TECHNISCHE UNIVERSITÄT WIEN

think ENERGY RESEARCH

How cost efficient is energy efficiency in buildings?

A comparison of building shell efficiency & heating system change in the European building stock

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Aim of the work

Background

- Remarkable potentials for heat savings exist in the EU building stocks
- The EU heating system has to become carbon neutral
- General principle: first, save energy, second, supply remaining energy with carbon neutral options (**energy efficiency first principle**)

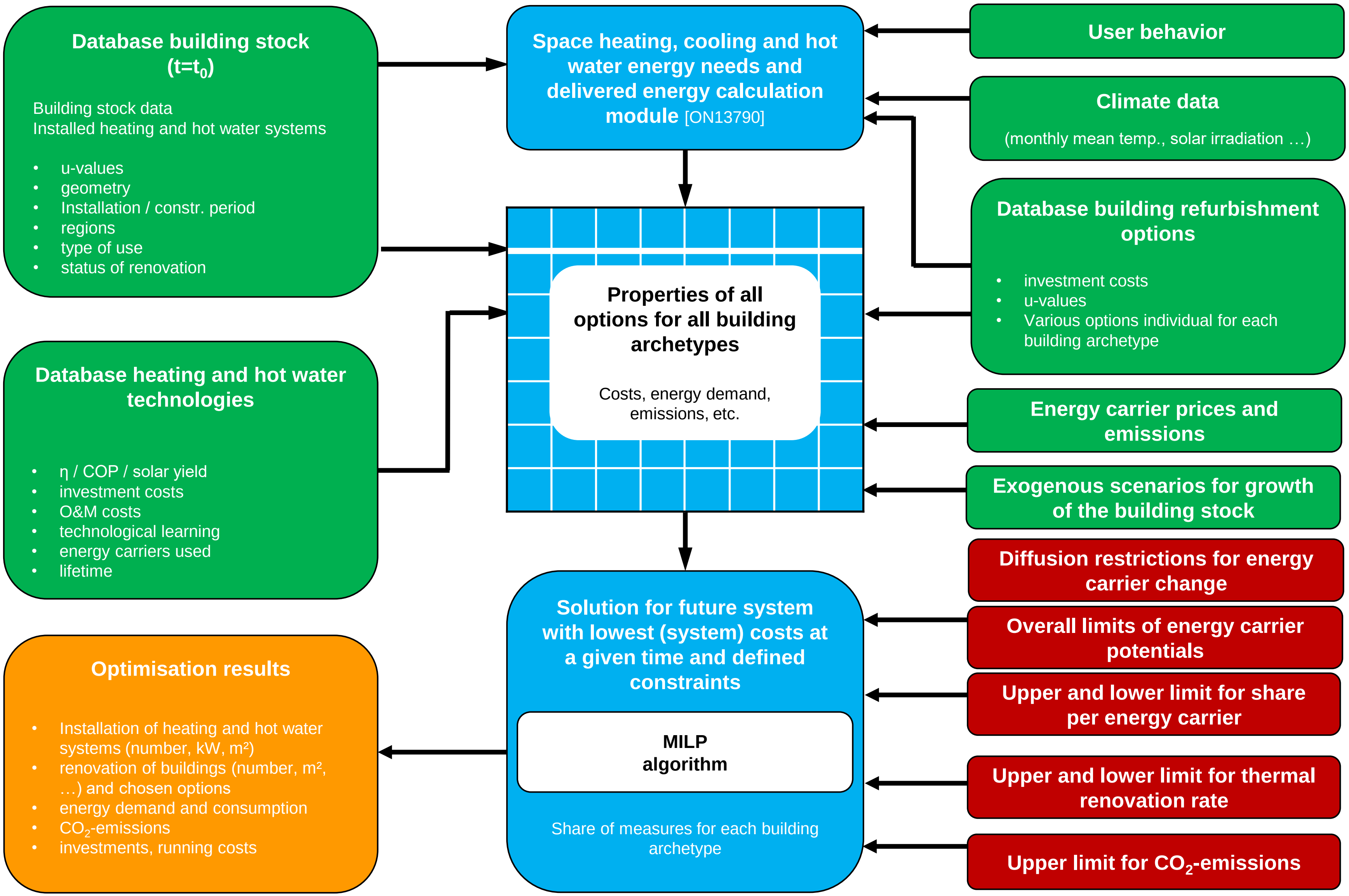
Research questions

- “**How cost efficient is it to follow the energy efficiency first principle in the EU building stock?**”
- “How cost efficient is energy efficiency in buildings?”

