls: Hard-wired safety + dew-point logic; Home Assistant for PV-aware orchestration and monitoring.

3.2 Performance Targets

- Envelope targets (typical for EH 85):
- Basement ceiling $U \leq 0.25$ W/(m^2·K)
- Roof/attic $U \leq 0.14$ W/(m^2·K)
- Windows $U_w \leq 0.90$ W/(m^2·K)
- Airtightness $n50 \leq 1.5\ h^{-1}$ (pre/post blower-door tests)
- Hydronic targets:
- Heating design $VL \leq 35$°C; long compressor runs.
- Cooling $VL \geq$ dew point + 2 K, typically 19–21°C.

- UFH cooling capacity expectation: 10–25 W/m^2 (≈1.1–2.8 kW total).

3.3 Expected Impacts (order-of-magnitude)

- Envelope + thermal bridge fixes: 25–40- PV 5.8–8 kWp: 5.5–8.5 MWh/yr generation; with battery 10 kWh, self-consumption 50–70- Hydronic cooling: pleasant background cooling; humidity managed by ventilation and dew-point limit (add dehumidifier only during unusual heat/humidity spells).

3.4 Constraints and Notes

- Open basement staircase: add airtight glazed partition and insulate basement ceiling.
- Loggia (interior balcony) and open entry are thermal bridges; see 05_envelope-airtightness.mdforoptions(winter

Chapter 4

Historical Consumption and Costs (2021–2023)

Figures extracted from district-heating statements (see source files below). Focused on amounts and costs.

4.1 Key Figures

- 2021
- Space heat: 14,542 kWh — 2,158.76 EUR
- DHW: 37.86 m^3 — 341.11 EUR
- Total billed (heat + DHW): 2,499.88 EUR
- 2022
- Space heat: 10,898 kWh — 1,917.08 EUR
- DHW: 23.00 m^3 — 232.04 EUR
- Total billed (heat + DHW): 2,149.12 EUR
- 2023
- Space heat: 9,824 kWh — 3,197.43 EUR
- DHW: 16.86 m^3 — 445.41 EUR
- Total billed (heat + DHW): 3,642.84 EUR
- CO2 info (statement): factor 0.251 kg CO2/kWh; emissions 2,961 kg; CO2 cost 95.04 EUR

4.2 Source Documents

- 2021: `infosAndStuff/2021_10000027695_818349.pdf`
- 2022: `infosAndStuff/2022_10000027695_818349.pdf`
- 2023: `infosAndStuff/2023_10000027695_818349.pdf`

Chapter 5

Design Architecture — Dual Buffers

Chapter 6

Design Architecture — Dual Buffers

This document defines the hydraulic concept, operating modes, key setpoints, and component sizing for the dual-buffer plan: a dedicated always-hot DHW heating buffer feeding a fresh-water station (FriWa), plus a separate heating/cooling buffer that is hot in winter and cold in summer. No air conditioners or fan-coils are used; cooling is via underfloor heating (UFH) with dew-point protection.

6.1 One-Line Hydraulic Schematic (ASCII)

```
          [PV + Battery + Critical Loads Subpanel]
                          |
                  [Electrical Supply]
                          |
                      [AWHP R290]
                          |
                  (optional Plate HX)
                          |
                +---------+---------+
                |                   |
     [Heating/Cooling Buffer]   [DHW Heating Buffer]
        800-1000 L, strat.         200-300 L, 55-60 C
                |                   |
                |                   +--> [FriWa] --> Potable DHW
                |                                ^
                |                                |
          +-----+----+                   Cold mains in
          |          |
      3-way        Return
      mixing         from
      valve        UFH
          |          ^
          v          |
       [UFH Supply] +---> [UFH Loops] ---> [UFH Return]

 [Wood Stove w/Back-Boiler] --(return lift, safety)--> Buffer Top
```

Notes: - The DHW heating buffer contains closed system water (not potable). The FriWa heats potable water on demand via a plate heat exchanger. - The heating/cooling buffer acts as hydraulic separator and energy store. In summer it is chilled at night; in winter it is kept warm. - An optional plate heat exchanger (PHE) between the AWHP and indoor circuit allows glycol on the AWHP side and protects indoor water quality.

6.2 Operating Modes

- Winter
- AWHP runs weather-compensated to charge the heating/cooling buffer (mid-zone) for space heating; VL design $\leq$ 35°C.
- Midday PV window: AWHP prioritizes DHW heating buffer to 55–60°C for FriWa draws; thereafter returns to space heating.
- Wood stove charges the buffer top via return-lift valve ($\geq$60°C) and has thermal discharge safety and gravity emergency cooling per EN 303-5.
- Home Assistant (HA) orchestrates priorities and notifications; safety/limits are hard-wired in dedicated controllers.
- Summer
- Night: AWHP chills the heating/cooling buffer to 16–18°C.
- Day: UFH supply is limited to $\geq$(dew point + 2 K), typically 19–21°C, to avoid condensation.
- DHW heating buffer remains hot year-round; AWHP charges it around midday using PV.
- Shoulder Seasons
- Minimal buffer setpoints; DHW midday priority; occasional night-chill during heatwaves.

