Towards Self-Sufficient Heating: A Thesis on Dual-Buffer HP Scenarios, Viability, and Savings

Project: 1972 Mid-Terrace House (Dual-Buffer Retrofit)

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Contents

Abstract

This thesis analyzes the economic and technical viability of a dual-buffer, reversible air-to-water heat pump (AWHP) retrofit with underfloor heating (UFH), a domestic hot water (DHW) fresh-water station (FriWa), decentralized heat recovery ventilation (HRV), and optional wood-fire oven assist. Using measured 2023 district-heat costs and consumption as baseline, we quantify Year-1, 10-year, and 20-year savings under multiple self-sufficiency (PV) scenarios and price-growth assumptions. We explain which scenarios are plausible, which are edge cases, and why. The conclusion provides a staged, risk-aware plan balancing comfort, complexity, and return.

Chapter 1

Abbreviations

AWHP	air-to-water heat pump
UFH	underfloor heating
DHW	domestic hot water
FriWa	fresh-water station (instantaneous DHW via plate heat exchanger)
HRV	heat recovery ventilation
PV	photovoltaics
SCOP	seasonal coefficient of performance (space heating)
COP	coefficient of performance (DHW heating)

Chapter 2

Background and Baseline

2.1 House and System Concept

The home is a *1972 mid-terrace house* planned for a dual-buffer retrofit: a *heating/cooling buffer* serving UFH and a dedicated *DHW heating buffer* feeding a *FriWa*. The primary source is a *reversible AWHP*; optional *wood-fire oven with water jacket* charges the top of the heating buffer in winter. Ventilation is via *decentralized HRV*. Controls prioritize PV self-consumption while enforcing dew-point safety for UFH cooling.

2.2 Measured Baseline (2023)

Space heat delivered (district heat)	9 824 $\mathrm{kWh_{th}}$/yr
DHW volume	16.86 $\mathrm{m^3}$/yr ($\approx$ 883 $\mathrm{kWh_{th}}$/yr)
District heat + DHW cost	3 642.84/yr
Effective heat tariff	0.340/$\mathrm{kWh_{th}}$ (3 642.84/10 707 kWh_{th})

Chapter 3

Methodology

3.1 Assumptions

Unless stated otherwise, we use *Year-1 tariffs* of 0.30/kWh for electricity and the measured district-heat cost above. Envelope reduction is 30 % for space heating (post-retrofit). We assume *SCOP* 3.3 for space heating and *COP* 2.4 for DHW. Price growth defaults: district heat +5 %/yr, electricity +3 %/yr. Self-sufficiency levels are modeled via the *grid share* of HP electricity; PV supplies the remainder.

3.2 Energy and Cost Model

Space-heating thermal energy after envelope is $Q_{\text{heat}} = 9\,824\,(1 - 0.30) = 6\,876.8\,\text{kWh}_{th}$. DHW thermal energy is $Q_{\text{dhw}} = 883\,\text{kWh}_{th}$. Year-1 HP electricity is $E_{\text{HP}} = Q_{\text{heat}}/\text{SCOP} + Q_{\text{dhw}}/\text{COP} = 2\,451.8\,\text{kWh}$. HP grid cost equals $E_{\text{HP}} \times \text{grid share} \times p_{\text{elec}}$. Avoided district-heat cost equals 3 642.84 in Year-1.

Chapter 4

Scenario Family: Self-Sufficiency Ladder

We define nine core scenarios by *self-sufficiency* (PV share of HP electricity) plus two *surplus* cases:

Scenario name	Self-sufficiency [%]	Grid share (HP elec.)
Surplus 110	110	0.00
Surplus 105	105	0.00
Island 100	100	0.00
Resilient 90	90	0.10
Resilient 80	80	0.20
Balanced 70	70	0.30
Balanced 60	60	0.40
Grid-Lean 50	50	0.50
Grid-Tilt 40	40	0.60
Grid-Tilt 30	30	0.70
Grid-Heavy 20	20	0.80

4.1 Year-1 Results (common efficiency)

Scenario	HP grid cost [EUR]	Year-1 savings [EUR]
Surplus 110	0.00	3 642.84
Surplus 105	0.00	3 642.84
Island 100	0.00	3 642.84
Resilient 90	73.56	3 569.28
Resilient 80	147.11	3 495.73
Balanced 70	220.66	3 422.18
Balanced 60	294.22	3 348.62
Grid-Lean 50	367.77	3 275.07
Grid-Tilt 40	441.32	3 201.52
Grid-Tilt 30	514.88	3 127.96
Grid-Heavy 20	588.43	3 054.41

Surplus note Surplus cases assume HP grid cost is zero; export revenue from PV (feed-in) is *not* included here.