Aim is to analyse …

- … the effect of different restrictions for refurbishment activities …
- … on the resulting cost optimal combinations …
- … of heating system change and thermal renovation …
- … with an established EU wide building stock model

The Invert/Opt model



Important assumptions

CO_2 emissions

- **95% reduction from 2017 until 2050** over the entire stock (in each country)

Energy carriers potentials

- Country-specific theoretical potential of **heated gross floor area** that can be supplied by an energy carrier (**saturation limit**)
- **Diffusion restrictions** in the scenario time frame
- Country-specific **resource restrictions for decentral biomass** utilisation (EU-27 total 91% of current use)

Energy carrier prices

- For most energy carriers **calculated with the Enertile model**:
  - methane, hydrogen, bio-liquids, e-liquids, electricity, district heat
  - Assumption of nearly full decarbonisation of electricity and district heat
- Only minor amounts of fossil gas/oil remain in the mix
- **Biomass** prices stay **constant**

Refurbishment and scenarios

- **Refurbishment in Invert**
  - Refurbishment = Maintenance* + thermal renovation

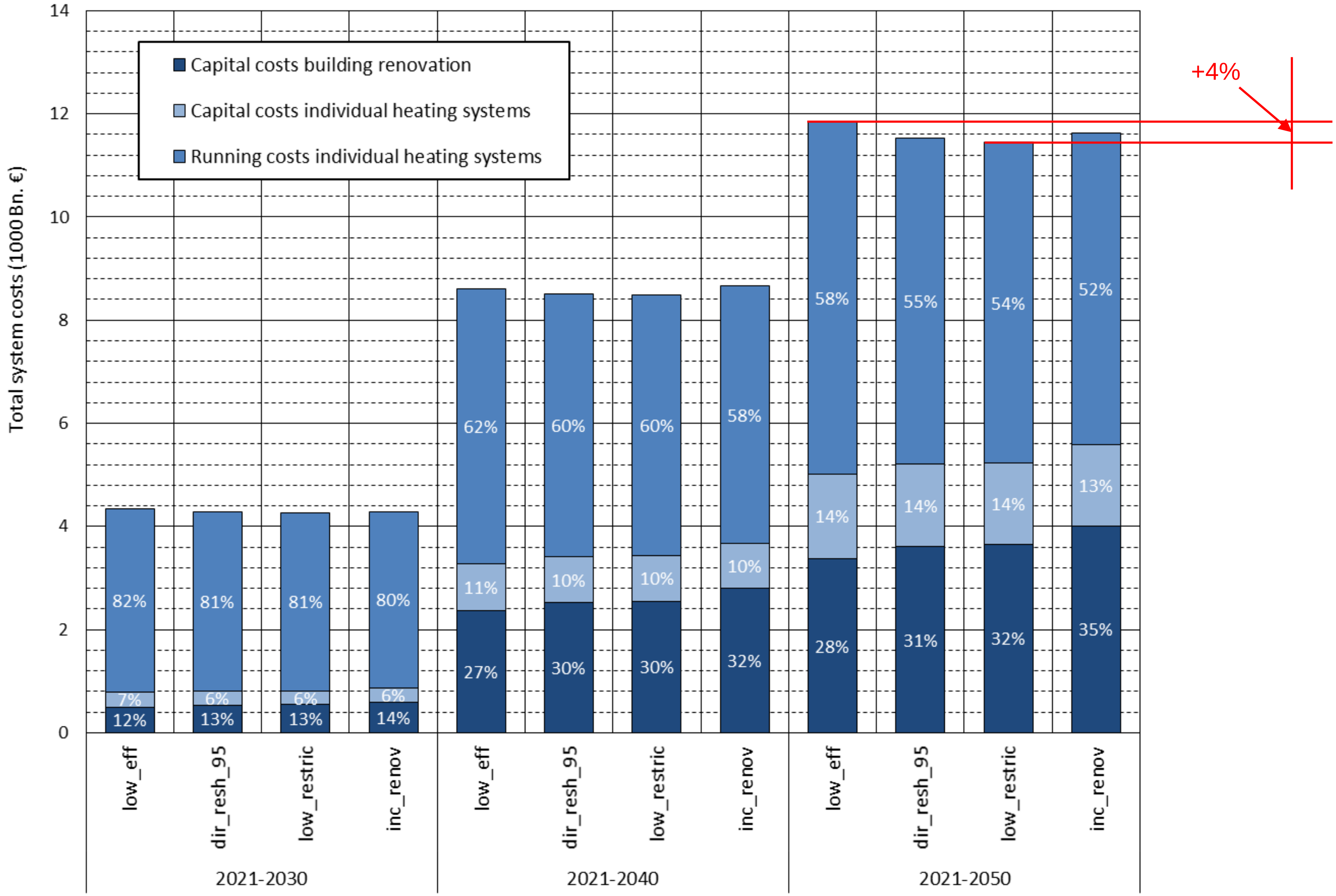
    *no effect on effective energy needs
  - Refurbishment cycles

