ISEC 2026, April 15th, 2026

ENERGY AND GREENHOUSE GAS EMISSION SAVINGS THROUGH SERIAL RENOVATIONS BY APPLYING THE **RENVELOPE** SYSTEM IN AUSTRIA

Alexis Mundt, IIBW
Wolfgang Amann, IIBW
Florin Leighton, AEE INTEC

RENVELOPE Energy Adaptive Shell

The GOAL

- To achieve international and national energy and greenhouse gas (GHG) emission targets, Austria requires **rapid and scalable renovation methods** for existing buildings.
- A massive wave of renovations is necessary to achieve climate neutrality by 2040
- The goal is to modernize buildings with outdated envelopes and inefficient heating systems while preserving „embodied energy“.
- **Serial renovation**: prefabricated timber-frame facade modules that incorporate insulation, windows, building technology and roofing elements; mounted directly on existing structures: „The RENVELOPE system“

- A bottom-up approach was used (our experts) to identify the target stock
- Traffic light colour scheme on building characteristics to identify the target stock

- In essence, buildings are most suitable when **a lot can be repeated across units** and the site allows **for** fast installation. In practice, the best candidates typically have/are:

  - **simple building geometry** (rectangular volumes, limited setbacks)
  - **standardized, repetitive layouts and façades** (many similar windows/balconies, similar floor plans across floors)
  - **2–8 storeys** (lower buildings do not achieve efficient renovation costs per usable m², while taller buildings are unsuitable due to fire safety regulations and technological hurdles)
  - reinforced **concrete** frame or brick wall buildings, prefabricated concrete buildings
  - **poor existing energy performance** (envelope and/or energy carrier)
  - good site logistics and **accessibility** (space for crane, staging, delivery, scaffolding)
  - façade/roof/window renewal needs attention anyway (so replacement aligns with life-cycle timing and avoids premature waste)
  - and others

- **Targeted building stock: 71,500 buildings from all over Austria**

- **What do we know about these buildings?**
  - Construction decades 1945-2000
  - 3 to 8 floors
  - predominantly residential buildings, 24% non-residential buildings (according to GFA: 34%!)
  - not comprehensively thermally renovated since 1990
  - poor to medium envelope
  - high proportion of fossil fuels as energy source, but not exclusively

1st step: Targeted building stock

***Table 2**. Identified target stock in numbers and shares*

Number of buildings	71,500
Of which residential buildings	54,500
Share of all residential buildings in Austria	3%
Share of all multi-family residential buildings in Austria	20%
Of which non-residential buildings	17,000
Share of all non-residential buildings in Austria	6%
Housing units in target stock	Approx. 526,000
Share of all housing units in Austria	11%

2nd step: energy and CO_2-savings

- **Goal:**Potential savings if all of these buildings were renovated with the RENVELOPE system
- Estimation of energy requirements (useful energy and final energy) and CO_2-emissions BEFORE renovation and AFTER renovation
- Point estimate for conservative scenario, ranges through sensitivity analysis
- At least some consideration of rebound effects
- Three model approaches (top-down vs. bottom up) are possible

Our model approach

- **Bottom-Up: Division of our potential stock into five segments:**
  - Residential buildings: Poor envelope, fossil fuels
  - Residential buildings: Poor envelope, higher proportion of renewables
  - Residential buildings: Medium envelope, fossil fuels
  - Residential buildings: Medium envelope, higher proportion of renewables
  - Non-residential buildings: averages

- **Breakdown: space heating, domestic hot water, household electricity**
  - BEFORE and AFTER renovation

- **Putting together space heat, hot water, electricity→ Final energy saving**

- **CO_2-emissions according to energy source and: electricity partially covered by PV system**

Calibration and validation

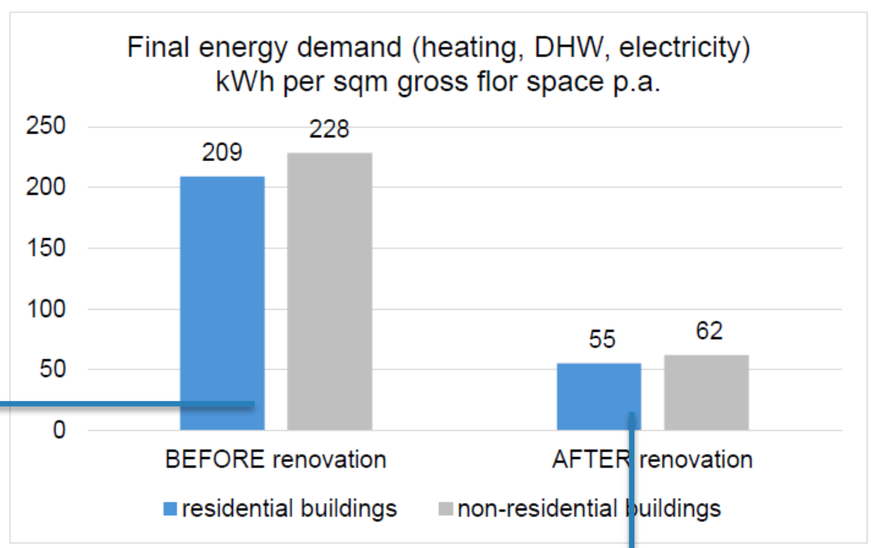
- Calibration of the parameters using literature, expert estimates, various data sources

