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Schweizer Bau- und Immobilienforum 2026
Poster exhibition · HSLU Rotkreuz · 11 November 2026

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INNOSUISSE INNOVATION PROJECT · 2026 – 2029

REMOPTI

A decision-support framework for strategic retrofit planning of building portfolios under uncertainty

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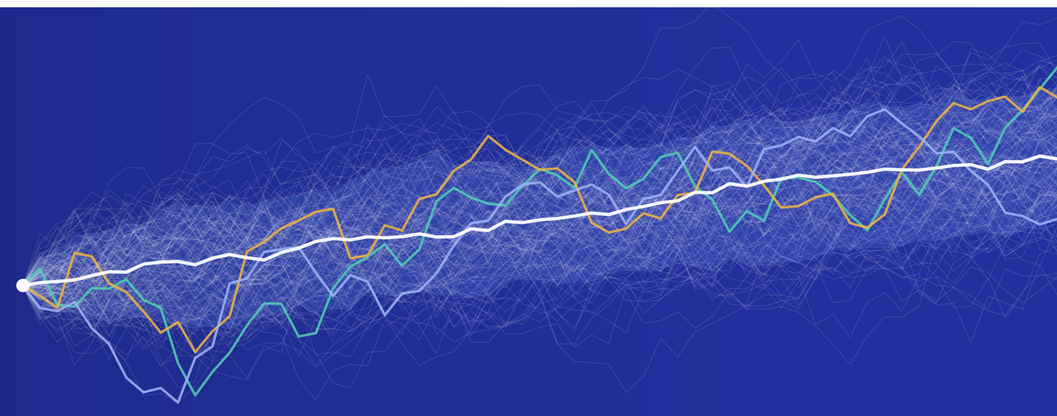


Every retrofit plan is stress-tested against thousands of plausible futures.

1 The challenge

Retrofit decisions lock in capital for decades, while prices, rates, climate and component lifetimes remain uncertain.

- Planning assumes a single “expected” future.
- Cost, energy and renovation planning are siloed.
- **Result:** sub-optimal investments and hidden risks.

2022–23 price jumps in one year (Swiss consumer prices)

+51 %	+63 %	+55 %	+25 %
gas	heating oil	pellets	electricity

2 Four main questions

Which measures?
Envelope and systems optimised together: walls, roof, windows, heating, hot water, ventilation, PV.

When?
Each measure timed in one of six 5-year windows, driven by ageing, failure risk and prices.

Which building first?
At portfolio level, shared budgets per period go where they create the most value.

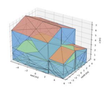
How much risk?
Each plan is tested on thousands of futures; owners cap the probability of loss or the worst-20 % outcome.

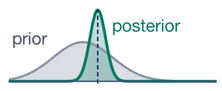
REMOPTI searches the intervention plan – what, at which level, and when – that best meets the owner’s objective, and verifies that it holds across the futures.

3 Method: from the building stock to robust decisions

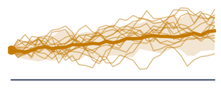
1 Building-stock data

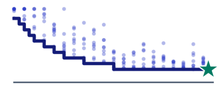
swisstopo 3D buildings, building register (EGID), SIA norms, metered data

2 Automatic energy models

3D geometry turned into checked EnergyPlus models [4]; >500,000 simulations

3 ML surrogate + calibration


XGBoost surrogate [5] in the loop; Bayesian calibration [6] on input data

4 Stochastic futures

Correlated prices [3], rates, inflation, climate, occupants, component ageing

5 Robust optimiser

Differential evolution [1], feasibility rules [2], probabilistic constraints

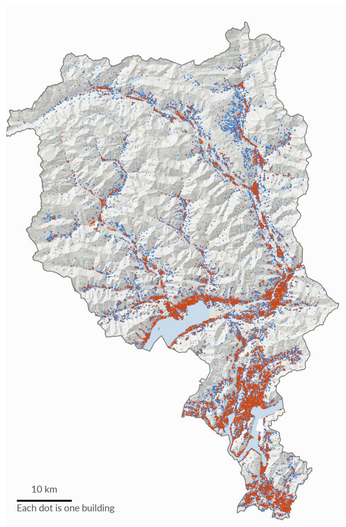
6 Decision support

Plan and KPIs with uncertainty bands, constraint check, portfolio dashboards

Fast, calibrated building energy model · Double loop: plans (outer) × futures (inner) · Platform & pilot

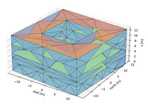
4 Building-stock digital twin

An automated pipeline turns national geodata into simulation-ready building models **– for an entire canton.**