    … are endogenously determined in the model
    … for each building component in each building
    … based on distributions of construction / past renovation moments
    … and Weibull distributions of lifetime of the components

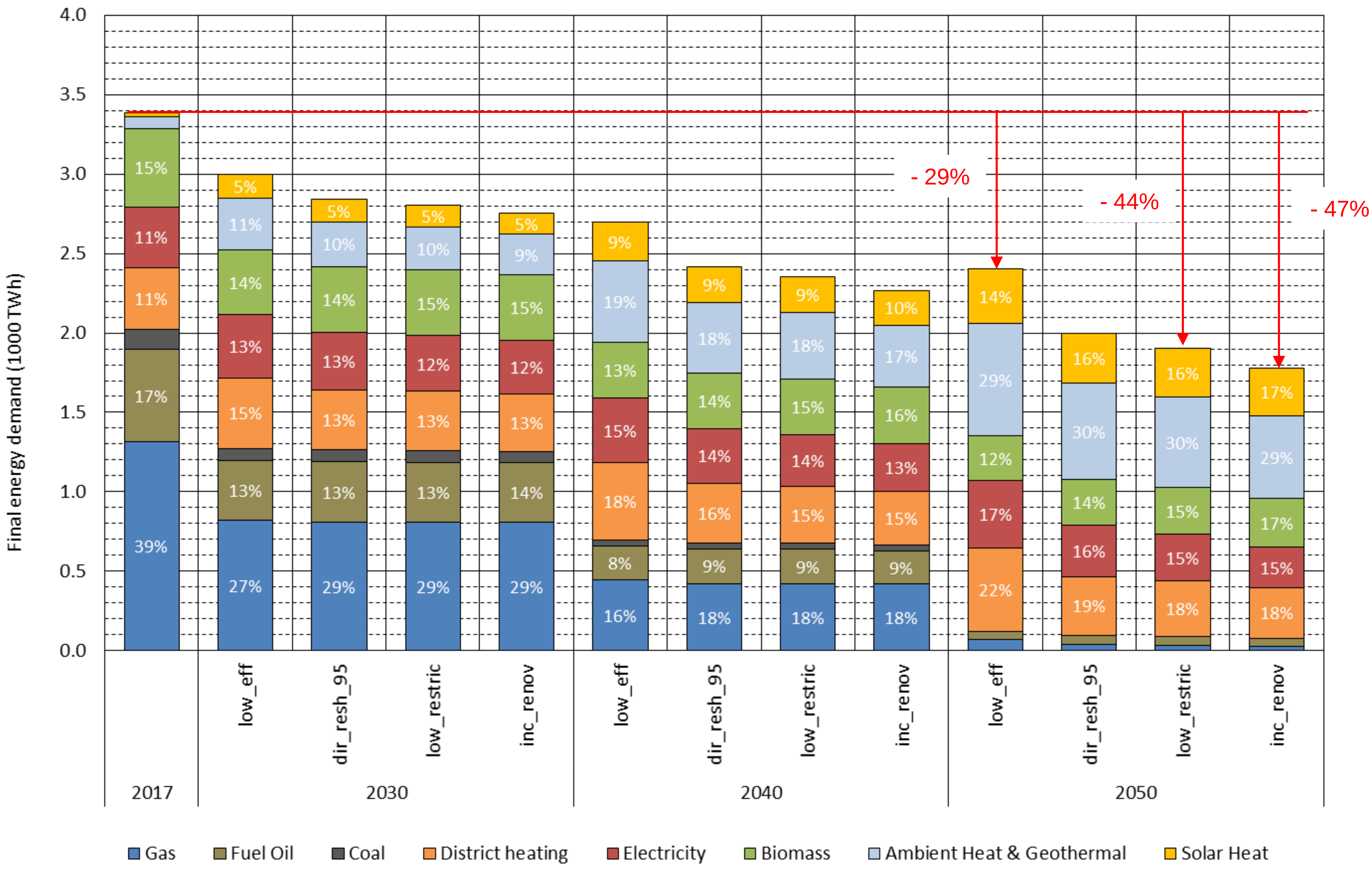
- Calculated **scenarios only differ in the settings on refurbishment** activities:

