ODYSSEE-MURE

UNIVERSITÉ DE GENÈVE

Energy Efficiency First – Retrofitting the building stock

Martin K. Patel, Kai Nino Streicher

Based on Ph.D. thesis of Kai Nino Streicher

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Background

Energy Efficiency First

"… means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions;"

European Commission: REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action, […], 11 December 2018

Importance of EE in buildings

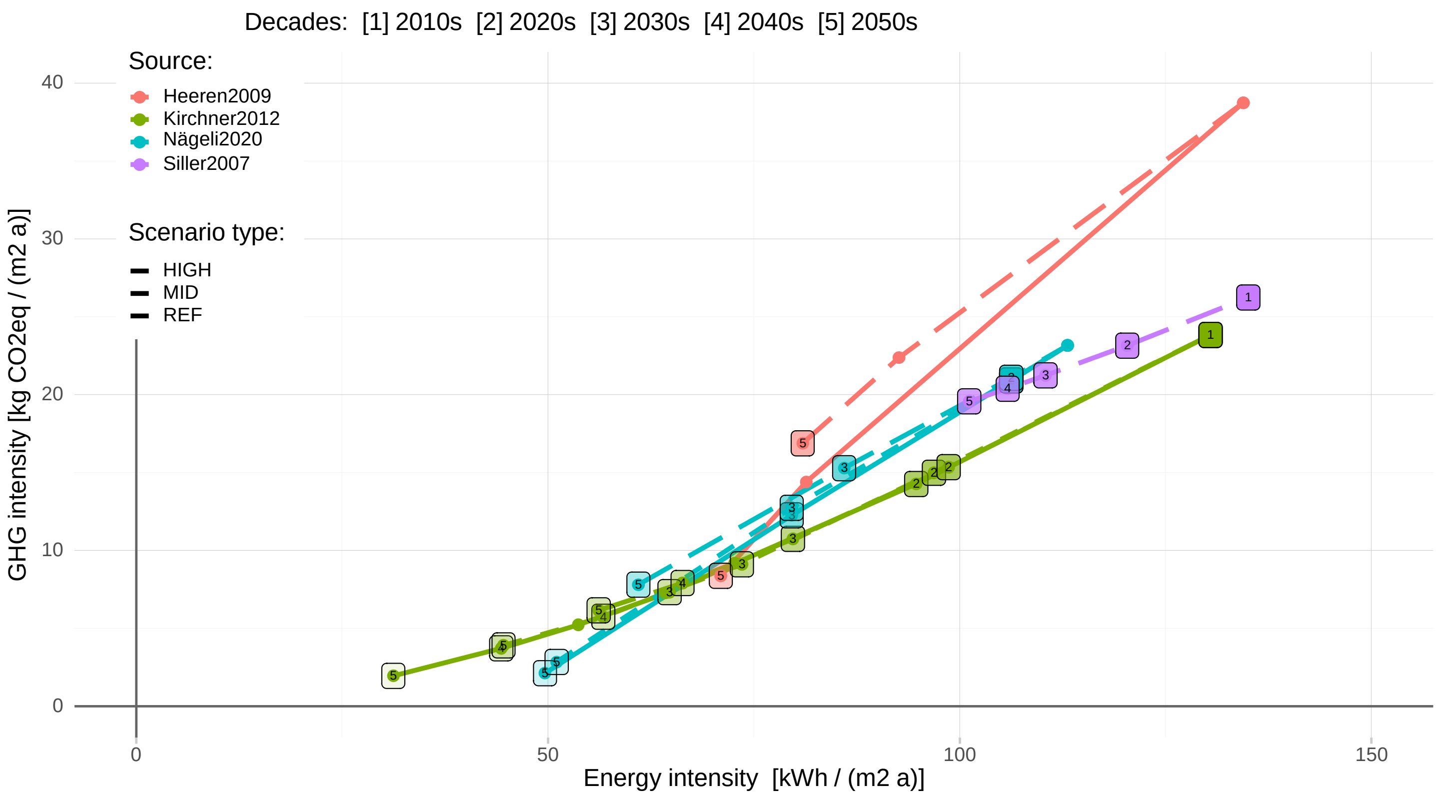
Swiss energy strategy

- Phase-out of nuclear energy & increased share of renewable energy
- Swiss electricity: has been near-zero-carbon
- 31% reduction of final energy demand (w/o aviation) from 2020 until 2050, 36% until 2060
- Annual emissions of ~1.0 t CO_2eq/capita by 2050 (w/o CCS etc.)

Households (as proxy for residential building stock)

- 18% reduction in total final energy demand from 2020 until 2050
- 30% in per-capita final energy demand

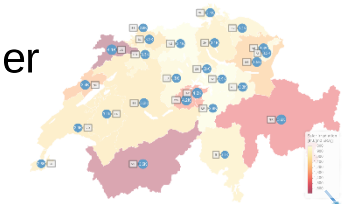
Source: Energy Perspectives 2050+



Methodology

Bottom-up model (SwissRes)

Weather data



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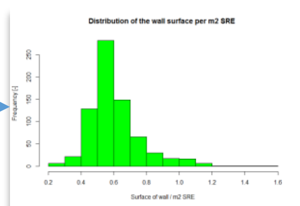
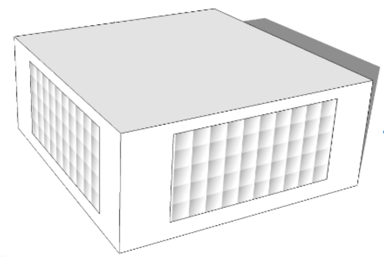
swiss society of engineers and architects

CECB Certificates

Statistical Analysis



Archetype Building



Energy Model

FINAL ENERGY		AGE	URBAN	MIXED	RURAL	AVERAGE	
	MFH	1945	132	159	138	143	86
		1950	114	132	111	119	
		1960	103	118	114	111	
		1970	99	108	105	104	
		1980	86	91	90	89	
		1990	66	67	62	65	
		2000	36	36	35	36	
		2005	20	23	24	22	
	SFH	1945	160	172	165	166	106
		1950	157	172	164	164	
		1960	164	168	163	165	
		1970	127	135	125	129	
		1980	92	95	92	93	
		1990	61	69	69	66	
		2000	37	40	38	39	
		2005	23	26	25	25	
	AVERAGE		92	101	95	96	