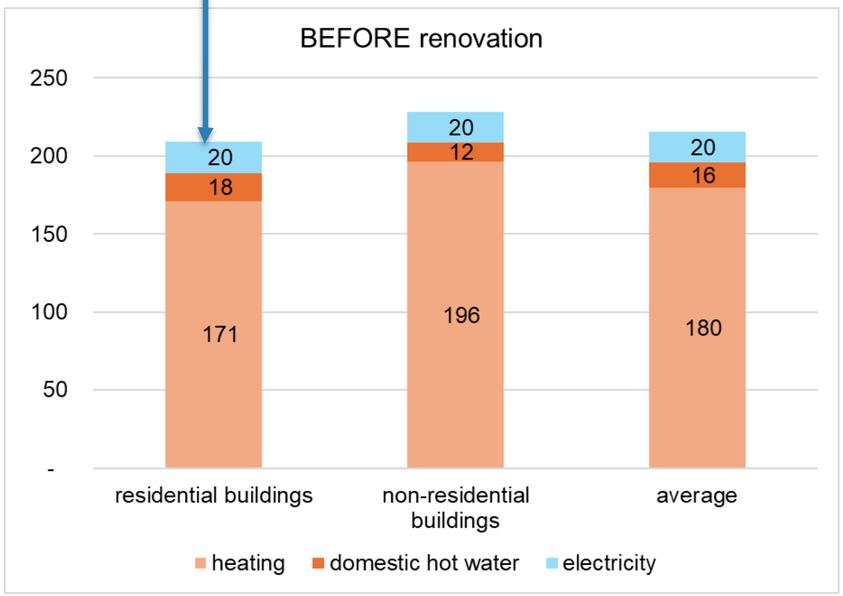
- Validation using efficiency scales for FED and CO_2eq-emissions
- Validation through top-down method for greenhouse gas balance (building sector plus estimate for district heating, electricity generation)

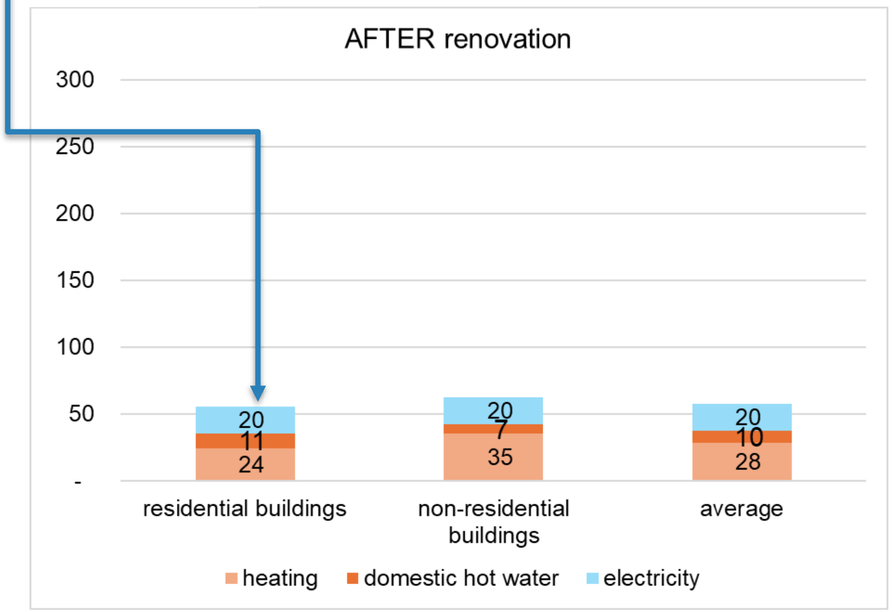
The most important calibration parameters

- Number of buildings (result “Targeted building stock”, IIBW)
- Average gross floor area per building according to building type, number of apartments, apartment size (validation with usable area per building according to AGWR)
- Heating demand (HWB) by sub-sector (residential building 2 qualities, non-residential buildings) (UBA data, TABULA project, EIV example houses, Vienna housing fund, pilots, etc.)
- Default values for hot water demand and electricity demand (EIV and ÖNORMB 8110-5)
- Energy sources before renovation (“Energy use of households”, literature)
- Energy source mix after renovation (Delphi method: heat pumps, district and local heating, biomass and others; expert estimates, climate plans, literature etc.)
- Energy consumption factors by energy source (mainly UBA data, OIB RL 6,Lit.)
- CO_2-factors according to energy sources (especially UBA data, OIB RL 6,Lit.)
- PV yield and degree of coverage (expert estimates)

Result: Final Energy Demand (heating, hot water, household electricity)