Scenario name		Share of maintenance on total refurbishment activities		Length of refurbishment cycles of building shell
long	short	in the entire stock	in single buildings	
Direct RES-H	dir_resh_95	20 - 50%	10 - 90%	1
Low efficiency	low_eff	65 - 90%	25 - 100%	1
Low restrictions	low_restric	10 - 90%	0 - 100%	1
Increased renovation	inc_renov	10 - 90%	0 - 100%	1/1.4

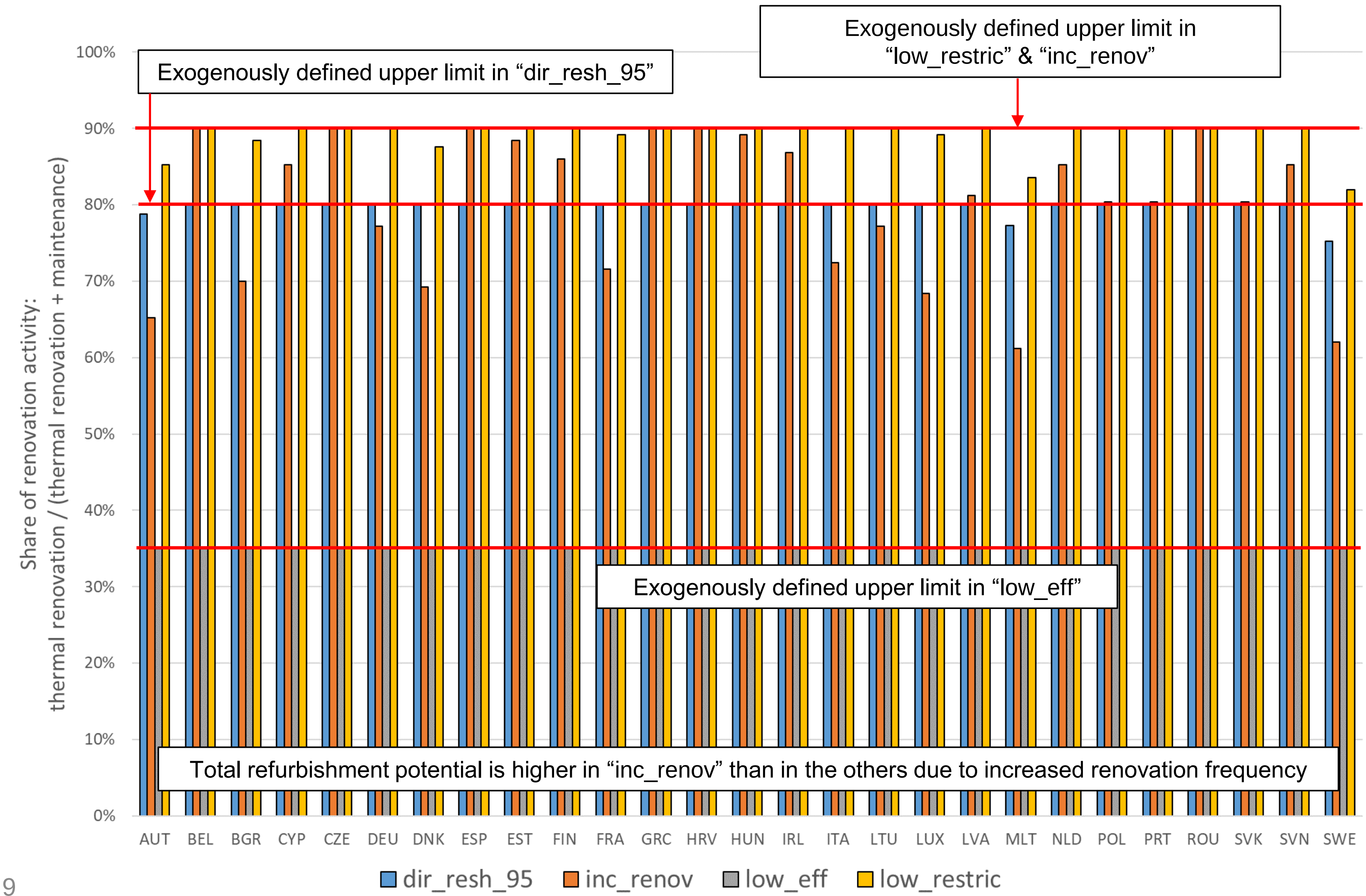
Total system costs – EU27



Final energy demand – EU27



Exploitation of renovation potential



Conclusions and discussion

- In order to reach a 95% reduction in CO_2 emissions in heat supply in the building stocks …
  - … **remarkable energy savings are cost efficient** in the different analysed scenarios and analysed settings (29 – 47% in terms of final energy)
  - … **in many buildings a thermal renovation is cost efficient** compared to a maintenance activity (82 – >90% depending on country)
  - … decreasing the length of refurbishment cycles leads to higher shares of thermal renovation in many countries, not in all; can be interpreted as **high economic renovation potential**

- Discussion and open questions
  - **Sensitivity on** energy carrier **potentials and prices** seems low, but to be checked
  - **Differences between countries** and between cheapest **options** in different building **archetypes** to be further analysed

Thanks for the interest!

Any questions?