6.3 Setpoints, Limits, and Sensors

- DHW heating buffer: 55–60°C setpoint; anti-scald mixing valves at fixtures if needed.
- Heating/Cooling buffer (winter): weather-compensated targets to achieve VL $\leq$ 35°C at design.
- Heating/Cooling buffer (summer): night target 16–18°C.
- UFH supply in cooling: $\geq$(dew point + 2 K). Example: 26°C and 60- Sensors (minimum):
- Buffers: top/mid/bottom temperatures on both tanks.
- UFH: supply and return temperatures; optional surface sensor at manifold.
- Ambient: at least one temperature/RH sensor per floor for dew-point calculation.
- Heat/cold metering: heat meters on AWHP to buffer and FriWa primary if feasible.

6.4 Component Sizing (Guidance)

- AWHP (reversible, R290): select by EN 12831 heat loss; typical post-retrofit terrace house 4–6 kW at -10°C; choose 6–10 kW class with good turndown and quiet operation.
- Heating/Cooling buffer: 800–1000 L, stratified, 100–150 mm insulation, low Δp connections, 3 thermowells (top/mid/bottom).
- DHW heating buffer: 200–300 L, 3 thermowells, maintained at 55–60°C year-round.
- FriWa: 25–35 kW plate HX module with variable-speed primary pump, flow sensor, electronic outlet control; potable-side filtration/anti-scale as required by local water hardness.
- Valves/Pumps: ECM circulation pumps; 3-way mixing valve for UFH with hard dew-point input; motorized isolation valves for summer/winter decoupling; check valves and balancing valves.
- Optional PHE: sized for full thermal capacity with low approach ΔT; glycol on AWHP side; include air/dirt separators on both circuits.

- Expansion vessels: sized for total volume (buffers + pipework + emitters); verify per manufacturer; often 50–80 L combined.

6.5 Safety and Water Quality

- Stove loop: return-lift (e.g., 60°C cartridge), thermal discharge safety valve to drain, gravity-safe emergency cooling path, adequate expansion vessel (EN 303-5 compliance).
- System protection: pressure relief valves (typically 3 bar), air/dirt separators, VDI 2035 water treatment (conductivity/hardness), full insulation of hot lines and diffusion-tight insulation on all cold lines with managed condensate.
- Electrical: critical-loads subpanel to maintain HP enable, pumps, controls, network, fridge, and selected lighting/outlets during outages via battery.

6.6 Control Allocation

- Safety/primary control: heat pump native controller; dedicated hydronic controller for mixing valves, pumps, temperature limits, dew-point cutout; hard interlocks, not dependent on HA.
- Orchestration (HA): PV-aware scheduling (e.g., DHW midday), seasonal mode toggles, notifications (wood stove use, filter service, abnormal RH/temps), data logging (buffer temps, RH, energy meters, COP proxy).

Chapter 7

Domestic Hot Water (DHW)

Chapter 8

Domestic Hot Water (DHW) — FriWa + DHW Heating Buffer

This design uses a dedicated DHW heating buffer (closed system water) held at 55–60°C, feeding a Frischwasserstation (FriWa). There is no potable water storage; potable water is heated on demand through a plate heat exchanger.

8.1 Rationale

- Hygiene: No stored potable hot water → minimized legionella risk; simple anti-scald control at outlets.
- Summer compatibility: The DHW buffer remains hot while the separate heating/cooling buffer can stay cold for UFH cooling.
- PV synergy: Midday charging of the DHW buffer with PV improves self-consumption and reduces evening load.

8.2 Hydraulics

- DHW heating buffer (200–300 L): maintained at 55–60°C year-round; fitted with top/mid/bottom sensors and good insulation.
- FriWa module (25–35 kW): includes plate HX, primary variable-speed pump, flow sensor, electronic temperature control; potable-side filter/strainer and service valves.
- AWHP priority logic: DHW charging has time-of-day priority (midday) and temperature priority (if buffer top < setpoint); otherwise AWHP serves space heating/cooling buffer.

8.3 Control and Setpoints

- DHW buffer setpoint: 55–60°C (tune to water hardness and comfort). Use anti-scald mixing valves at fixtures.
- PV-aware charging: If battery state of charge (SoC) is high and PV surplus available, run DHW charge to target; otherwise defer to off-peak schedule.
- Standby losses: Keep buffer well insulated; consider night setback only if draw patterns allow and comfort unaffected.