Retrofit options

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Swiss Statistics

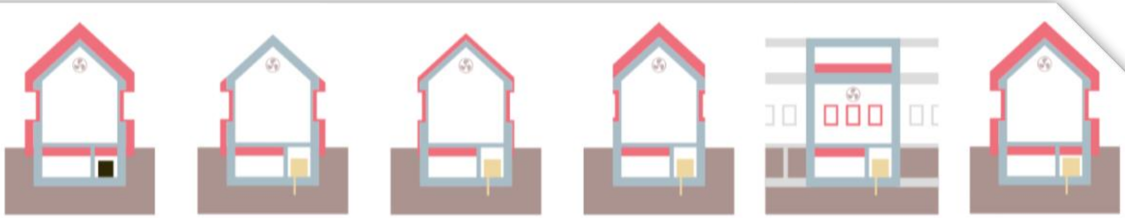
ERA

	AGE	URBAN	MIXED	RURAL	TOTAL		FINAL ENERGY
MFH	1945	7.2%	15.8%	3.2%	26.2%	67.4%	
	1950	3.4%	4.3%	0.8%	8.6%		
	1960	3.7%	5.4%	1.2%	10.3%		
	1970	3.1%	4.6%	1.3%	9.0%		
	1980	1.9%	3.5%	1.0%	6.4%		
	1990	1.5%	2.3%	0.7%	4.5%		
	2000	0.4%	0.5%	0.1%	1.0%		
	2005	0.5%	0.8%	0.3%	1.6%		
SFH	1945	3.3%	5.8%	1.4%	10.5%	32.6%	
	1950	1.6%	2.7%	0.5%	4.8%		
	1960	1.2%	2.6%	0.5%	4.3%		
	1970	1.3%	3.0%	0.6%	4.9%		
	1980	1.0%	2.5%	0.5%	4.0%		
	1990	0.6%	1.6%	0.4%	2.6%		
	2000	0.2%	0.5%	0.1%	0.8%		
	2005	0.1%	0.5%	0.1%	0.7%		
TOTAL		31.0%	56.3%	12.7%	46 TWh/a		

ARCHETYPES

AGE	TYPE	TYPOLOGY	HEATING SYSTEM
Before 1920	MFH	Urban	Oil
1921-1945	SFH	Mixed	Gas
1946-1960		Rural	Direct electric
1961-1970			District heating
1971-1980			Heat pump
1981-1990			Wood
1991-2000			
2001-2010			
2011-2018			
9 *	2 *	3 *	6 = 324

Bottom-up model (SwissRes)



	System 1	System 2	System 3	System 4	System 5	System P
Envelope U-Values (W/m2K)	Roof ≤ 0.17 Wall ≤ 0.25 Window ≤ 1.0 Ground ≤ 0.25	Roof ≤ 0.3 Wall ≤ 0.4 Window ≤ 1.0 Ground ≤ 0.25	Roof ≤ 0.25 Wall ≤ 0.5 Window ≤ 1.0 Ground ≤ 0.25	Roof ≤ 0.17 Wall ≤ 0.7 Window ≤ 1.0 Ground ≤ 0.25	Roof ≤ 0.17 Wall ≤ 1.1 Window ≤ 0.8 Ground ≤ 0.25	Roof ≤ 0.17 Wall ≤ 0.2 Window ≤ 1.0 Ground ≤ 0.25
Heat generation	Fossil	Heat pump				
Ventilation*	with heat recovery	without heat recovery				with heat recovery

* All solutions are requiring a mechanical ventilation system

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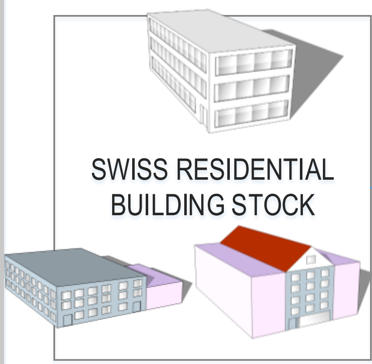