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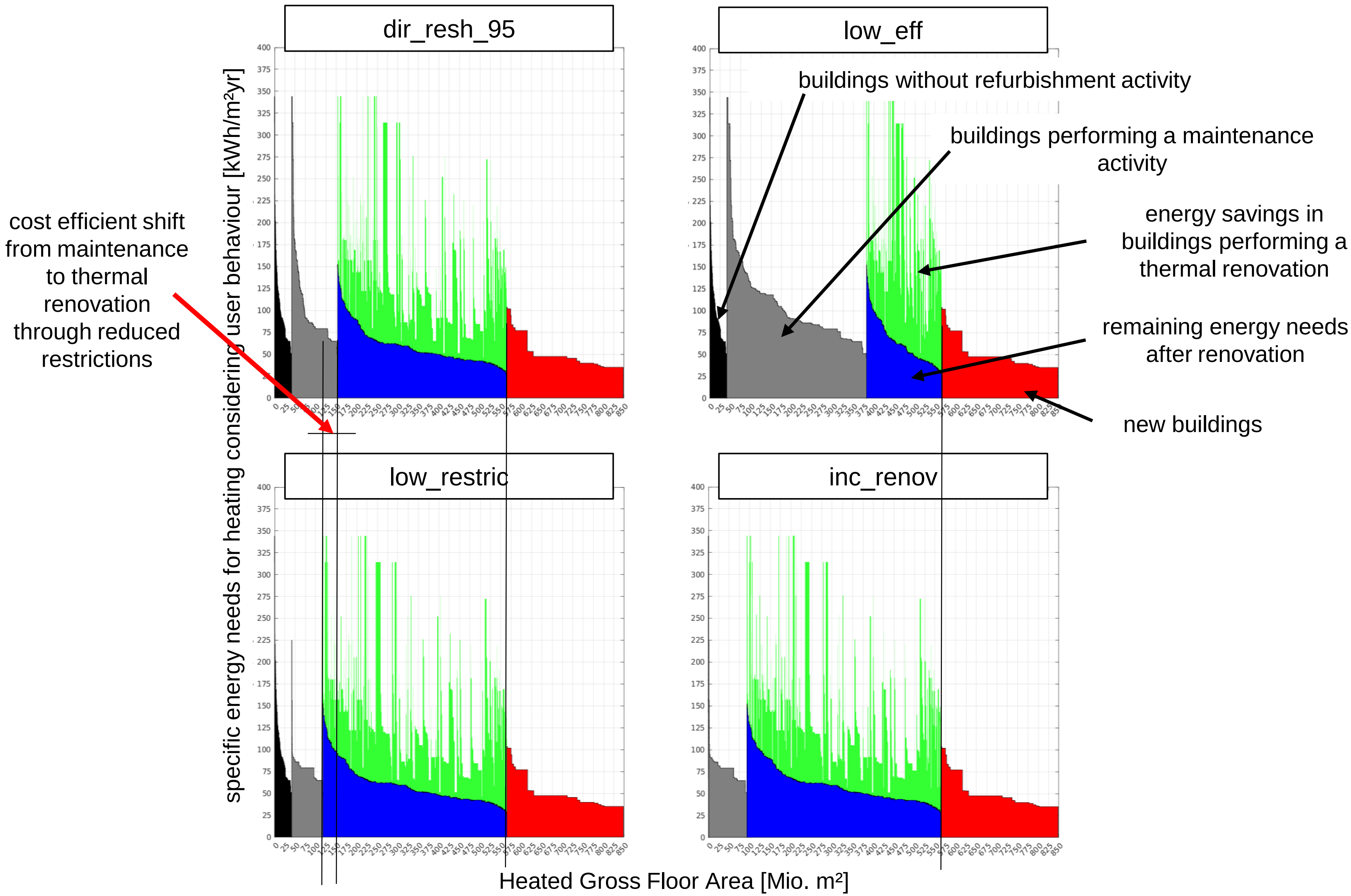