8.4 Sizing and Performance

- Buffer volume: 200–300 L is typically sufficient for 3 persons with showers and occasional bath; choose larger end if simultaneous draws are common.

- FriWa capacity: 25–35 kW HX module typically gives 10–16 L/min at 40–45°C with sufficient primary temperature; confirm with manufacturer curves.
- Approach temperature: Ensure primary (DHW buffer) temperature margin to meet outlet setpoint during peak draws; tune FriWa PID.

8.5 Water Quality and Maintenance

- Potable side: inline filter/strainer; periodic inspection/descaling based on local hardness.
- Primary side (system water): VDI 2035 treatment to protect plate HX, pumps, valves; monitor conductivity/hardness.
- Serviceability: install isolation valves, drains, and test taps for FriWa and DHW buffer.

8.6 Commissioning Checks

- Verify FriWa outlet stability from 2–16 L/min; ensure no overshoot/undershoot.
- Confirm anti-scald protection at outlets (thermostatic mixers where applicable).
- Log DHW charging periods and temperatures; validate PV alignment.

Chapter 9

Ventilation — Decentralized HRV

Chapter 10

Ventilation — Decentralized Single-Room HRV (DIN 1946-6)

No central ventilation is feasible; this plan uses 6–8 decentralized HRV units to provide base air exchange with heat recovery, local boosts, and summer bypass.

10.1 Design Principles

- Balance and coverage: Provide continuous background ventilation in living/bedrooms; stronger extraction or boost in wet rooms.
- Acoustic comfort: Low noise at base flow, night mode for bedrooms, acoustic liners/baffles.
- Simplicity: Short core drill per unit (160–200 mm), slight outward slope for condensate, easy filter access.

10.2 Unit Types

- Dual-fan continuous units (preferred): simultaneous supply and exhaust through a small counter-flow core; more stable balance.
- Alternating push-pull units (paired): ceramic core stores heat; install in pairs to approximate balance.

10.3 Placement and Air Paths

- Wet rooms (bath, WC, kitchen): units with boost 40–60 m^3/h; grease filters where needed.
- Living/bedrooms: base 15–30 m^3/h per room; night mode in bedrooms.
- Door undercuts/transfer grilles to enable crossflow; avoid short-circuiting supply to immediate exhaust.
- Exterior intakes with weather hoods and insect screens; consider façade acoustics.

10.4 Controls

- Local control: manual boost switches (bath fans), humidity/CO_2-based automatic boosts, night modes.
- Central overview (optional): dry contacts or Modbus/IP bridge to integrate with Home Assistant for visibility and logging (not safety-critical).
- Summer bypass: enable to prevent unwanted heat recovery during cooling season; querventilation possible.

10.5 Installation and Commissioning

- Core drills with slight outward slope for condensate; ensure airtight sleeve sealing.
- Configure design flow rates per DIN 1946-6 ventilation concept; measure and record flows.
- Filters: set maintenance intervals; keep spare sets; include filter-service notifications.

10.6 Interaction with Hydronic Cooling

- HRV aids humidity control but does not dehumidify aggressively; monitor RH per floor.

- If RH $>$ 60

Chapter 11

Envelope, Airtightness, Thermal Bridges

Chapter 12

Envelope, Airtightness, Thermal Bridges

This section defines measures for insulation, airtightness, and mitigation of key thermal bridges (loggia, open entrance/vestibule, open staircase to cellar).

12.1 Targets (EH85-aligned)

- Basement ceiling $U \leq 0.25\ W/(m^2{\cdot}K)$
- Roof/attic $U \leq 0.14\ W/(m^2{\cdot}K)$
- Windows $Uw \leq 0.90\ W/(m^2{\cdot}K)$ with warm edge spacers
- Airtightness $n50 \leq 1.5\ h^{-1}$ (blower-door before/after)

12.2 Measures

- Basement ceiling insulation (must): rigid boards or blown-in solutions; ensure continuous coverage around beams and services; seal penetrations.
- Roof/attic insulation (must): on-roof insulation or upper ceiling; maintain continuous airtight layer; detail penetrations and edges.
- Windows (must): triple glazing, airtight installation with tapes and compressible seals; verify reveal insulation.
- Facade (optional, recommended): external WDVS where feasible; if not, capillary-active internal insulation (e.g., CaSi/wood fibre) at critical interior surfaces; model details to avoid vapor traps.
- Airtightness package (must): professional sealing, tape schedules, and blower-door test pre/post.

12.3 Staircase to Cellar (Open Stair)

- Install airtight glazed partition/door at basement or ground-floor landing; maintain natural light; perimeter seals.
- Combine with basement ceiling insulation to cut stack-effect losses.