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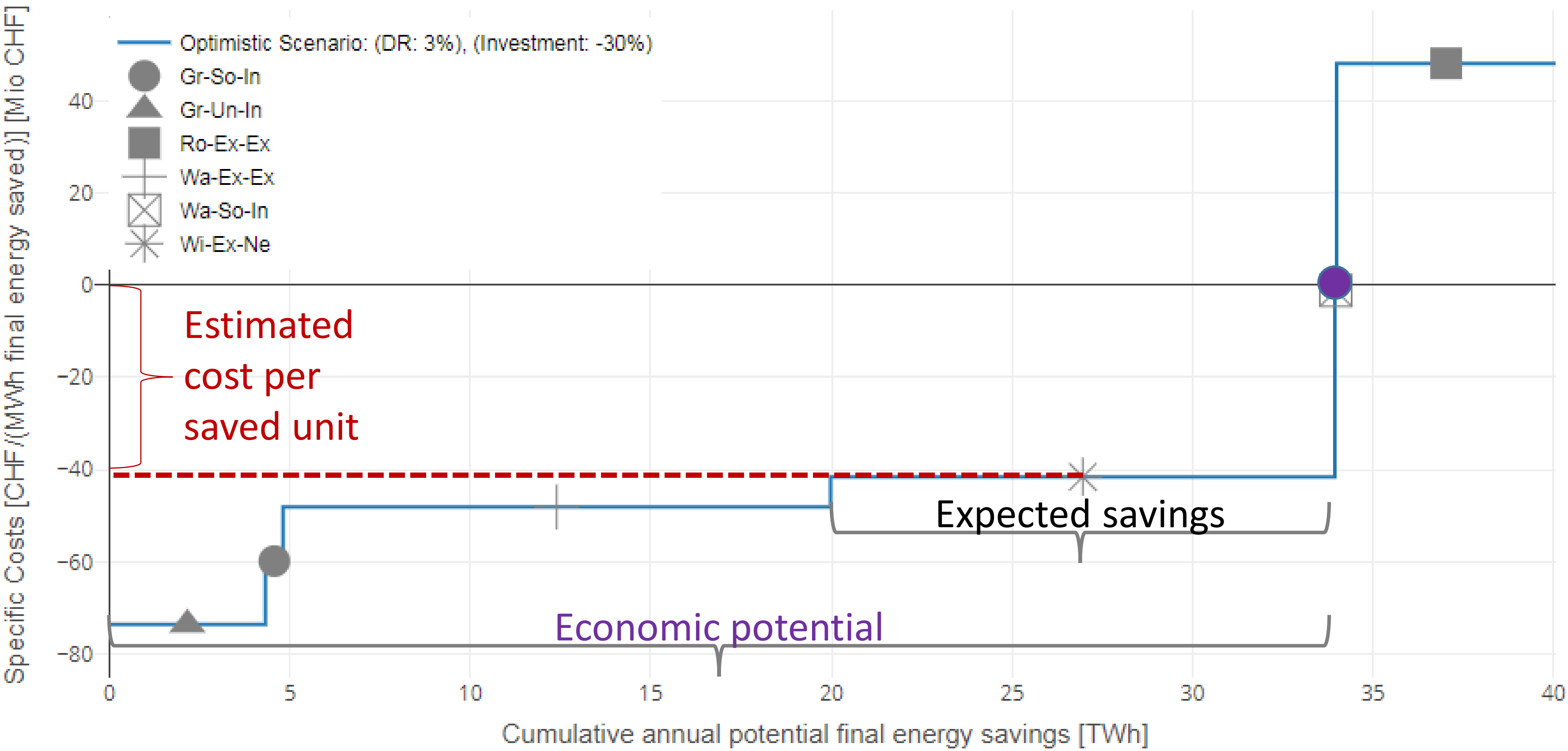
Energy Efficiency Cost Curves (EECC)

- **EECC Method**
  - Sector-wide energy saving potential and related cost-effectiveness of energy efficiency measures
  - Cost analysis with discounting (levelized cost)
  - Multiple indicators (e.g., final energy, primary energy, CO_2eq emission)



Cost assessment approaches (1/2)

Approach	FULL (Early replacement simple)	IMPROVEMENT (Failure/Natural replacement)	INTRINSIC VALUE *) (Early replacement advanced)
Investment and operational cost	Full cost of retrofit	Cost for energy retrofit only = (Full cost for retrofit) – (non-retrofit related costs)	Same as "Improvement approach" but additionally accounts for residual value i) in the case of early replacement and ii) at the end of the lifetime (20% default value) (Full cost for retrofit) – (non-retrofit related costs) + (Residual value)
Energy and cost savings	Before minus afterwards	Conventional practice minus afterwards	Before minus afterwards for remaining lifetime. Conventional practice minus afterwards for period after remaining lifetime.
Mindset	Total investment costs need to be raised.	As above but "Anyway costs" are deducted; this approach implicitly assumes energy retrofit at end of life.	Considers that assets still have a value at their end of life (salvage value) and accounts for lost asset value as a consequence of early replacement.
Drawback	Main objective profitability leads too low potential.	Waiting for end of life might be too slow to reach reduction targets.	More complex dynamic calculation with high data requirements.

*) in PhD thesis referred to as Depreciation approach (DEP)

Cost assessment approaches (2/2)

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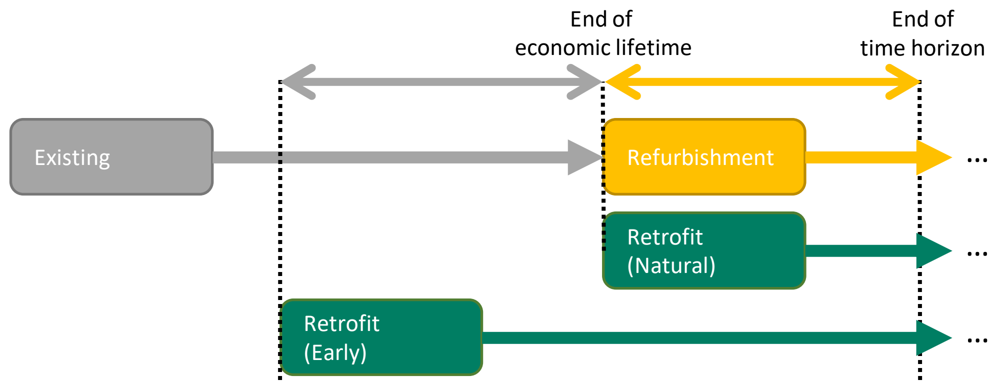
- **Economic assessment approach**
  - Based on different stakeholder perspectives/strategies

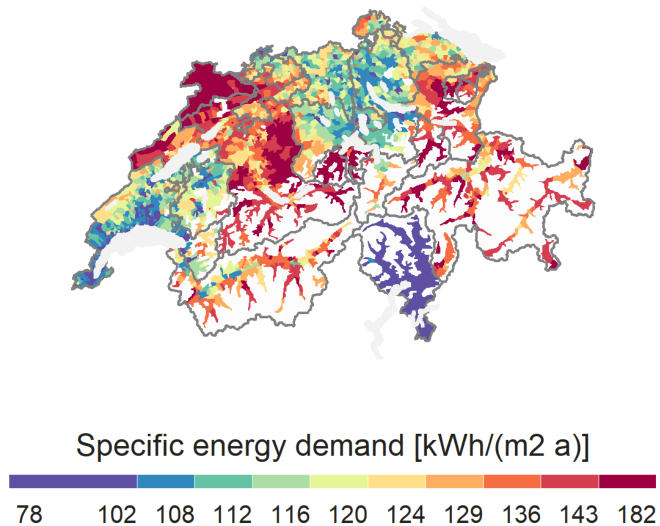


Approach	**Calculation of** • **Investment (I)** • **Operational cost (OM)**	**Calculation of annual savings** • **Energy difference (ΔE)** • **Cost difference**		**Description**
FULL	= Retrofit	= Existing - Retrofit	= Existing - Retrofit	Total investment cost need to be raised.
IMPROVEMENT	= Retrofit - Refurb.		= Refurb. - Retrofit	As above, but "anyway costs" are deducted. This approach implicitly assumes energy retrofit at end of life.
INTRINSIC	= Retrofit - Refurb. + Residual f(t)	= Exisiting - Retrofit	= Refurb. - Retrofit	Considers that asset still have a value at their end of life (salvage value) and accounts for lost asset value as a consequence of early replacement.
		Before end of economic lifetime	**After** end of economic lifetime	