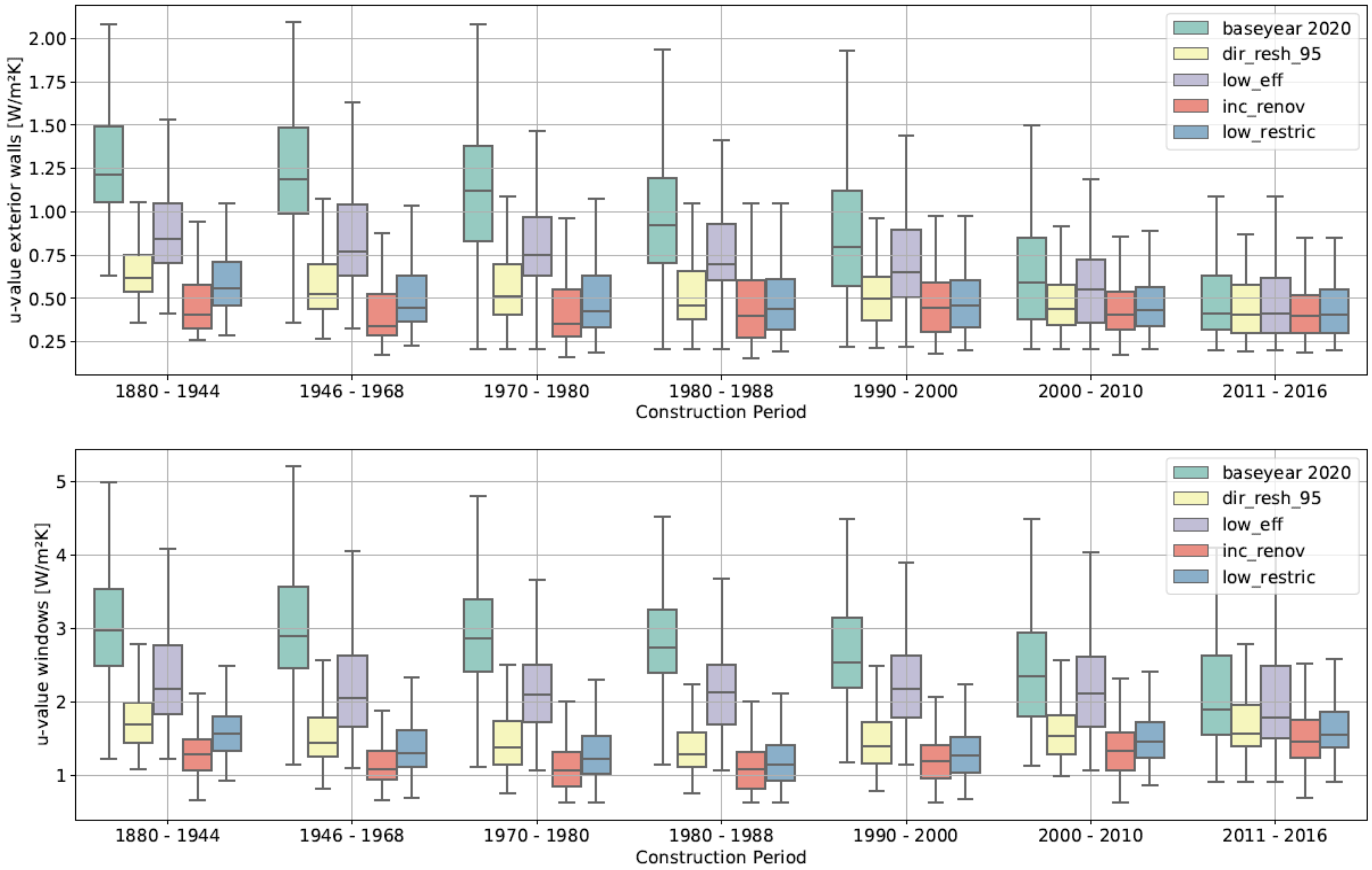
Orig. Photo: Patrick Stargardt