12.4 Loggia (Interior Balcony) Options

- Winter garden conversion: high-performance triple glazing, thermally broken frames, insulated parapets/soffits, exterior shading; best comfort and thermal-bridge fix; requires structural and permit checks.

- Targeted thermal-bridge remediation: capillary-active internal insulation at junctions; add exterior insulation if feasible; less impact but lower cost.

12.5 Open Entrance / Covered Entry (Below Living Space)

- Glazed vestibule (Windfang): insulated framing and external door; major infiltration/comfort improvement; may require permit.
- Underside insulation: rigid PIR/EPS below ceiling; seal side-wall junctions; economical but smaller impact.

12.6 Verification

- Thermography after completion to identify residual thermal bridges.
- Blower-door test ($n50 \leq 1.5\ h^{-1}$) with documented leakage sealing actions.

Chapter 13

Controls, Sensors, Monitoring

Chapter 14

Controls, Sensors, Monitoring

Safety controls must be hard-wired; Home Assistant (HA) is used for orchestration and monitoring only. Dew-point protection is mandatory for UFH cooling.

14.1 Safety/Primary Controls (Hard-wired)

- Heat pump controller: compressor protections, defrost logic, supply/return limits.
- Hydronic controller: 3-way mixing valve control for UFH, pump control, buffer temperature limits, DHW priority.
- Dew-point cutout: direct input limiting UFH supply temperature to $\geq$(dew point + 2 K); independent of HA.
- Stove safety: return-lift valve ($\geq$60°C), thermal discharge safety valve, gravity emergency cooling path; pressure relief; expansion vessel sizing.

14.2 Sensors and Instrumentation

- Buffers: top/mid/bottom temperatures on DHW and heating/cooling buffers.
- UFH: supply and return temperatures; optional manifold surface temperature.
- Ambient: at least one temperature/RH sensor per floor for dew point.
- Energy metering: heat meters for AWHP$\rightarrow$buffer and FriWa primary (optional), electric sub-meter for HP.
- Flow/pressure: as required by FriWa and UFH balancing; include purge points and drains.

14.3 Orchestration (Home Assistant or similar)

- PV-aware schedules: DHW buffer charge at midday; optional winter buffer preheat during PV surplus.
- Seasonal modes: winter (heating), summer (cooling + DHW only), shoulder (adaptive minimal setpoints).
- Notifications: wood stove opportunity prompts; filter service (HRV/FriWa); abnormal RH/temperature alerts; fault relays from HP.
- Data logging: buffer temps, UFH VL/RL, indoor RH/T, HP power, heat meter data; derive coefficient of performance (COP) proxy where meters available.

14.4 Example Dew-Point Logic

- Inputs: indoor T, indoor RH $\rightarrow$ dew point; measured UFH supply temperature.

- Limit: UFH supply target = max(heating curve demand, dew point + 2 K) with absolute min typically 19–21°C.
- Fault/lockout: if supply < (dew point + 2 K) or manifold surface moisture detected, close mixing valve/stop pump until conditions safe.

14.5 Electrical and Resilience

- Critical-loads subpanel: HP enable, circulators, hydronic controller, HA host, network gear, fridge, selected lights/outlets.
- Surge protection: SPD coordination for PV, battery, HP, control electronics.
- Night mode: reduce acoustic output of outdoor unit and HRV where possible.

Chapter 15

Funding, Compliance, Documentation

Chapter 16

Funding, Compliance, Documentation

This section outlines a funding approach aligned with current concepts. Always verify current program rules and eligibility with an Energie-Effizienz-Experte (EEE) and your bank before committing.

16.1 Primary Route — KfW 261 (Wohngebäude – Kredit)

- Goal: Effizienzhaus 85 + Erneuerbare-Energien-Klasse (≥65- Credit scope: heat pump system, buffers, FriWa, hydraulic periphery, safety, system electricals; potentially wood stove with back-boiler as part of the system scope.
- Repayment bonus: typically 10- Important: Costs financed within the EH loan pot cannot be double-funded elsewhere.

16.2 Complementary — Einzelmaßnahmen (BAFA/BEG)

- Apply to building envelope (basement/roof/windows/facade), decentralized HRV, measurement/control/automation (MSR), and UFH distribution.
- Typical rates: 15- Rule: No double-funding of the same cost position if already in KfW 261 EH pot.

16.3 Additional Financing

- Supplementary loans (e.g., KfW programs 358/359) for Einzelmaßnahmen up to common caps per dwelling.
- PV and battery: 0

16.4 Process and Timing

- Engage an EEE early. Obtain “Bestätigung zum Antrag” (BzA) before awarding contracts, or use suspensive clauses.
- Clean cost separation: define which positions are under EH-loan vs. Einzelmaßnahmen to avoid double-funding.
- Post-completion “Bestätigung nach Durchführung” (BnD) to trigger repayment bonus and finalize grants.