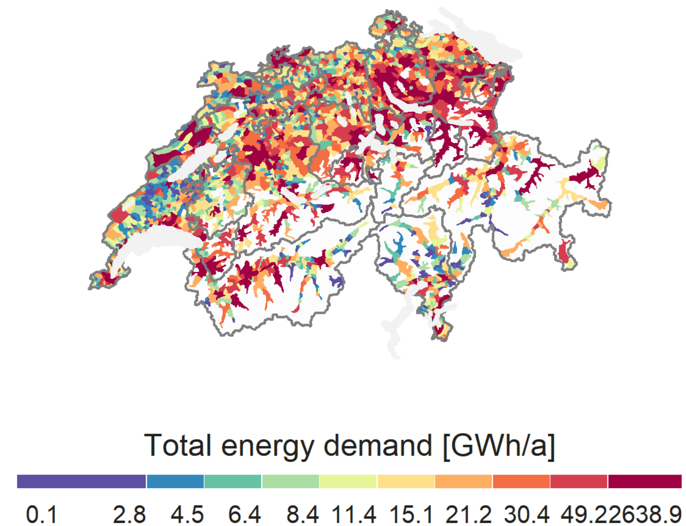
Results

Specific and total energy demand and impact

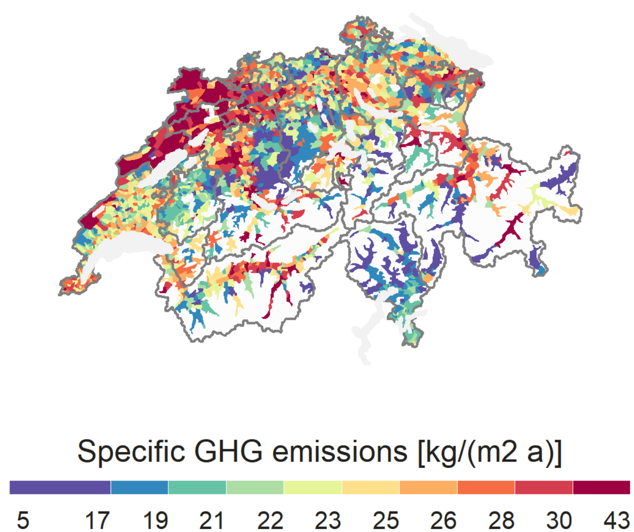
Specific energy demand



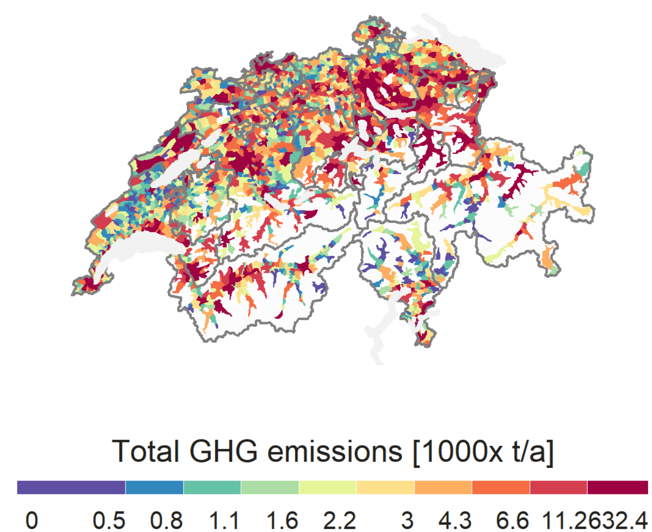
Total energy demand



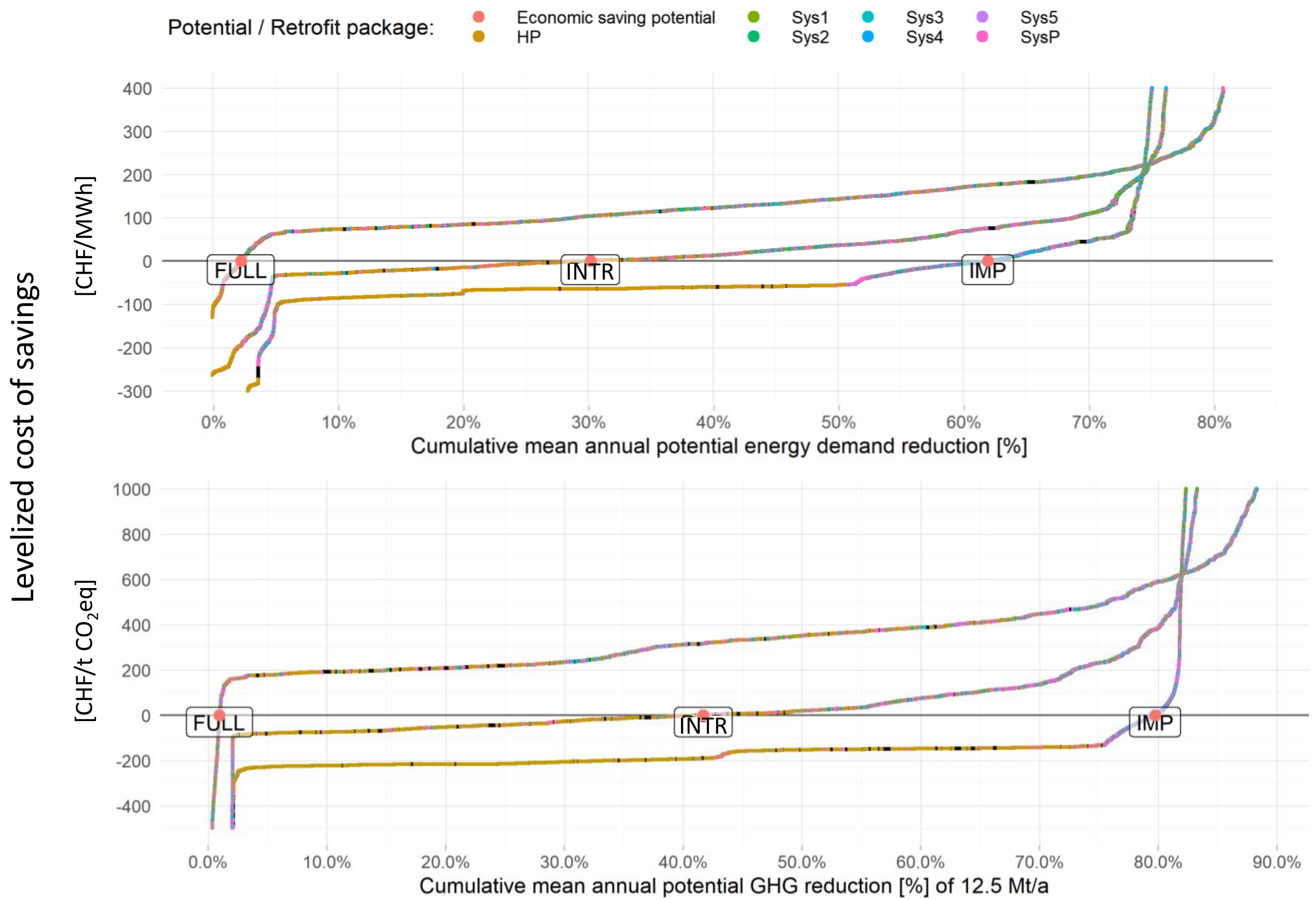
Specific emissions



Total emissions



Economic potential – Static (1/2)



Economic potential – Static (2/2)