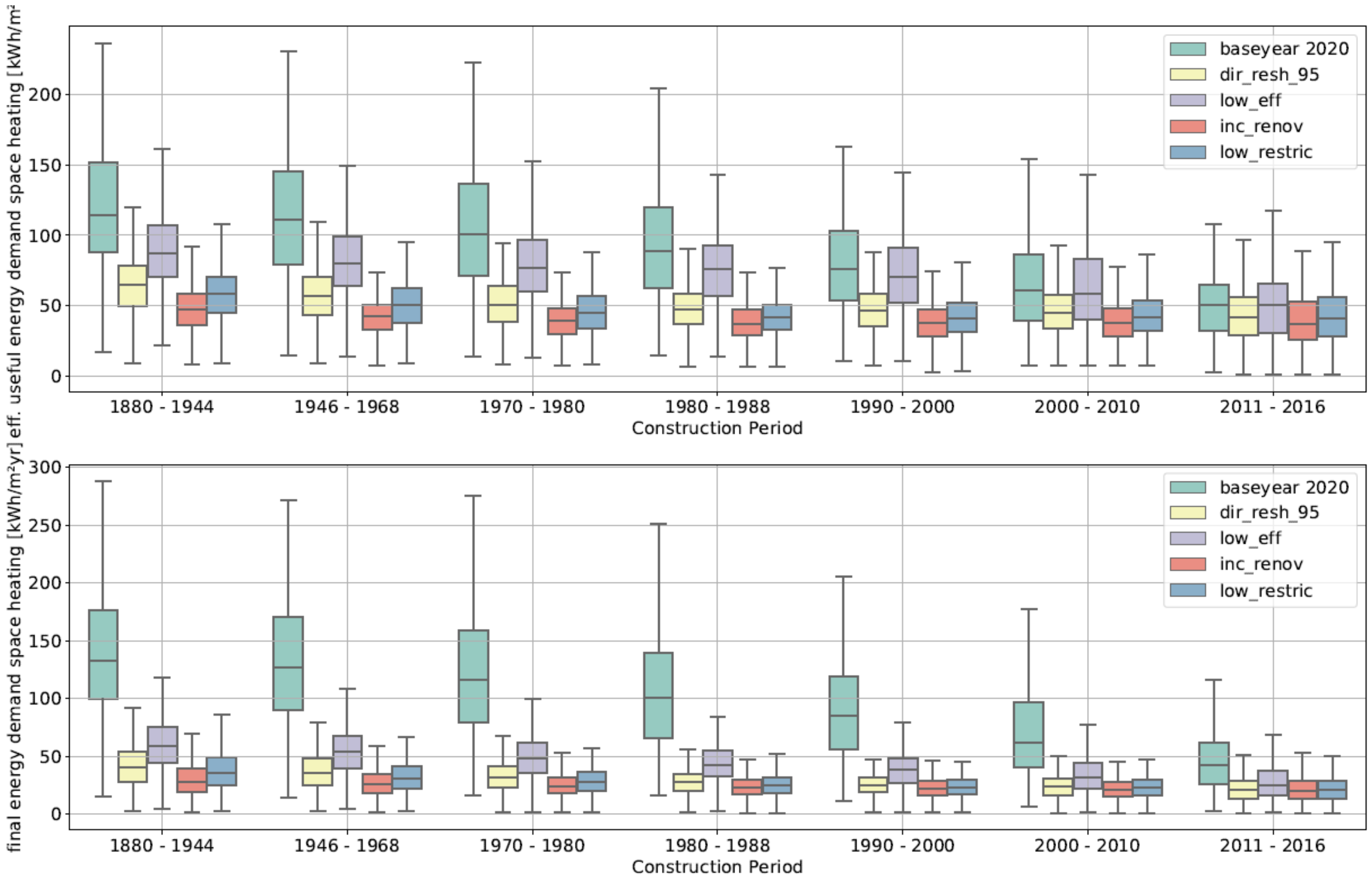
Renovation vs. maintenance – Austria



Change in selected u-values – EU27



Change in energy demand per HFA – EU27



Saturation restrictions for energy carriers

Maximum share of heated floor area, in which different space heating technologies can be applied until 2050: saturation constraints of energy carriers and heating system technologies

	Solar thermal/ PV	Natural Gas	Oil	Coal	Wood log [a]	Wood chips [a]	Pellets [a]	Direct electricity for heating	Heatpump Ground source	Heatpump Air source	District heat
AT	45%	67%	100%	100%	48%	48%	78%	100%	54%	56%	46%
BE	50%	71%	100%	9%	9%	10%	22%	100%	37%	49%	22%
BG	50%	32%	100%	25%	25%	10%	25%	100%	46%	56%	32%
CY	80%	1%	100%	9%	9%	10%	22%	100%	40%	55%	3%
CZ	50%	55%	100%	16%	16%	15%	30%	100%	46%	50%	35%
DE	50%	76%	100%	100%	10%	10%	17%	100%	77%	54%	25%
DK	50%	38%	100%	15%	15%	12%	28%	100%	46%	54%	57%
EE	50%	36%	100%	24%	24%	15%	35%	100%	44%	52%	47%
ES	75%	54%	100%	13%	13%	10%	25%	100%	39%	46%	23%
FI	40%	17%	100%	16%	16%	11%	28%	100%	50%	59%	52%
FR	50%	65%	100%	14%	14%	9%	26%	100%	43%	55%	19%
GR	80%	39%	100%	18%	18%	12%	25%	100%	47%	55%	22%
HR	65%	62%	100%	24%	24%	10%	32%	100%	52%	53%	22%