115,919
buildings in Ticino with simulation-ready 3D models
99.6 % of stand-alone buildings

+74,797
attached buildings and annexes being added



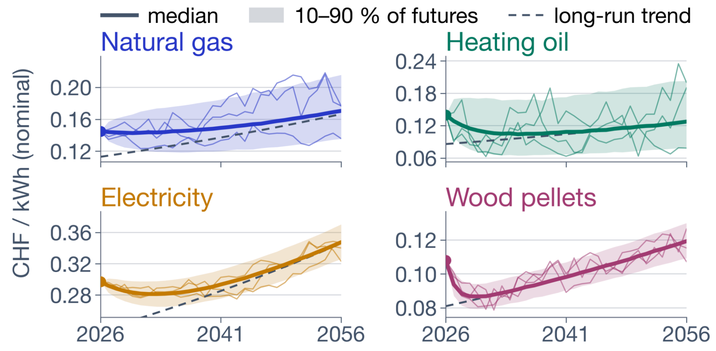
- 3D model ready
- attached, in progress

Quality gate: every model re-checked in EnergyPlus – 0 severe errors, volume and floor area within ±0.1 %.

Calibration data (*at the moment*): 9 metered series from 4 buildings (AIL, SUPSI), 10–15 min resolution.

Map and models: REMOPTI; data © swisstopo, FSO (GWR).

5 Uncertainty made explicit

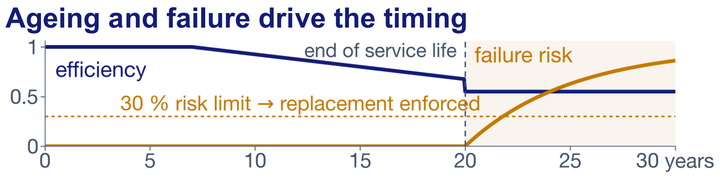


Energy-price scenarios 2026–2056: mean-reverting models [3] calibrated on Swiss data 1998–2021 and back-tested on the 2022–23 shock (illustrative re-simulation).

One future = one building version × one economic

25 **building versions** (U-values, airtightness, lifetimes)
× 5 **economic paths** (prices, rates, climate, occupants)
= 125 **futures per plan** – up to 10,000 in the final check

Ageing and failure drive the timing



6 Robust optimisation engine

≈ 1.2 × 10⁸
possible retrofit plans per building:
7 measure families × levels × six 5-year windows

Owner-defined objective: four profiles

A Value – maximise expected NPV

B Risk – expected NPV with loss limits (P(NPV<0), CVaR)

C Climate – minimise life-cycle CO_2, incl. embodied

D Energy – minimise primary energy at the horizon

Constraints as limits or probabilities: budget per period, total investment, failure risk ≤ 30 %, payback, comfort, CO_2 cap, minimum saving …

Search, control, final verification

Search 125 futures · ~6,000 plans
Control 2,000 futures · ≤ 20 plans
Final check 10,000 new futures · ≤ 11 plans

≈ 5.4 million evaluations per run, made tractable by the surrogate.

7 First results: prototype run on an existing residential building

Optimal plan, profile A (maximise expected NPV)

years from now	0–5	5–10	10–15	15–20	20–25	25–30
Windows	install	double low-e glazing, U = 1.1 W/m²K				
Walls		install	8 cm EPS insulation			
Roof		install	12 cm insulation			
Heating			install	air-to-water heat pump		
Others	*hot water, ventilation, PV: no action*					

Timing follows residual service life: windows first, heating at end of life.

Compared with two reference strategies

	Do nothing	Replace at end of life	REMOPTI plan
Expected NPV k CHF	1,266	1,356	**1,436**
NPV, worst 20 % k CHF	1,176	1,267	**1,348**
Life-cycle CO_2 kg/m²a	127.4	54.5	**23.2**
Investment k CHF	0	351	**306**

+13 % expected NPV vs do nothing
−57 % life-cycle CO_2 vs end-of-life replacement

- **4 of 6 constraints met**
- **Flagged:** budget 306 > 250 k CHF, payback 21 > 20 years

Prototype run: simplified physics-based energy model (surrogate in training), provisional cost and price parameters – figures are illustrative. 60 plans × 100 generations; final ranking on 10,000 futures.

8 Conclusions

Risk becomes a design variable: plans are ranked on their distribution of outcomes, not on one forecast.

Transparent and owner-specific: goals, limits and risk appetite set by the user, all constraints reported.

Scalable to portfolios: canton-wide automatic models and a fast ML surrogate enable portfolio prioritisation.

From research to practice: pilot with AIL; a basis for performance contracting and long-term asset strategies.

Contact

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