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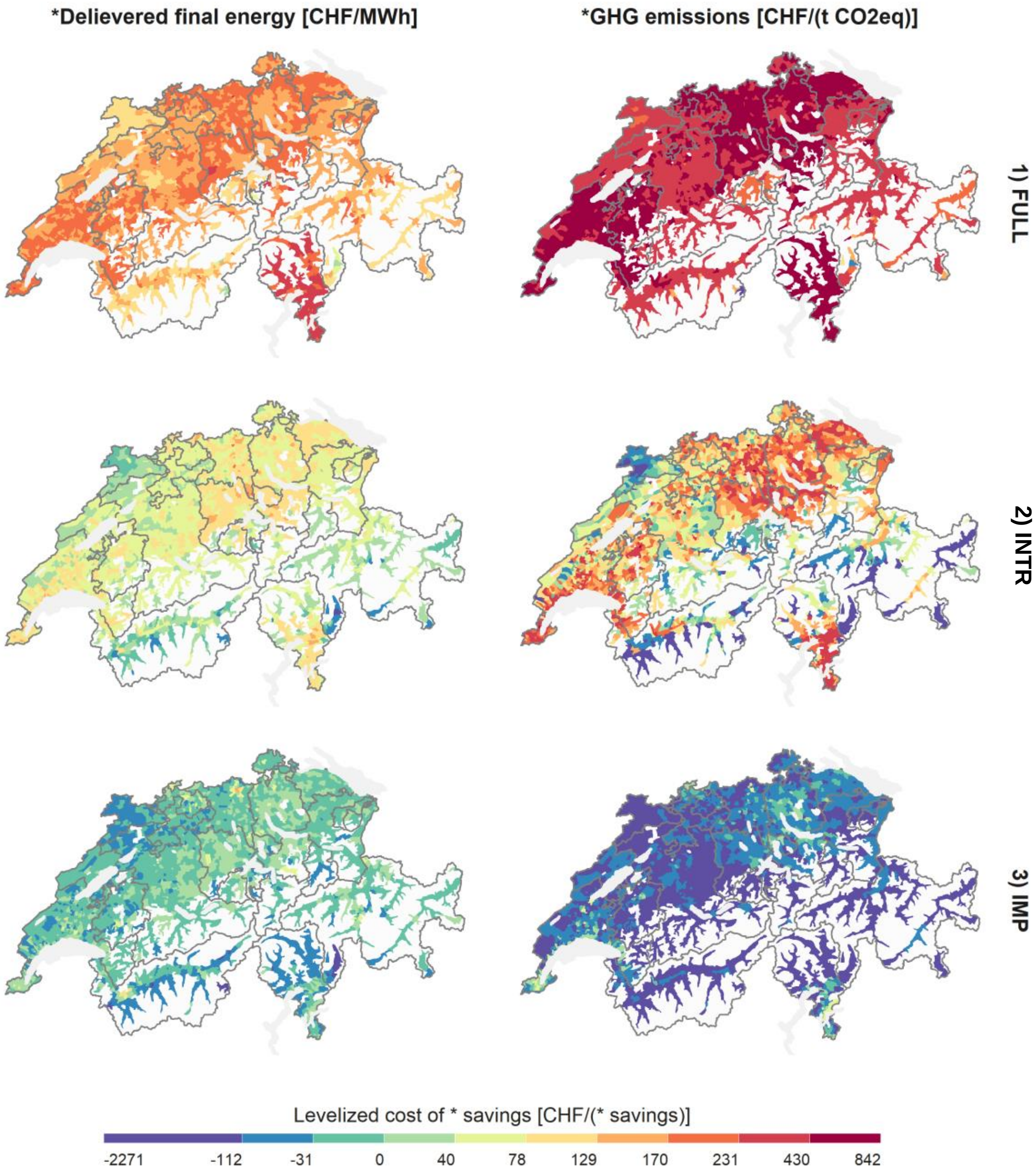