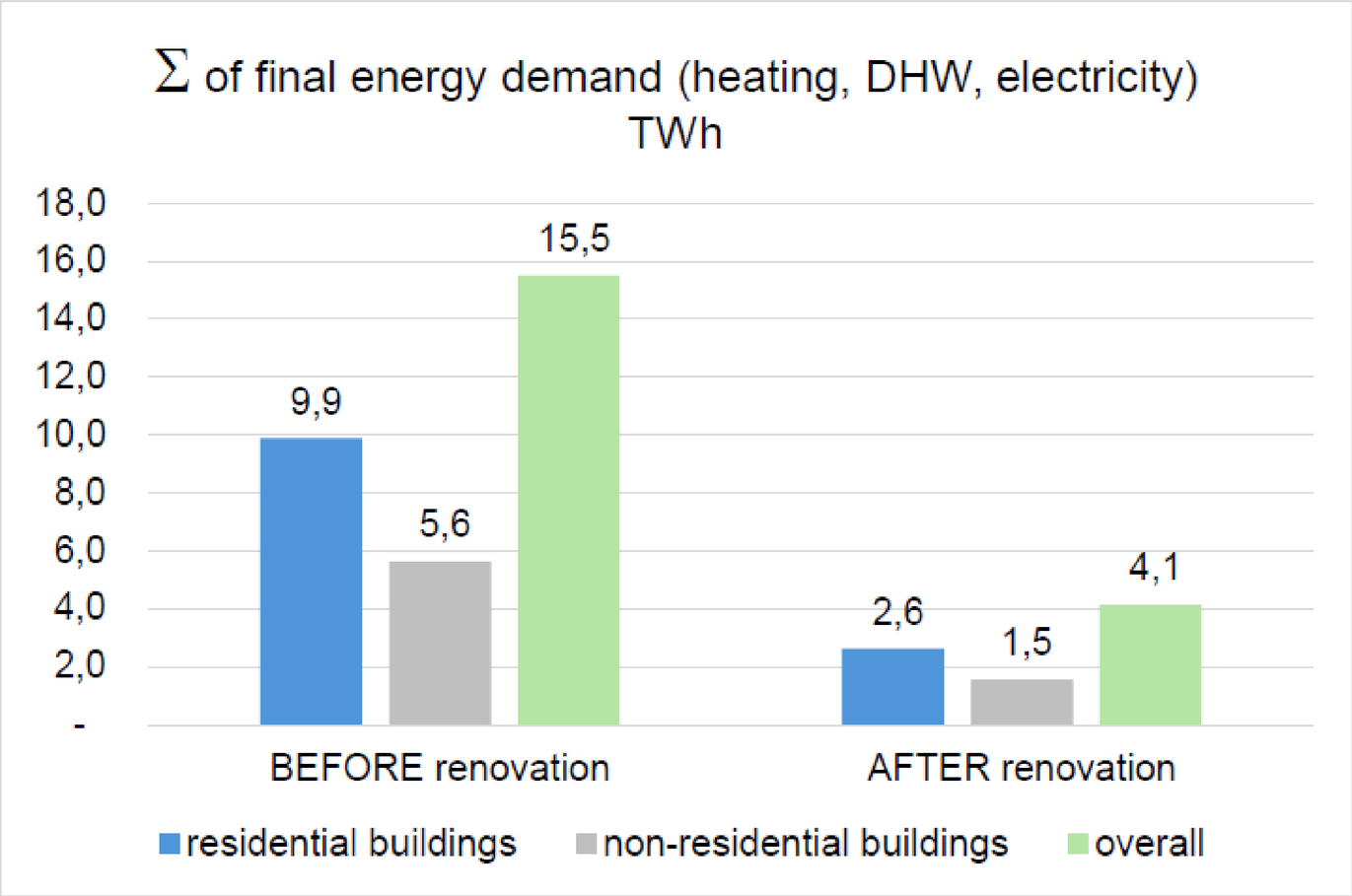






RENVELOPE

Final energy demand (heating, hot water, electricity): SUM TOTALS of the targeted building stock