16.5 Documentation and Compliance

- Design calculations: EN 12831 heat load; ventilation concept per DIN 1946-6; dew-point logic; thermal bridge details.
- Commissioning protocols: blower-door (pre/post), hydraulic balancing, water quality (VDI 2035), pressure tests, heat meter setup, HP commissioning.
- Safety: stove per EN 303-5 with return lift, thermal discharge, emergency cooling; electrical SPDs and backup subpanel documentation.
- Monitoring: first-season data logs (temperatures, humidity, heat/power meters) to validate performance.

16.6 Notes

- Funding programs evolve. Validate all rates, caps, and eligibility windows at application time.
- Maintain a single source of truth for cost allocation and supporting documents to simplify audits.

Chapter 17

Commissioning and Acceptance

Chapter 18

Commissioning and Acceptance

This checklist defines the procedures and evidence required to safely commission and accept the system. It is structured to match funding documentation needs.

18.1 Pre-Commissioning

- Mechanical:
- Pipework flushed, pressure tested; leak-free.
- Expansion vessels sized and pre-charged for total volume (buffers + circuits).
- Air/dirt separators installed at strategic points; vents accessible.
- Insulation complete: hot lines insulated; cold lines diffusion-tight with condensate routes.
- Electrical:
- Critical-loads subpanel wired; circuits labeled; RCD/MCB verified.
- Surge protection devices (SPDs) installed and coordinated with PV/battery.
- Control wiring (sensors, valves, pumps) labeled; emergency stops documented.
- Water quality:
- System water prepared per VDI 2035; conductivity/hardness logged.
- Safety (stove):
- Return-lift valve operation verified; thermal discharge safety connected to drain; gravity emergency cooling path tested; chimney approvals.

18.2 Controls and Sensors Validation

- Buffers: confirm top/mid/bottom sensor readings; directions of flow validated.
- UFH: verify supply/return sensors; 3-way valve orientation; pump rotation.
- Dew-point logic: inject high RH in test zone or simulate via controller; confirm UFH supply limit and lockout behavior.
- HP controller: weather curve loaded; limits set (min/max VL, anti-short-cycle).
- FriWa: outlet temperature control tuned; stable performance over 2–16 L/min draws; anti-scald verified.

18.3 Functional Tests

- Heating mode (winter simulation):
- Long steady compressor operation; buffer stratification observed; target VL achieved at test outdoor setpoint.
- DHW midday priority: buffer top reaches 55–60°C; resume space heating post-charge.
- Cooling mode (summer simulation):

- Night buffer chill to 16–18°C; daytime UFH VL maintained at dew point + 2 K; no condensation on manifolds/lines.
- Stove integration:
- Charge buffer top; verify AWHP priority reduction on high top-of-buffer temperature.

18.4 Hydraulic Balancing

- UFH circuits: measure and record volume flows per loop; adjust to design; document setpoints.
- Heat meters: verify installation direction and pulse outputs if logging.

18.5 Ventilation (Decentralized HRV)

- Design flows set per room; boost functions verified; summer bypass configured.
- Filters installed; maintenance calendar established; acoustic checks.

18.6 Acceptance Documentation

- Blower-door test results (pre + post) with achieved n50 $\leq 1.5\ h^{-1}$ (target).
- Hydronic balancing protocol (flows per loop), HP and FriWa commissioning reports.
- VDI 2035 water quality report; pressure test certificates; electrical test reports (RCD/insulation/SPD).
- Schematics: final hydraulic diagram, control I/O map, sensor list.
- Safety attestations: stove compliance (EN 303-5), chimney sweep approvals, emergency procedures.
- Monitoring plan: which data is logged and retention period (first season minimum).

Chapter 19

Project Phases and Recommended Order

Chapter 20

Project Phases and Recommended Order

A practical sequence minimizes rework, aligns with funding steps, and protects commissioning quality.

20.1 Phases

1) Pre-checks and Surveys - Hazard screening (1972 build): asbestos in adhesives/fibre-cement, PCB, old mineral wool. - Roof statics for PV; outdoor unit siting and acoustics; local permits (loggia/vestibule).

2) Concept and Calculations - EN 12831 heat and (if needed) cooling loads; DIN 1946-6 ventilation concept. - Thermal-bridge detailing at loggia and entry; dew-point strategy for UFH cooling. - Define cost allocation to EH loan vs. Einzelmaßnahmen.

3) Funding Applications - EEE issues BzA (confirmation before application) and supports bank discussion. - Submit KfW 261 EH loan; plan complementary Einzelmaßnahmen (BAFA/BEG) and any supplementary loans.

4) Envelope and Airtightness - Basement ceiling, roof/attic, windows; optional facade. - Stair partition; loggia/vestibule if approved. - Blower-door test (intermediate if feasible) for QA.