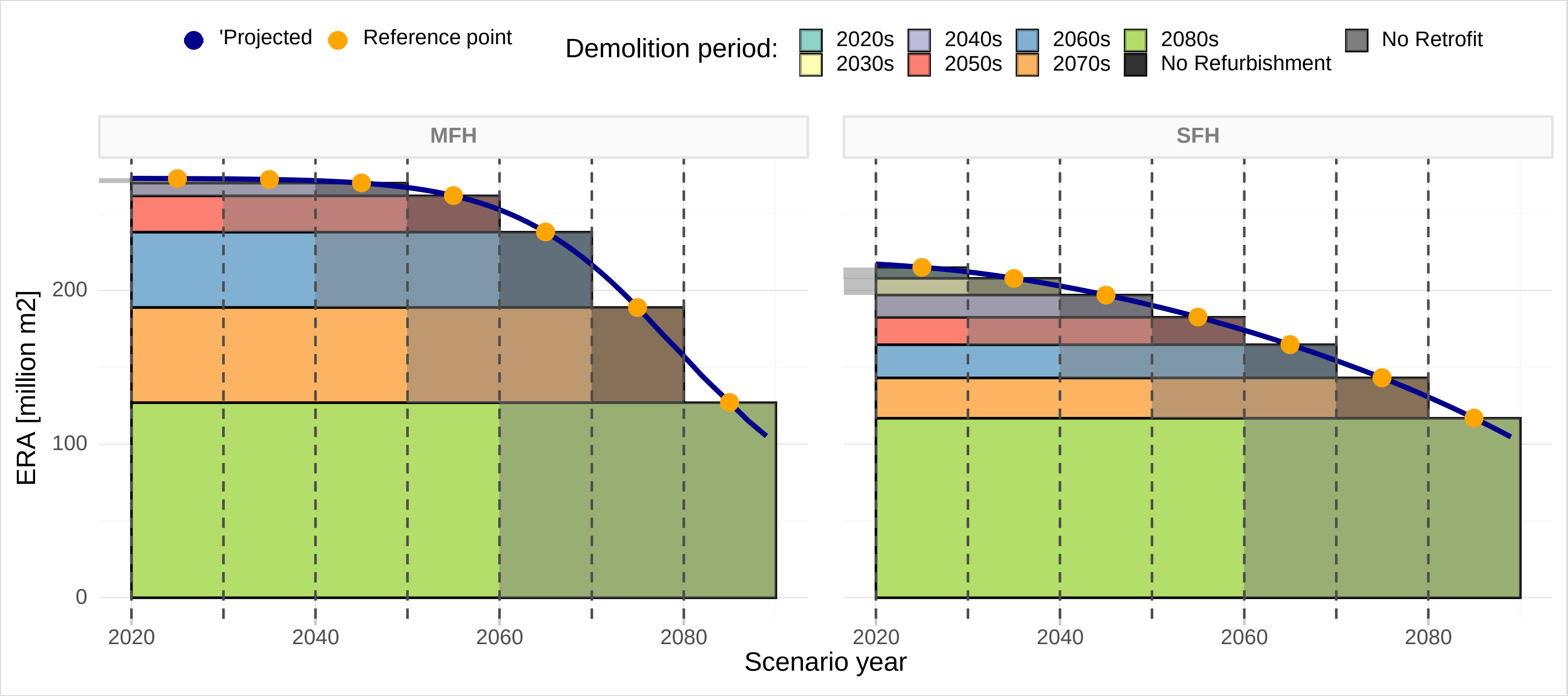
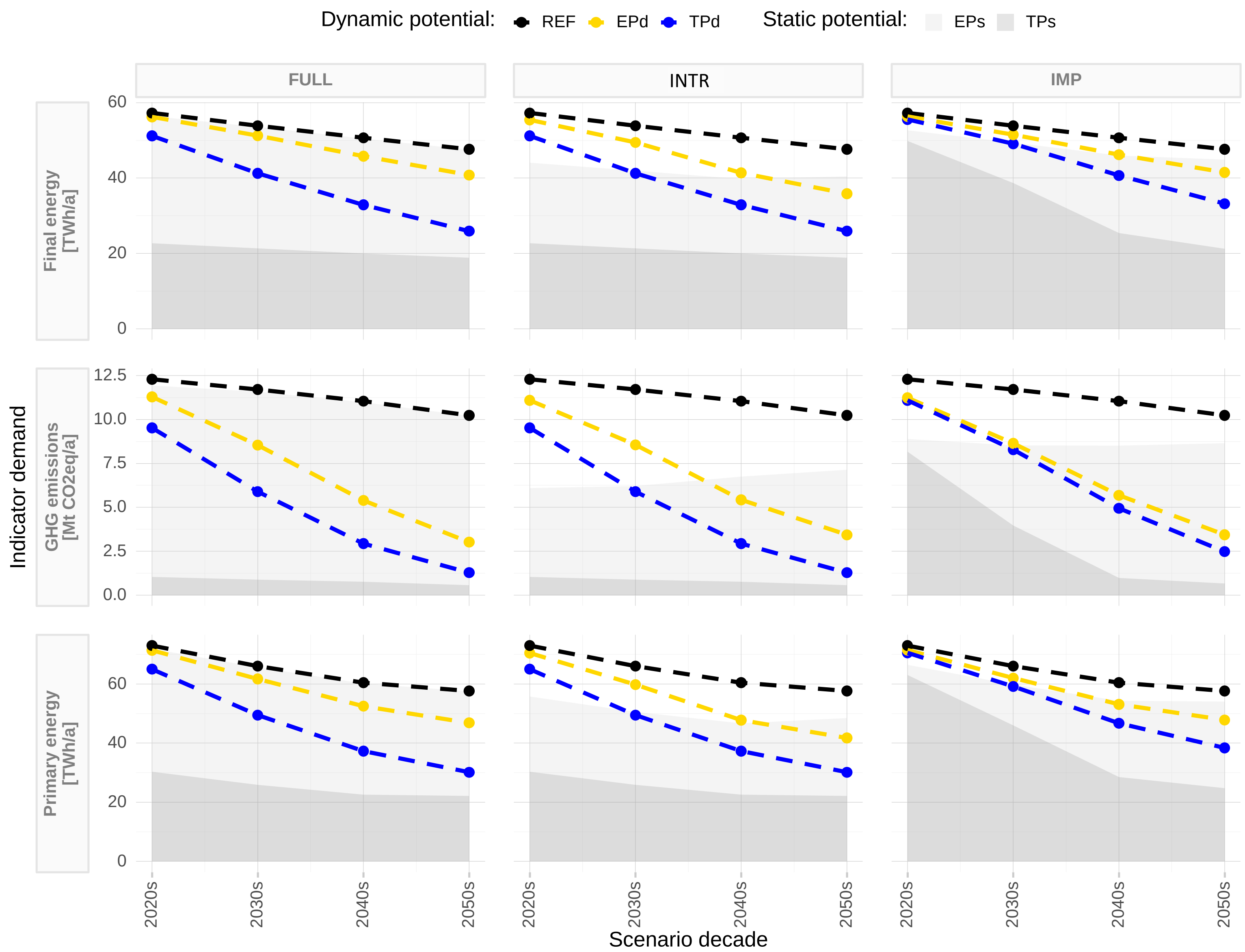