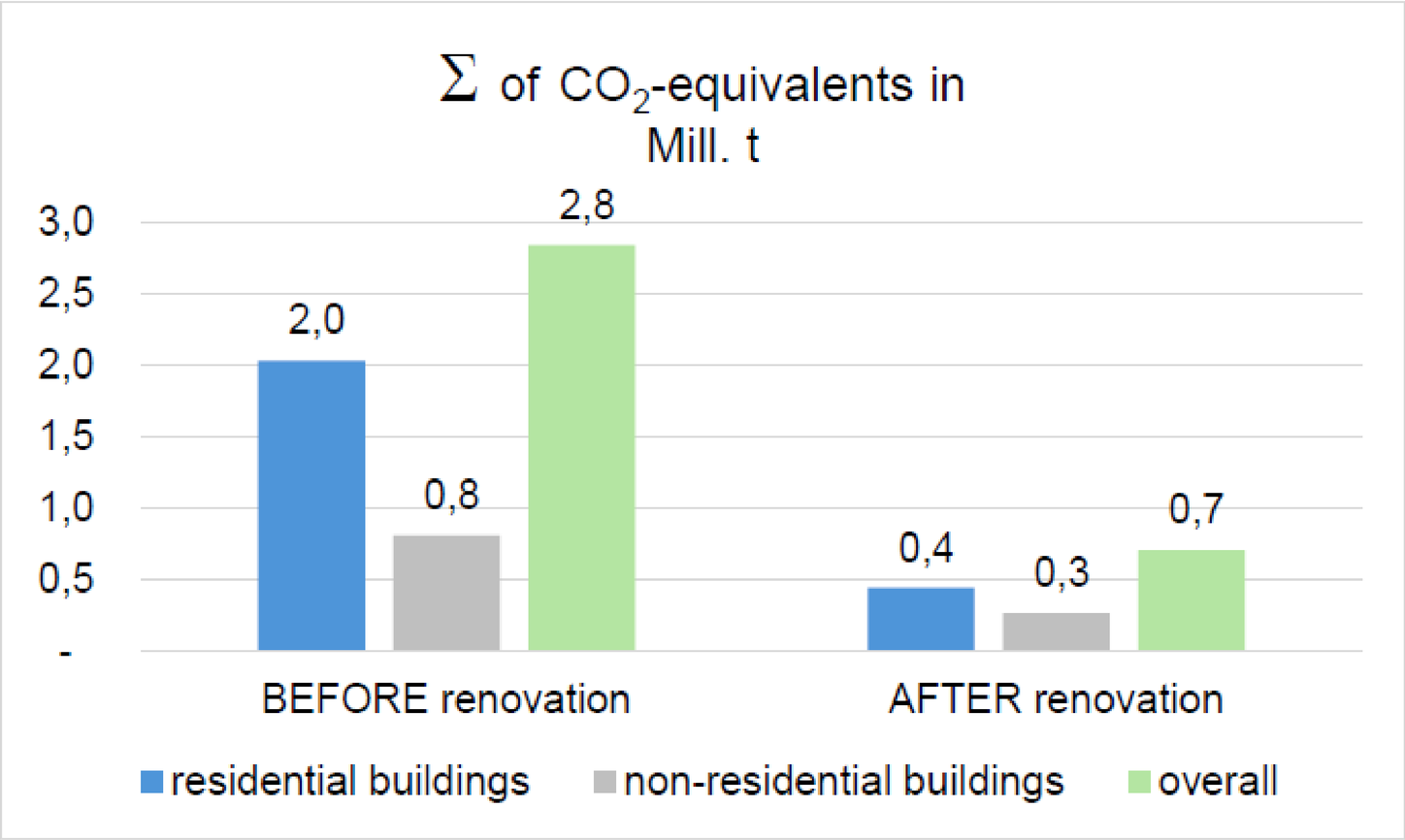


In total:

- **Savings 11.4 TWh**
- **That's 73% of the initial value**
- **FED Austria totals approx. 300 TWh**
- **So 4% savings potential based on the entire FED in Austria!**

RENVELOPE

CO_2 equivalents: TOTALS of the targeted building stock



In total:

- **Savings of 2.1 million t CO_2eq**
- **That's 75%**

Comparison top-down:

- **Building sector currently (excluding district heating and electricity), approx. 7.3 million. t CO_2eq**

RENVELOPE

Sensitivity analysis

- **The “medium” scenario is not overly optimistic, but realistic (see HWB after renovation)**

- **Bandwidths: by adapting the parameters, in particular:**
  - HWB after renovation (this means rebound effects can also be reflected)
  - Energy source mix after renovation (e.g. variation in biomass share): little impact, because the majority are heat pumps, district heating, biomass
  - PV coverage ratio
  - CO_2-factors of the electricity mix (continuous improvement?)
  - among others

Sensitivity analysis: result

- **Bandwidths**

	Final energy savings	CO_2 savings
Medium scenario	73%	75%
Best case scenarios	77%	84%
Worst case scenarios	68%	68%

- **Best: e.g. even lower HWB after renovation, continuous improvement of the electricity mix CO_2-factor**

- **Worst: e.g. less ambitious HWB after renovation, higher rebound effect, higher electricity share with bad CO_2-factor**

RENVELOPE

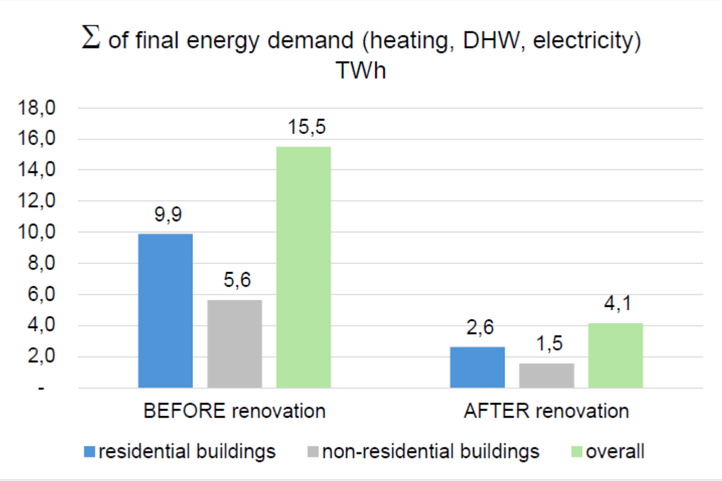
Conclusion

- Even if you think pessimistically...: Through RENVELOPE renovations of the targeted building stock, final energy and CO_2 emissions from these buildings can be reduced by 68%.
- Savings of 73% for final energy and 75% for CO_2 are more realistic
- The high savings potential results from the significant improvement in the shell and from the switch to renewable energy sources; concerning CO_2 emissions also from PV systems and the reduction in reliance on the general power grid.

In sum: Large positive effects on overall final energy demand in Austria and on CO_2-emissions from the building sector!