5) Technical Systems - UFH installation and distribution; hydraulic balancing readiness. - AWHP, buffers (DHW + heating/cooling), FriWa, pumps/valves, sensors, electrical subpanel. - Decentralized HRV units with commissioning of design flows.

6) PV and Battery - PV array and battery install; integrate critical-loads subpanel; SPDs.

7) Commissioning and Tuning - Flush, pressure test, VDI 2035; parameterization; dew-point test; stove safety tests. - Hydraulic balancing protocol; data logging setup.

8) Post-Completion - EEE issues BnD (confirmation after completion); repayment bonus/grants processed. - First-season monitoring; optimize setpoints; perform thermography if needed.

Chapter 21

Bill of Materials

Chapter 22

Bill of Materials (Specification Classes)

Brand-agnostic list with size ranges. Final selections should follow detailed calcs and installer standards.

22.1 Heat Generation and Storage

- Reversible AWHP (R290), 6–10 kW class, monobloc or split; low noise kit; night mode.
- Optional Plate Heat Exchanger (AWHP$\leftrightarrow$House), sized for full capacity with low approach ΔT; glycol on AWHP side.
- Heating/Cooling Buffer: 800–1000 L, stratified, 100–150 mm insulation, 3$\times$ thermowells.
- DHW Heating Buffer: 200–300 L, high insulation, 3$\times$ thermowells.
- FriWa Module: 25–35 kW plate HX, variable-speed primary pump, flow sensor, electronic outlet control, service valves, potable filter/strainer.
- Wood Stove w/Back-Boiler (optional): rated output matched to buffer; return-lift valve ($\geq$60°C), thermal discharge valve, emergency cooling path components; chimney parts as required.

22.2 Hydronic Periphery

- Circulation Pumps: ECM pumps for AWHP loop(s), buffer charging, UFH circuits, FriWa primary.
- Valves: 3-way mixing valve (UFH), motorized zone valves for seasonal decoupling, check valves, balancing valves, drain/fill valves.
- Separators: air and dirt separators at key locations; magnetic dirt separator if needed.
- Expansion Vessels: sized for total water volume; service valves and gauges.
- Safety: PRVs (typically 3 bar), manometers, automatic air vents; condensate traps for cold lines.

22.3 Distribution

- UFH Manifolds and Loops: oxygen-barrier PEX/MLCP, manifold cabinets, flow meters, actuators if zoned.
- Pipe Insulation: hot lines to code; cold lines diffusion-tight; manifold/valve box insulation where possible.

22.4 Ventilation (Decentralized HRV)

- 6–8 single-room HRV units (dual-fan continuous or push-pull pairs), wall sleeves, exterior hoods, acoustic liners, filters.
- Control accessories: boost switches, humidity/CO_2 sensors (where supported), integration gateway (optional).

22.5 Controls, Sensors, Electrical

- Hydronic Controller: mixing valve + pump control with dew-point input and lockout.
- Sensors: buffer temps (top/mid/bottom), UFH VL/RL, ambient T/RH per floor, optional manifold surface probe.
- Energy Meters: heat meter(s) on AWHP and FriWa primary (optional), sub-meter for HP electrical.
- Electrical: critical-loads subpanel, automatic transfer switch (ATS) for backup, surge protective devices (SPDs), labeling, wiring accessories.
- Home Assistant Host: small, reliable compute (e.g., SBC or mini-PC), network connectivity, UPS (optional).

22.6 Water Treatment and Service

- VDI 2035 treatment unit/chemistry, test kit (conductivity/hardness), fill/drain assemblies.
- Filters/Strainers: potable filter for FriWa; strainers where needed on primary; spare filter sets.
- Serviceability: isolation valves, drain points, thermowells/test points, access panels.

Chapter 23

Risks and Mitigations

Chapter 24

Risks and Mitigations

Key technical and project risks with practical mitigations.

24.1 Hydronic Cooling and Condensation

- Risk: UFH surface and manifolds falling below dew point $\rightarrow$ condensation, damage.
- Mitigations: hard dew-point limit controlling mixing valve; diffusion-tight insulation on cold lines; condensate routing; humidity monitoring per floor; disable cooling if RH persistently > 60

24.2 System Complexity

- Risk: Dual buffers + FriWa + stove add components and controls.
- Mitigations: safety interlocks in dedicated controllers (not HA); clear operating modes; thorough commissioning; labeled valves/wiring; service documentation.

24.3 Noise (Terrace Context)

- Risk: Outdoor unit and HRV noise disturbing occupants/neighbors.
- Mitigations: acoustic siting and shielding; resilient mounts; night mode; façade-friendly HRV placements with baffles.