Scenario development

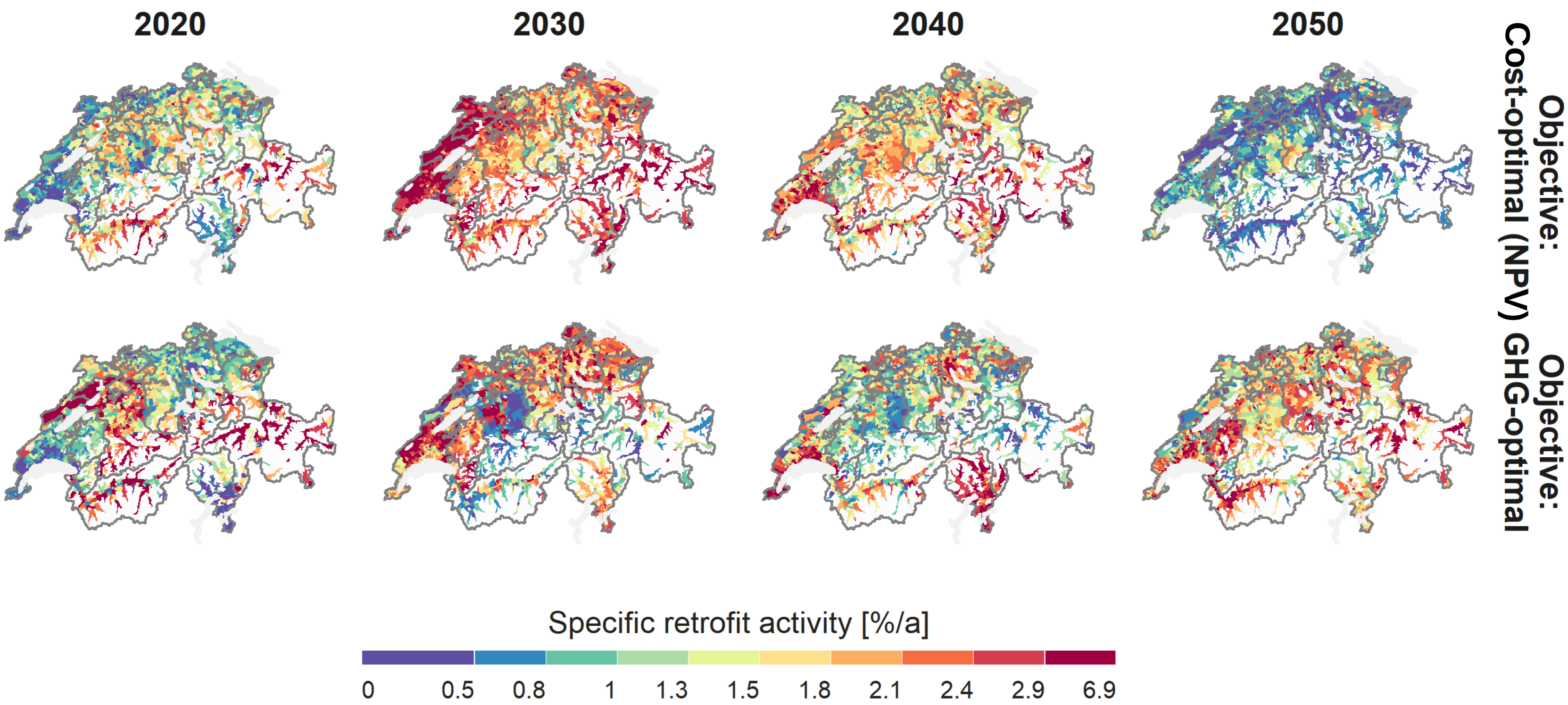
- **Refurbishment**
  - Standard heating replacement and non-energy measures
  - Natural refurbishment cycles and associated costs accounted for
- **Demolition periods**
  - Share of buildings demolished in a certain decade based on projected ERA
- **Energy retrofit**
  - No later than 30 years before demolition



Optimisation results for retrofit pathways (1/3)



