Savings Scenarios
Dual-Buffer Heat Pump Retrofit

Project: 1972 Mid-Terrace House

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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
PV	photovoltaics
SCOP	seasonal coefficient of performance (heating)
COP	coefficient of performance (DHW)

Chapter 2

Baseline and Assumptions

2.1 Baseline (2023 statements)

Space heat delivered (district heat)	9 824.00 $\mathrm{kWh_{th}}$/yr
DHW volume	16.86 $\mathrm{m^3}$/yr ($\approx$ 883.00 $\mathrm{kWh_{th}}$/yr)
District heat + DHW cost	3 642.84/yr
Effective heat tariff	0.34/$\mathrm{kWh_{th}}$ ($\approx$ 3 642.84/10 707.00 $\mathrm{kWh_{th}}$)
Household electricity (context)	2 671.00 kWh/yr (tariff not used in savings calc)

2.2 Retrofit set-up used in scenarios

- Reversible air-to-water heat pump (AWHP), dual buffers: DHW heating buffer feeding FriWa, and a separate heating/cooling buffer.
- Envelope improvements reduce space-heating demand (range shown per scenario).
- DHW setpoints 55–60 °C; FriWa prepares potable hot water on demand.
- Photovoltaics (PV) coverage is represented as a fixed share of the HP electricity displaced (grid-share factor).

2.3 Scenarios

We report three brackets: Worst, Mid, Best. Each specifies envelope reduction, HP efficiencies, electricity tariff, PV/grid share for HP electricity, and price growth of electricity and district heat.

Scenario	Heat red.	SCOP (heat)	COP (DHW)	Elec. price	Grid share	Growth (DH / Elec)
Worst	15.00 %	3.00	2.20	0.35/kWh	1.00	3.00 % / 6.00 %
Mid	30.00 %	3.30	2.40	0.30/kWh	0.60	3.00 % / 3.00 %
Best	40.00 %	3.60	2.60	0.25/kWh	0.30	6.00 % / 0.00 %

Notes: Grid share is the fraction of HP electricity bought from the grid (the balance is assumed covered by PV self-consumption). Growth rates apply year-on-year to prices (not volumes): first value to district-heat tariff, second to electricity.

Chapter 3

Year-1 Results

Space-heating thermal energy after envelope: $Q_{\text{heat}} = 9824\,\text{kWh}_{th} \times (1 - \text{reduction})$. DHW thermal energy left unchanged at $Q_{\text{dhw}} = 883.00\,\text{kWh}_{th}$.

HP electricity (year 1): $E_{\text{HP}} = Q_{\text{heat}}/\text{SCOP} + Q_{\text{dhw}}/\text{COP}$. Grid electricity for HP: $E_{\text{grid}} = E_{\text{HP}} \times \text{grid share}$. HP electricity cost: $C_{\text{HP}} = E_{\text{grid}} \times p_{\text{elec}}$.

Avoided district-heat cost (year 1): $C_{\text{DH},0} =$ 3 642.84.

Scenario	HP elec. [kWh]	HP grid cost [EUR]	Avoided DH [EUR]	Year-1 savings [EUR]
Worst	3 184.83	1 114.69	3 642.84	2 528.15
Mid	2 451.80	441.33	3 642.84	3 201.51
Best	1 976.95	148.27	3 642.84	3 494.57

For reference, the *gross* HP electricity cost (if entirely paid from the grid without PV) would be: Worst 1 114.69; Mid 735.54; Best 494.24.

Chapter 4

10-Year and 20-Year Cumulative Savings

Let the year-1 avoided DH cost be $C_{\mathrm{DH},0}$ and HP grid cost be $C_{\mathrm{HP},0}$. With annual price growth rates g_{DH} and g_{elec}, the cumulative savings over N years are approximated by

$$\sum_{t=1}^{N} C_{\mathrm{DH},0}(1+g_{\mathrm{DH}})^{t-1} - \sum_{t=1}^{N} C_{\mathrm{HP},0}(1+g_{\mathrm{elec}})^{t-1}$$

which equals

$$C_{\mathrm{DH},0}\,\frac{(1+g_{\mathrm{DH}})^{N}-1}{g_{\mathrm{DH}}} \; - \; C_{\mathrm{HP},0}\,\frac{(1+g_{\mathrm{elec}})^{N}-1}{g_{\mathrm{elec}}}$$

when growth rates are nonzero, and reduces to simple $N \times C$ when a growth rate is zero.

Using the scenario growth rates:

Scenario	10-year cumulative [EUR]	20-year cumulative [EUR]
Worst (DH +3%, Elec +6%)	27 046.70	56 931.80
Mid (DH +3%, Elec +3%)	36 677.10	86 081.20
Best (DH +6%, Elec +0%)	46 535.00	131 009.80

Notes:

- The figures above use HP grid costs (i.e., after PV self-consumption per scenario). The corresponding 10/20-year savings using *gross* HP grid share (no PV) are: Mid 33 305.00 / 78 176.00; Best 43 075.00 / 124 090.00.
- Volumes are kept at the 2023 baseline for the counterfactual (no retrofit). Savings therefore include both the unit-cost advantage of electricity via HP *and* the envelope-driven demand reduction.
- Adding small wood-stove coverage would further reduce HP electricity costs in winter (small upside not included).