Chapter 5

Why Scenarios Are Likely or Not

5.1 PV and Storage Constraints

Self-sufficiency above 90 % (*Resilient 90* and *Island 100/Surplus*) requires large PV (8–10 kWp), generous battery, and strict load shifting. Winter irradiance and high heat load limit feasibility. *Likelihood*: Island 100 **1/5**, Resilient 90 **2/5**.

5.2 Balanced Operation (60–70%)

With 6–8 kWp PV, a smart midday DHW boost, and night charging disabled during low PV days, *Balanced 60/70* are common outcomes. Grid covers deep-winter nights; PV serves shoulder months. *Likelihood*: **4/5**.

5.3 Grid-Lean to Grid-Heavy (20–50%)

These reflect limited PV, shaded roofs, or occupant behavior that does not shift loads. Still strongly cost-positive because heat-pump unit cost per $\mathrm{kWh_{th}}$ remains far below district-heat. *Likelihood*: **5/5**.

5.4 Wood-Fire Oven Assist

If a wood-fire oven (water jacket) offsets 10 % of post-envelope space-heat, HP electricity drops by roughly $Q_{\text{heat}} \times 0.10/\text{SCOP}$, a modest but reliable saving. Larger coverage increases savings but adds operational effort. Overheating risk is contained with return-lift and thermal discharge safety.

5.5 What Makes Sense vs. Not

- **Makes sense**: Balanced 60–70 with reversible AWHP, dual buffers, FriWa, UFH, and decentralized HRV; PV 6–8 kWp; battery sized for resilience not full self-sufficiency; dew-point controls; envelope first.
- **Edge case but OK**: Resilient 80–90 if roof allows large PV and behavior supports load shifting; higher cost/complexity for marginal gains in winter.

- **Typically not worth it**: Designing for 100–110% year-round self-sufficiency—oversized PV/battery yields diminishing returns; feed-in remuneration often lower than on-site displacement value.

Chapter 6

Cumulative Savings

Using district-heat +5 %/yr and electricity +3 %/yr growth, cumulative savings (examples):

Scenario	10-year [EUR]	20-year [EUR]
Island 100 / Surplus 105/110	45 819	120 454
Balanced 60	42 446	112 545
Grid-Heavy 20	39 073	104 636

Chapter 7

Risks and Uncertainties

- **Tariffs and policy**: Electricity price spikes erode savings but remain favorable vs. district-heat at SCOP ≥ 3. Feed-in rules affect surplus scenarios.
- **Weather variability**: Cold winters reduce SCOP; warm winters help. Balanced 60–70 stay robust across typical variance.
- **Commissioning quality**: Poor hydraulic balance or dew-point control can degrade performance. Safety interlocks must be hard-wired.
- **Occupant behavior**: Daytime DHW charging and comfort setpoints influence PV utilization and COP.

Chapter 8

Conclusions and Recommendations

8.1 Most Viable Path

Aim for **Balanced 60–70**: envelope first, reversible AWHP + dual buffers + FriWa + UFH, decentralized HRV, 6–8 kWp PV, modest battery, and PV-aware DHW boosts. Expect Year-1 savings 3.2–3.4 kEUR, 10-year 42–46 kEUR, 20-year 110–120 kEUR ranges (with growth).

8.2 Role of the Wood-Fire Oven

Treat wood as **comfort plus resilience**. A 10–20% winter coverage reduces HP electricity and adds flexibility during grid outages, with small economic upside and operational overhead.

8.3 What to Avoid

Over-optimizing for 100–110% self-sufficiency (year-round) typically does not pay back relative to the extra PV/battery required. Favor reliability, commissioning quality, and safety over maximal autonomy.

8.4 Next Steps

Refine SCOP/COP with vendor data, confirm PV/battery sizing by roof study, and validate noise/placement. Lock in envelope details and HRV design. Update the scenario with actual tariffs; add feed-in remuneration if you plan export.