24.4 Thermal Bridges (Loggia, Entry)

- Risk: Heat loss, cold surfaces, moisture.
- Mitigations: Prefer enclosure (winter garden/vestibule); otherwise capillary-active internal insulation and exterior shading; thermography post-works.

24.5 Water Quality and Scaling

- Risk: Scaling and corrosion in plate HX, pumps, valves.
- Mitigations: VDI 2035 treatment; potable-side filters; periodic checks; bypass/flush ports for service.

24.6 Funding/Timing Errors

- Risk: Double-funding, out-of-sequence contracting jeopardizing eligibility.

- Mitigations: EEE involvement; BzA before award; clean cost split; BnD after completion; maintain documentation.

24.7 Safety (Stove Integration)

- Risk: Overheating without heat dump; low return temp tar formation; insufficient expansion.
- Mitigations: return-lift valve ($\geq 60°C$), thermal discharge valve to drain, gravity emergency cooling path, expansion vessel sizing; certified components and installation.

Chapter 25

Open Decisions and Options

Chapter 26

Open Decisions and Options

Use this page to track pending choices and finalize with the installer/EEE.

26.1 DHW and Buffers

- Confirm DHW heating buffer volume: 200 L vs. 300 L based on peak draw habits.
- FriWa capacity class: 25 kW vs. 35 kW based on simultaneous draw expectations.
- Optional cross-charge: allow emergency heat transfer from heating/cooling buffer top to DHW buffer (complexity vs. resilience).

26.2 Separation and Fluids

- Optional AWHP↔House plate heat exchanger (glycol on AWHP side):
- Pros: freeze protection and oxygen ingress isolation.
- Cons: small efficiency penalty; added components.

26.3 Loggia and Entryway

- Loggia: winter garden enclosure (permit, cost, highest benefit) vs. targeted internal insulation + exterior shading (budget option).
- Entry: glazed vestibule (high impact) vs. underside insulation only (lower impact).

26.4 HRV Units

- Device type: dual-fan continuous vs. push-pull pairs; acoustic priorities.
- Controls: standalone vs. optional gateway into HA for monitoring.

26.5 Heat Pump Selection

- Capacity class: based on EN 12831 result and modulation range.
- Acoustic package and siting: night mode, shielding, neighbor impact.

26.6 Monitoring and Data

- Heat meters scope: AWHP only vs. AWHP + FriWa primary.
- Data retention: first season mandatory; optional long-term trends.

Chapter 27

Hydraulic Diagram — Tags and I/O Map

Chapter 28

Hydraulic Diagram — Tags and I/O Map

This augments the architecture with reference tags for components, sensors, and control I/O. Use it to drive wiring, labels, and commissioning.

28.1 Tagging Convention

- Tanks: T1 = Heating/Cooling Buffer, T2 = DHW Heating Buffer
- Heat Pump: HP1
- Plate Heat Exchanger (optional): HX1 (AWHP↔House)
- FriWa: FW1
- Wood Stove Loop: WS1
- Pumps: P-xx, Valves: V-xx, Sensors: S-xx, Controllers/Relays: C-xx/R-xx

28.2 Components and Tags

- HP1: Reversible AWHP (R290)
- HX1: Optional PHE with glycol on HP1 side
- T1: Heating/Cooling Buffer (800–1000 L)
- S-T1-TOP, S-T1-MID, S-T1-BOT (temperatures)
- T2: DHW Heating Buffer (200–300 L)
- S-T2-TOP, S-T2-MID, S-T2-BOT (temperatures)
- FW1: FriWa module (plate HX, primary pump, outlet control)
- S-FW-FLOW (flow sensor), S-FW-OUT (DHW outlet temp)
- WS1: Wood stove with back-boiler and safety kit
- V-WS-RL (return-lift valve ≥60°C), V-WS-TD (thermal discharge safety)
- UFH: Manifold(s) and loops
- V-MX-UFH (3-way mixing valve), P-UFH (circulator), S-UFH-VL/S-UFH-RL (temps), S-UFH-SURF (optional surface)
- Seasonal Decoupling Valves
- V-SEAS-T1 (isolate T1), V-SEAS-T2 (isolate T2) as needed for service/mode control

28.3 Ambient Sensors

- S-AMB-GF: Ground floor T/RH (dew-point input)
- S-AMB-DG: Top floor T/RH (dew-point input)

28.4 Electrical and Meters

- R-HP-EN: Heat pump enable relay (from hydronic controller/safety chain)
- M-HP-EL: Electric sub-meter for HP
- M-HP-HT: Heat meter HP→T1
- M-FW-HT: Heat meter T2→FW1 primary (optional)

28.5 Control I/O Map (Example)

- Controller C-HYD (hydronic):
- Inputs: S-T1-TOP/MID/BOT, S-T2-TOP/MID/BOT, S-UFH-VL/RL, S-AMB-GF/DG, S-UFH-SURF (opt.)
- Outputs: V-MX-UFH (0–10 V), P-UFH (on/off or PWM), P-FW-PRI (via FW1), R-HP-EN, V-SEAS-T1/T2, alarm relay
- Logic: dew-point limit; DHW priority window; seasonal mode; anti-short-cycle; safe shutdown
- Controller C-HP (in HP1):
- Weather curve; supply/return temp limits; defrost; interface with R-HP-EN.
- FW1 internal controller:
- Outlet temperature setpoint; modulates P-FW-PRI by flow/ΔT.