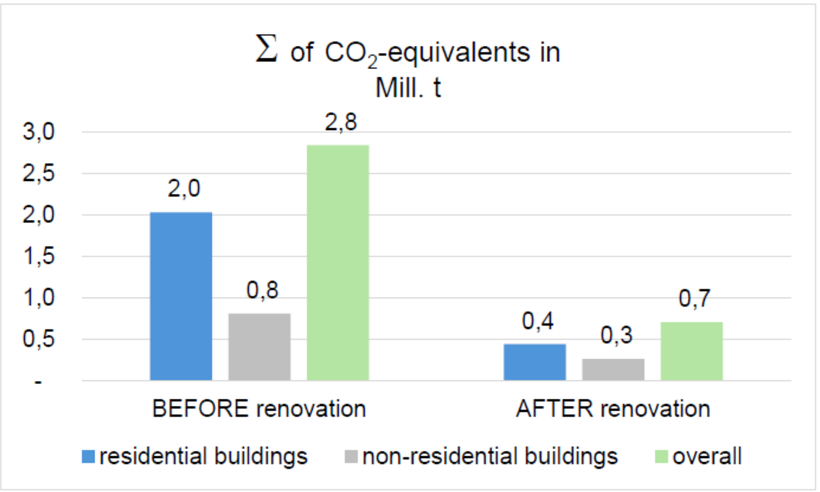
Final results Energy and CO_2 saving potential through RENVELOPE renovations

- 71,500 buildings in Austria are suitable for RENVELOPE renovations.
- On average, the final energy requirement (heating, hot water, household electricity) for residential buildings can be reduced from 209 kWh per m² GFA to 55 (-74%). For average non-residential buildings, the FED drops from 228 to 62 kWh.
- As for CO_2 emissions, the potential is just as clear: for residential buildings -78%, for non-residential buildings -67%.
- **This results from a significant improvement of the envelope and the switch to renewable energy sources (especially heat pumps, district heating, biomass), and additional PV yields also reduce the need for grid electricity**



Summed up over the entire target stock:

- FED saving:**11.4 TWh**
- CO_2 emissions: **2.1 million t CO_2eq**
- **This is relevant for Austria's overall climate balance!**



RENVELOPE

RENVELOPE

Energy Adaptive Shell

EXTRA slides

Extra

Greenhouse gas inventory (UBA):

Treibhausgas-Emissionen in Österreich 1990–2023

Mio. t CO_2-Äquivalent	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023	2022–2023	1990–2023
Energie & Industrie mit Emissionshandel	36,6	35,8	36,2	41,8	39,3	35,4	35,0	36,7	34,2	35,3	32,7	34,7	32,7	29,9	-8,6%	-18,3%
Energie & Industrie ohne Emissionshandel *				**6,0**	**6,6**	**5,9**	**6,0**	**6,1**	**5,8**	**5,7**	**5,7**	**6,0**	**6,1**	**5,5**	-10,0%	
Energie & Industrie Emissionshandel **				35,7	32,7	29,5	29,0	30,6	28,4	29,6	27,0	28,7	26,6	24,4	-8,3%	
Verkehr (inkl. nationalem Flugverkehr)	13,8	15,7	18,5	24,6	22,1	22,1	23,0	23,7	23,8	23,9	20,7	21,6	20,6	19,8	-3,9%	44,2%
Verkehr (exkl. nationalem Flugverkehr)*				**24,5**	**22,1**	**22,1**	**23,0**	**23,6**	**23,8**	**23,9**	**20,7**	**21,5**	**20,6**	**19,8**	-3,9%	
Gebäude*	**12,9**	**13,5**	**12,4**	**12,7**	**10,3**	**8,2**	**8,5**	**8,6**	**7,9**	**8,1**	**8,1**	**8,8**	**7,3**	**6,3**	-13,7%	-51,0%
Landwirtschaft*	**10,0**	**9,5**	**9,2**	**8,7**	**8,6**	**8,7**	**8,9**	**8,7**	**8,6**	**8,6**	**8,6**	**8,7**	**8,6**	**8,5**	-1,3%	-14,5%
Abfallwirtschaft*	**4,7**	**4,3**	**3,6**	**3,5**	**3,2**	**2,7**	**2,7**	**2,6**	**2,4**	**2,4**	**2,3**	**2,3**	**2,2**	**2,2**	+1,0%	-51,9%
F-Gase*	**1,6**	**1,5**	**1,4**	**1,8**	**1,8**	**2,1**	**2,1**	**2,2**	**2,3**	**2,2**	**2,2**	**2,0**	**1,9**	**1,8**	-4,7%	+17,3%
THG nach KSG				**57,37**	**52,5**	**49,6**	**51,1**	**51,9**	**50,8**	**50,9**	**47,50**	**49,2**	**46,78**	**44,2**	-5,5%	
Gesamte Treibhausgase	***79,4***	***80,4***	***81,2***	***93,2***	***85,3***	***79,2***	***80,1***	***82,5***	***79,3***	***80,5***	***74,6***	***78,0***	***73,4***	***68,6***	-6,5%	-13,6%

** Sektoreinteilung nach Klimaschutzgesetz (KSG)*
*** Daten für 2005 bis 2012 wurden entsprechend der ab 2013 gültigen Abgrenzung des EH angepasst.*
Die aktuellen Emissionsdaten weichen von bisher publizierten Zeitreihen ab.