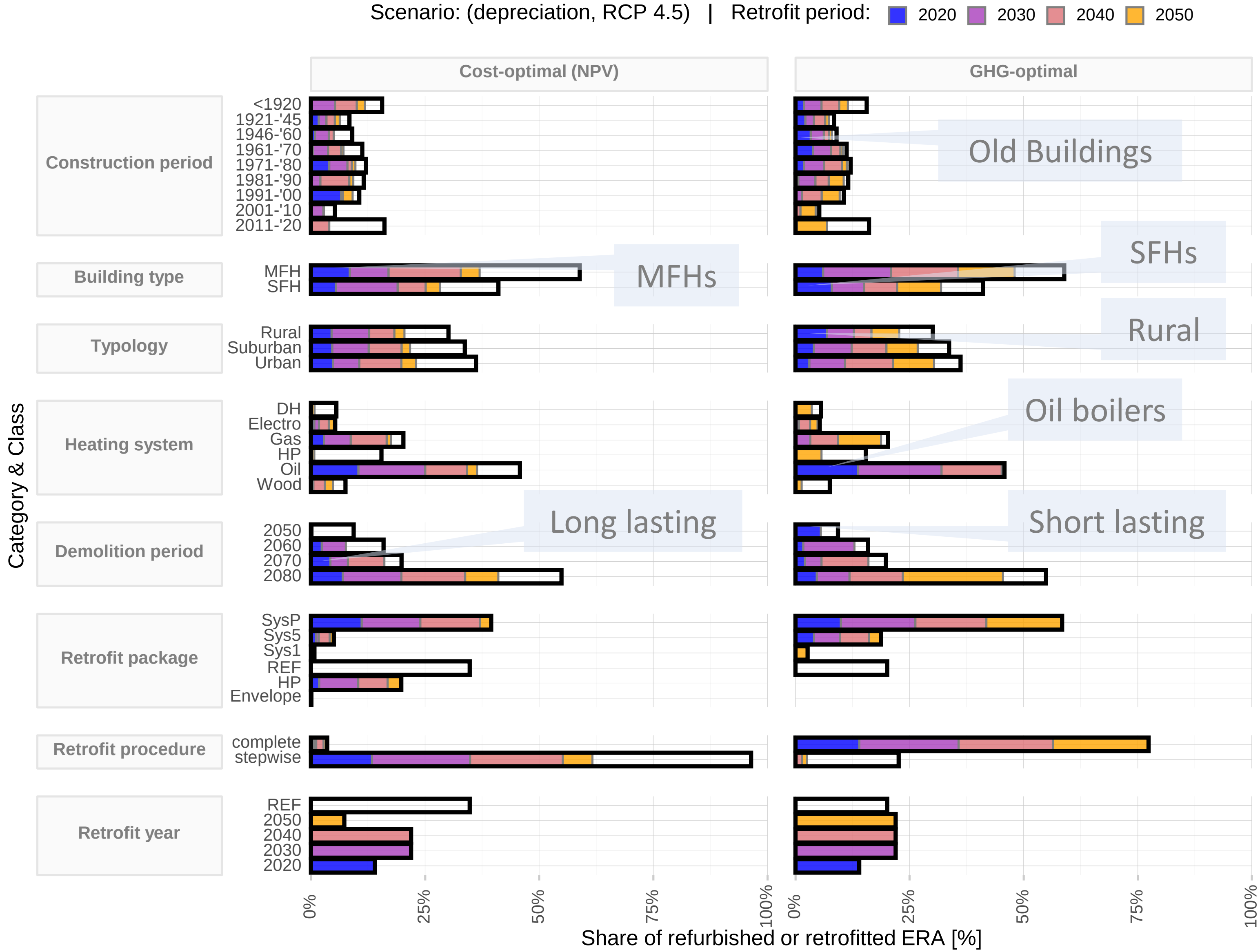
Optimisation results for retrofit pathways (2/3)



Key results:

- Despite switch from old to new and warmer climate, only 25% reduction of environmental impacts for no or partial retrofit actitivies until 2060.
- Maximum technical GHG abatement potential of -90% in 2060 with 182 CHF/t CO_2eq.
- Cost-optimal GHG abatement potential of 77% in 2060 with -138 CHF/t CO_2eq.
- Different climate change projections have no major influence on retrofit strategies.
- Early energy retrofit is cost-optimal and allows deep GHG emission reduction.

Optimisation results for retrofit pathways (3/3)



Discussion and Conclusions

Key messages - Methodological

- Findings on **cost-effectiveness** of energy retrofitting strongly depend on **chosen approach**
  - Cost assessment approaches represent different stakeholder preferences
  - Strong arguments for Intrinsic value approach (INTR) as default
  - Large differences among different cost analyses for static approach, less large differences for dynamic approach (Pathway approach)
- It is important to conduct **pathway analysis**
  - Strong influence on results
  - More awareness about methodological choices needed
- **Optimisation models** in combination with pathway analysis offer valuable policy-relevant insights
  - Information on which measures to implement for which archetype, in which location and when
  - Cost optimisation is of particular relevance in the context of EE 1st

Energy Efficiency First, analytically....

"… means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions;"

- *Optimisation models*
- *Cost minimisation*
- *(External cost)*
- *(Macroeconomic assessment)*

European Commission: REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action, […], 11 December 2018

Key messages – Empirical

- Energy retrofitting of residential buildings **can be cost-effective** while contributing very significantly to decarbonisation.
  - GHG reduction **by ~75% in 2060** (while 90% reduction incurs net additional cost)
  - **Includes early retrofit** for specific measures (i.e., not as blanket statement)
  - Retrofit measures: **HP installation and thermal performance**

- Retrofit (incl. early retrofit) remains attractive **in spite of global warming**
  - Low sensitivity of results to the extent of climate change

Key messages – Limitations

- Data inputs are subject to **uncertainties**
  - Investment costs, future energy prices, future CO_2 levy
- Larger potentials to be expected when accounting for **further external costs**
  - Primarily investor's perspective
  - External effects only for CO_2 and only up to ~100 CHF/t CO_2
- **Inertia and obstacles** to be taken into account separately
  - Real-life transition will be slower
  - Real-life cost minimisation will allow to exploit only part of these potentials
  - Fast transition requires additional measures and incentives

Key messages – Conclusions

Energy retrofit is technically feasible and economically viable in many cases for deep reduction of energy use and GHG emissions.

Further policy measures are required in order to better exploit cost-effective early retrofit and retrofit at the end of life.

Most important publications

- Doctoral thesis of **K.N. Streicher**: Cost-effective energy retrofit at national building stock level: Data-driven archetype modelling of the techno-economic energy efficiency potential in the Swiss residential sector

- **K.N. Streicher**, Berger, M.; Panos, E.; Narula, K.; Soini, M.C.; Patel, M.K.: Optimal building retrofit pathways considering stock dynamics and climate change impacts. Energy Policy, Volume 152, May 2021, https://www.sciencedirect.com/science/article/pii/S0301421521000896

For these and other publications by K.N. Streicher, see https://archive-ouverte.unige.ch/authors/view/105938 .

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