28.6 Labeling and Documentation

- Each tag must appear on: hydraulic schematic, wiring diagram, device labels, and commissioning forms.
- Provide a printed tag legend and laminate a small copy near T1/T2 manifolds.

Chapter 29

Operating Guide

Chapter 30

Operating Guide — Daily Use and Seasonal Tips

This guide summarizes how to operate the system day-to-day and what to expect seasonally.

30.1 Everyday

- DHW is on demand via FriWa; expect stable temperature at taps. Large simultaneous draws may cause a brief temperature dip; the DHW buffer will recover quickly.
- The system prefers midday DHW charging using PV. If weather is poor, DHW will still be maintained.
- Home Assistant shows buffer temps, humidity, and basic status; use notifications for filter service and unusual conditions.

30.2 Winter (Heating)

- Weather-compensated heating curve aims for low VL (28–35°C). Radiant comfort is gradual but steady.
- Wood stove usage: enjoy as desired; it will lift buffer top temperature and the heat pump will trim back accordingly.
- If rooms feel cool, increase room setpoint slightly or raise the heating curve minimally; avoid large jumps.

30.3 Summer (Cooling)

- Night charging chills the buffer to 16–18°C. Daytime UFH supply is limited by dew-point logic (typically 19–21°C); expect gentle background cooling.
- If indoor RH rises toward 60

30.4 Shoulder Seasons

- Minimal buffer temps; most comfort from passive gains and small heating boosts. DHW still prioritized around midday.

30.5 Maintenance

- Filters: HRV and FriWa potable filter — inspect every 3–6 months (adjust to dust/water conditions).

- Visual checks: inspect for any condensation on cold manifolds/lines in early summer; increase dew-point margin if needed.
- Annual service: verify safety valves, expansion vessel pressures, water quality (VDI 2035), heat meter readings.

30.6 Troubleshooting Hints

- Hot water too cool: check DHW buffer temperature, FriWa outlet setting, and potable filter cleanliness.
- Cooling feels weak: check dew-point limit vs. supply temp; if RH high, dry the air (ventilate when dry or dehumidify temporarily).
- Noise: enable night modes (HP and HRV), verify mounts and baffles.

Chapter 31

Costing — Order-of-Magnitude

Chapter 32

Costing — Order-of-Magnitude Ranges

Indicative ranges only; verify with quotes and current funding rules.

32.1 Envelope

- Basement ceiling insulation: €20–90/m^2
- Roof/attic insulation: €50–200/m^2
- Triple-glazed windows incl. airtight install: €600–1,000 per window (or €280–900/m^2 window area)
- Facade insulation (WDVS): €90–210/m^2 (if feasible)
- Airtightness package + blower-door (pre/post): €1,500–4,200
- Stair partition (glazed): €1,000–3,000
- Loggia winter garden: €5,000–20,000 (design-dependent)
- Entry vestibule (glazed): similar to above, case-dependent

32.2 Generation, Storage, Distribution

- Reversible AWHP (R290), installed: €18,000–35,000
- Heating/Cooling buffer 800–1000 L: €2,200–6,000
- DHW heating buffer 200–300 L: €800–1,800
- FriWa station: €1,700–3,500
- UFH retrofit (materials + install): €60–145/m^2
- Hydronic periphery + full pipe insulation: €1,500–3,500
- Optional PHE (AWHP↔house): €800–2,700
- Wood stove with safety kit + flue works: €3,500–10,000 (+€800–3,000 chimney adjustments)

32.3 Ventilation, PV, Electrical

- Decentralized HRV (6–8 units): €6,000–12,000
- PV 5.8–8 kWp: €8,000–12,000 (0- Battery 10 kWh with backup: €6,000–10,000 (0- Critical-loads subpanel + transfer: €1,500–3,000

32.4 Soft Costs

- EEE (confirmations, site supervision): €2,000–5,000

- Technical planning (heat/cool load, schematics, LV, oversight): €3,000–8,000
- Commissioning and balancing protocols: €1,000–2,500

32.5 Totals (Very Rough)

- Without facade: €67,000–90,000
- With facade: €82,000–115,000

Funding may reduce net costs (e.g., EH loan repayment bonus; Einzelmaßnahmen 15–20