Datenstand: Jänner 2025

Quelle: Umweltbundesamt

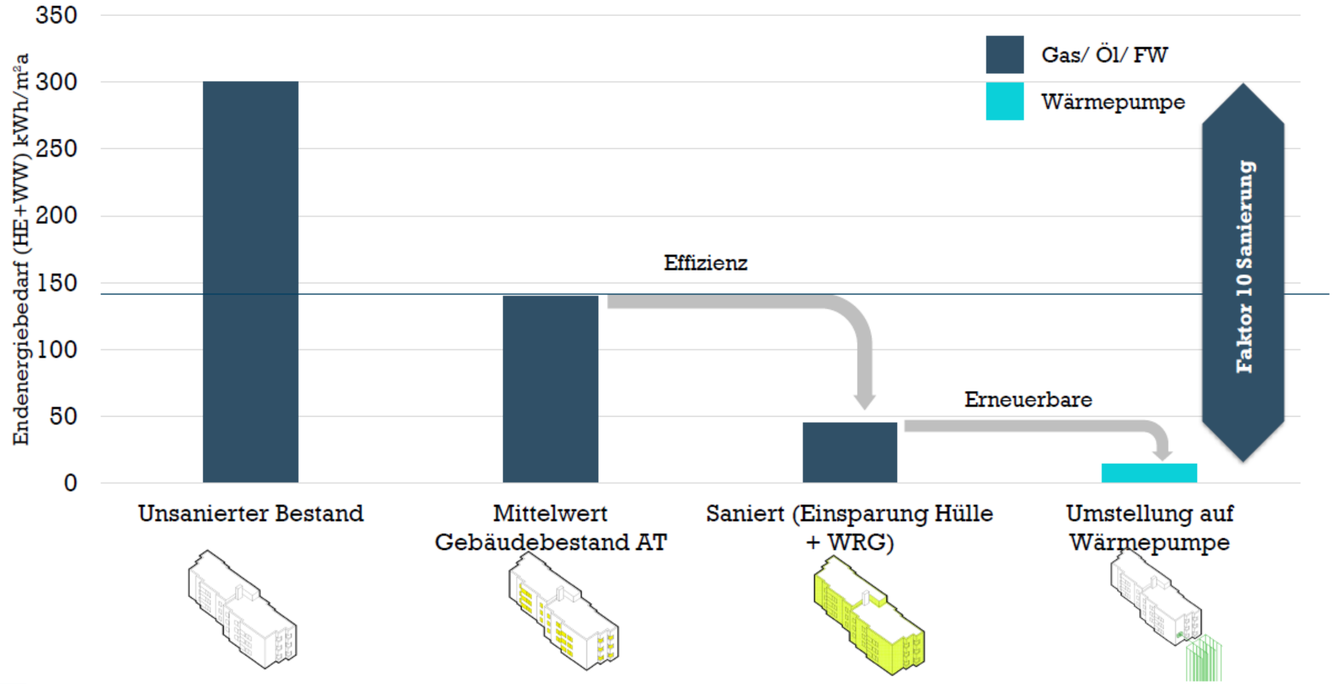
umweltbundesamt

RENVELOPE

Extra

Factor 10 renovation according to TobiasWhite(Final energy requirement from 300 to 30)

„Faktor 10 Sanierung“
Einsparungen HWB von 70 - 80% + Umstellung auf WP



RENVELOPE

Further dissemination efforts

- **More:**
  - Wolfgang Amann: Contacts with the real estate and building products industry, timber construction
  - Dr. Anzengruber (Austrian government coordinator for reconstruction in Ukraine, possible development of prefabrication industry in Ukraine for Austria, DL,vt. Ukraine)
  - Contacts with portfolio holders, e.g. ÖBB, GBVs
  - Participation in the reform of the building regulations in Vienna (building line topic), Lower Austrian building law (position name, building line topic)
  - Further communication of results in other research collaborations, e.g. “MasSan“, “Life in the Existing Stock”, “GBV Deka”
  - Involvement in government negotiations forDecarbonization package (WA ist einer der von den NEOS berufenen Experten)

Plans:

- Impact Days?, other publications, specialist articles?, follow-up projects?, etc.

RENVELOPE

Model access A

Top-Down: Austria's greenhouse gas balance (Sector classification) created by UBA (Federal Environment Agency) based on OLI (Austrian Air Pollutant Inventory):

- Building sector 2022: 7.3 million t CO_2Equivalents (falling sharply in 2023).
- But: no division into building segments!
- But: no final or primary energy requirement information to form the basis for this
- But: how to deal with itSector allocation(e.g. district heating, electricity)?

- **Estimate how much of this is "our" buildings**

- **Percentage savings (CO_2eq) through RENVELOPE renovation**based on pilots (EA-based!) or samplesWohnfonds_Vienna(or similar), square meters based on gross floor area

Model access B

- **Assuming five subsectors according to PEB or EEB and CO_2eq based on the energy certificate energy efficiency scale according to OIB RL 6:**

- **Extrapolate above average Gross floor area**

Optimal: Factor 10 renovation according to AEE Intec:
Final energy requirement from 300 to 30

Energieausweise sind von qualifizierten und befugten Personen auszustellen.