Chapter 5

Self-Sufficiency Ladder (9 Scenarios)

We consider "prices rise" for both district-heat and electricity (assumed +5%/yr and +3%/yr respectively). Envelope reduction is held at 30.00 %, seasonal coefficient of performance (SCOP) for space heating 3.30, coefficient of performance (COP) for DHW 2.40, and year-1 electricity tariff 0.30/kWh. The nine scenarios vary only by self-sufficiency level for heat-pump electricity (i.e., PV coverage), expressed via the grid-share parameter.

5.1 Definitions

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

5.2 Year-1 Results (common efficiency assumptions)

HP electricity (with 30% envelope reduction) is 2 451.80 kWh. HP grid cost equals HP electricity $\times$ grid share $\times$ tariff; avoided district heat is 3 642.84.

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

5.3 Cumulative Savings (10y / 20y)

Using +5%/yr district-heat price growth and +3%/yr electricity growth (year-1 avoided 3 642.84; year-1 HP grid cost per table):

Scenario (examples)	10-year [EUR]	20-year [EUR]
Surplus 110	45 819.00	120 454.00
Surplus 105	45 819.00	120 454.00
Island 100	45 819.00	120 454.00
Balanced 60	42 446.00	112 545.00
Grid-Heavy 20	39 073.00	104 636.00

Note on surplus production Scenarios above 100% self-sufficiency ("Surplus 105/110") assume HP grid cost is zero; any export revenue from surplus PV is *not* credited here. If desired, feed-in remuneration (e.g., 0.08/kWh) can be added to savings as an extra term.

5.4 Viability and Likelihood

Scale: 1 = very unlikely; 3 = plausible; 5 = very likely for this home with ≈ 6–8 kWp PV and battery.

Scenario	Likelihood (1–5)	Notes
Island 100	1	Year-round 100% HP self-sufficiency is rare in DE climate; feasible only i
Resilient 90	2	High PV+battery and aggressive daytime charging; winter weeks still nee
Resilient 80	3	Plausible with ∼8 kWp, good load shifting and mild winters; winter grid
Balanced 70	4	High likelihood with 6–8 kWp PV and smart DHW midday boosts.
Balanced 60	4	Typical for well-run systems; modest storage suffices.
Grid-Lean 50	5	Very likely; represents conservative planning baseline.
Grid-Tilt 40	5	Very likely; acceptable even with limited PV.
Grid-Tilt 30	5	Very likely; grid provides most winter HP energy.
Grid-Heavy 20	5	Very likely; minimal PV contribution.

5.5 Wood-Fire Oven (water jacket) Assist

If the wood-fire oven provides a share of the *space-heating* thermal energy, HP electricity drops proportionally to the displaced load divided by SCOP. Example ("Balanced 60 + wood 10%"

at year-1 assumptions):

- Space-heating after envelope: $Q_{\text{heat}} = 9824\,(1 - 0.30) = 6\,876.80\,\text{kWh}_{th}$.
- Wood 10% coverage: $\Delta Q = 687.68\,\text{kWh}_{th}$ not served by HP.
- HP electricity reduction: $\Delta E = \Delta Q/\text{SCOP} = 208.39\,\text{kWh}$ (with SCOP=3.30).
- New HP electricity: $2\,451.80 - 208.39 = 2\,243.41\,\text{kWh}$; with 40% grid share $\Rightarrow$ grid energy $897.36\,\text{kWh} \Rightarrow$ HP grid cost 269.21.
- Year-1 savings increase by $\approx$ 25.00 vs. 3 348.62 baseline ("Balanced 60").

Rule of thumb: each 10% wood coverage of post-envelope space-heating reduces HP electricity by $\approx Q_{\text{heat}} \times 0.10/\text{SCOP}$, a modest but positive effect. Larger wood contribution or higher electricity prices scale the benefit.

Chapter 6

Takeaways

- With 2023 district-heat unit costs ($\approx$ 0.34/kWh$_{\text{th}}$), an AWHP with SCOP ≥ 3.00 remains strongly cost-positive across realistic price-growth brackets.
- Envelope measures that enable lower flow temperatures (UFH) and modest UFH cooling do not erode the business case; they help by reducing kWh demand.
- PV improves savings by displacing a share of HP electricity; even without PV coverage (gross case), savings remain large in all three brackets.

Parameter Tweaks

If desired, this sheet can be extended with an input table for tariffs, SCOP/COP, envelope reduction, and PV grid share, to regenerate the numbers for your utility quotes.