Für die grafische Darstellung in der Energieeffizienzskala auf der ersten Seite des Energieausweises werden folgende Klassengrenzen festgelegt:

Klasse	$HWB_{Ref,SK}$ [kWh/m²a]	PEB_{SK} [kWh/m²a]	$CO_{2eq,SK}$ [kg/m²a]	$f_{GEE,SK}$ [-]
A++	10	60	8	0,55
A+	15	70	10	0,70
A	25	80	15	0,85
B	50	160	30	1,00
C	100	220	40	1,75
D	150	280	50	2,50
E	200	340	60	3,25
F	250	400	70	4,00
G	> 250	> 400	> 70	> 4,00

Die verpflichtende Angabe des Heizwärmebedarfes und des Gesamtenergieeffizienz-Faktors in Anzeigen in Druckwerken und elektronischen Medien gemäß Energieausweis-Vorlage-Gesetz 2012 bezieht sich auf die dem Labeling zugrundeliegenden Werte für den $HWB_{Ref,SK}$ und den $f_{GEE,SK}$ bzw. bei Gebäuden der Gebäudekategorie 13 auf den $HWB_{Ref,SK}$.

RENVELOPE

Extra

Energy sources after renovation (space heatingtw. hot water) and corresponding energy expenditure figures and CO_2-Factors

energy source	Scenario Normal	Biomass scenario	Energy expenditure number	CO_2-Factor
Heat pump	55%	50%	0.30	0.238
District/local heating	30%	25%	1.05	0.179
Biomass	10%	20%	1.60	0.024
(Other) Direct electricity	5%	5%	1.15	0.238
sum	100%	100%		
weighted factors (normal scenario)			0.698	0.199
weighted factors (biomass scenario)			0.790	0.180

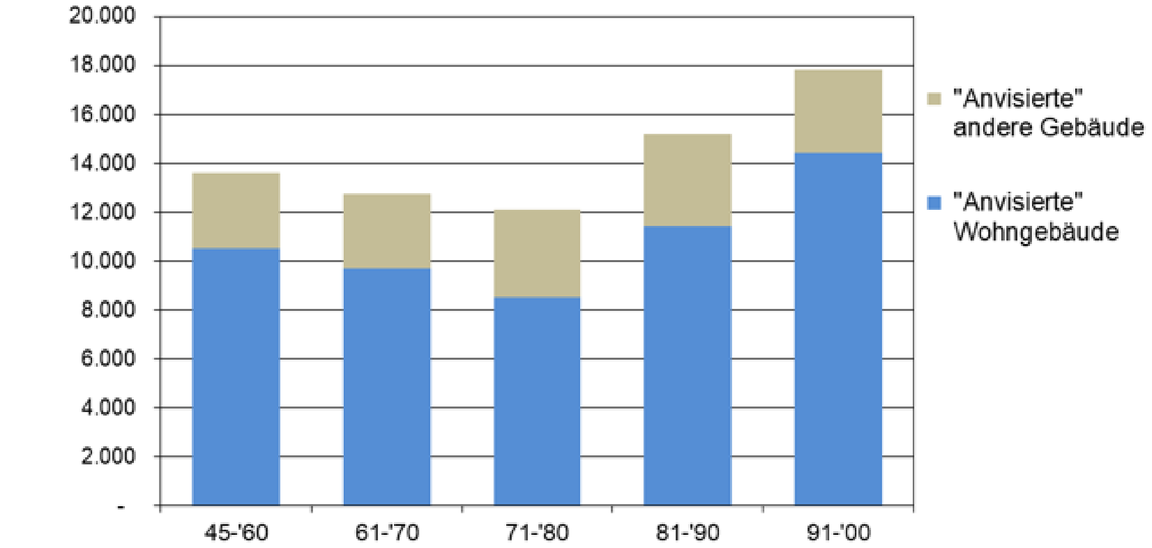
Conclusion: Great consensus on energy sources AFTER renovation. The biomass scenario does not make a huge difference because the heat pump is at least 50%.

Extra: Classification according to important building characteristics

	Anvisierter Gebäudebestand		Vorerst ausgeschlossen	Relevante Dimension der Einteilung
Eigenschaft	**Besonders gute Eignung**	**Eignung gegeben**		
Gebäudeklasse, Gebäudehöhe, Fluchtniveau	- Gebäudeklasse 2-4	- Gebäudeklasse 5 (bis 22 m Fluchtniveau)	- Hochhäuser (über 22 m Fluchtniveau)	Brandschutzbestimmungen, Statik, Krantechnologie
Geschoßanzahl	- bis ca. 4 Geschoße	- Geschoße, ca. 4 bis ca. 8 Geschoße - (bis 22m Fluchtniveau)	- 1 Geschoß (Eigenheime, ohne Serialität) - 9, 10 Geschoße - ab Fluchtniveau 32 m (ca. 10+ Geschoße)	Brandschutzbestimmungen, Statik, Krantechnologie
Baualter	- 1945 bis 1980er	- andere Baualter bis ca. 2000	- Denkmalschutz, Ensembleschutz - Neubau ab ca. 2000	Technologie, Ökologie
Fassadendesign	- geschlossene Fassade - „Lochfassaden“ - keine Vorsprünge - kein sehr hoher Öffnungsanteil - fixes Raster	- durchgängiges Fensterband, (sofern vertikale Schächte nicht notwendig sind)	- viele Vorsprünge - komplizierte Balkone	Technologie, Ausmaß des Öffnungsanteils
Fassadenmaterial	- Putz - Beton - Holz - Faserzementplatten	- Alu-Paneele - Glasfaserbeton	- Naturstein	Eigengewicht, Nachhaltigkeit, Gestaltungsmöglichkeiten
Bauweise	- Stahlbeton und Mantelbeton - Ziegel		- „Sandwich-Bauweise“ - Leichtbauweise (Holz) - sehr schlechte Bausubstanz	Technologie; Möglichkeit der Bauteilaktivierung
Fenster	- Fenster am Ende des Lebenszyklus (25 J)	- Fenster bleiben, werden nicht versetzt		Technologie, Ökologie
Energieträger	- Fossil		- dekarbonisiertes System mit hoher Effizienz in Kombination mit hoher thermischer Qualität	Ökologie
Wärmeverteilsystem	- dezentral - Einzelöfen	- bereits zentralisiertes System		Ökologie, Einsparungspotenzial
Vollwärmeschutz (WDVS)	- keiner	- WDVS mäßiger Qualität (bis max. 2010er) - 6 bis 8 cm - am Ende des Lebenszyklus - schadhaft	- WDVS hoher Qualität und Dicke	Technologie, Heizwärmebedarf, Einsparungspotenzial und Ökologie,
On-site Installationsmöglichkeit	- freistehend, oder einfache Montage	- schwierige Montage	- Installationsmöglichkeit nicht gegeben	Technologie, Logistik
Transportmöglichkeit	- Standardmodulgrößen	- Module passen auf max. Sondertransporte.	- Module sind zu groß	Beschränkungen der LKW- Sondertransporte
Aufstockungspotenzial	- Je mehr, desto besser	- Baurecht, Flächenwidmung, Statik, etc. erlaubt keine Aufstockung		Kosteneffizienz, Baurecht, Widmung, Technologie
Vergabemöglichkeit, Komplexität der Ausschreibung	Systemausschreibung ist möglich, keine Ausschreibung der Einzelleistungen, einfache Beschlussfassung zur Vergabe	Ausschreibung komplizierter, weil gesetzliche Vorgaben zur Ausschreibung (z.B. Bundesvergabegesetz), Entscheidungsfindung zur Vergabe zeitaufwendiger (z.B. Aufsichtsrat etc.)		Zeiteffizienz, Verfügbarkeit von geeigneten Unternehmen, Entscheidungsfindung

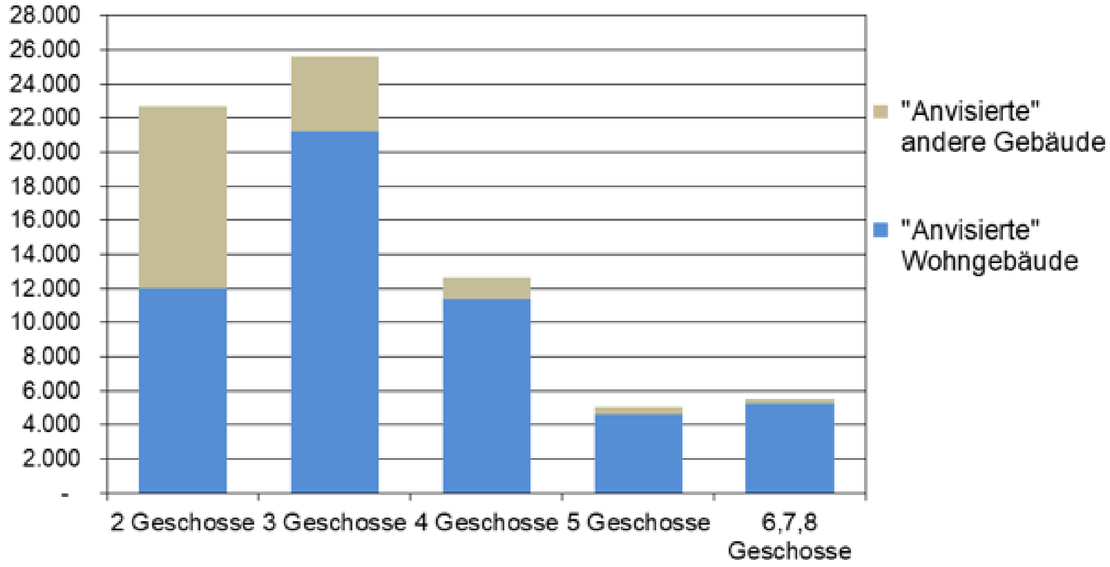
Extra: Result of targeted building stock

Grafik 5: Anvisierter Gebäudebestand nach Gebäudeart, Baujahrzehnt



Anm.: Ergebnis Schätzmodell, nähere Beschreibung siehe Text.
Quelle: Statistik Austria, AGWR und eigene Berechnungen

Grafik 6: Anvisierter Gebäudebestand nach Gebäudeart, Geschoßanzahl



Anm.: Ergebnis Schätzmodell, nähere Beschreibung siehe Text.
Quelle: Statistik Austria, AGWR und eigene Berechnungen

RENVELOPE