HU	50%	74%	100%	16%	16%	12%	30%	100%	51%	51%	29%
IE	50%	49%	100%	15%	15%	17%	29%	100%	50%	55%	20%
IT	65%	73%	100%	17%	17%	9%	24%	100%	41%	52%	26%
LT	45%	35%	100%	27%	27%	17%	32%	100%	45%	48%	46%
LU	50%	68%	100%	11%	11%	12%	27%	100%	51%	52%	28%
LV	45%	32%	100%	26%	26%	18%	31%	100%	43%	51%	47%
MT	80%	29%	100%	6%	6%	8%	16%	100%	27%	38%	1%
NL	50%	89%	100%	8%	8%	9%	20%	100%	34%	47%	28%
PL	50%	37%	100%	20%	20%	20%	52%	100%	59%	53%	22%
PT	70%	40%	100%	27%	27%	9%	27%	100%	47%	51%	4%
RO	50%	45%	100%	28%	28%	11%	36%	100%	51%	50%	32%
SE	50%	18%	100%	17%	17%	10%	27%	100%	48%	74%	69%
SK	50%	68%	100%	12%	12%	13%	27%	100%	51%	51%	46%
SI	50%	45%	100%	26%	26%	11%	31%	100%	54%	53%	23%

(a) **For biomass heating systems, the model considers an additional total biomass potential restriction allocated to decentral heating systems.**

Diffusion restrictions for energy carriers

	Direct RES-H
Solar thermal	≤100%
Gas (natural gas, biogas, H2, e-gas)	≤50%
Oil (heating oil, bio oil, e-liquids)	≤25%
Wood log [(a)]	≤100%
Wood chips [(a)]	≤100%
Pellets [(a)]	≤100%
Electricity (pumps and direct electric heating	≤50%
District heat	<50%
Gas Heatpump	≤50%
Gas micro-CHP	≤50%

Decentral biomass resource restrictions

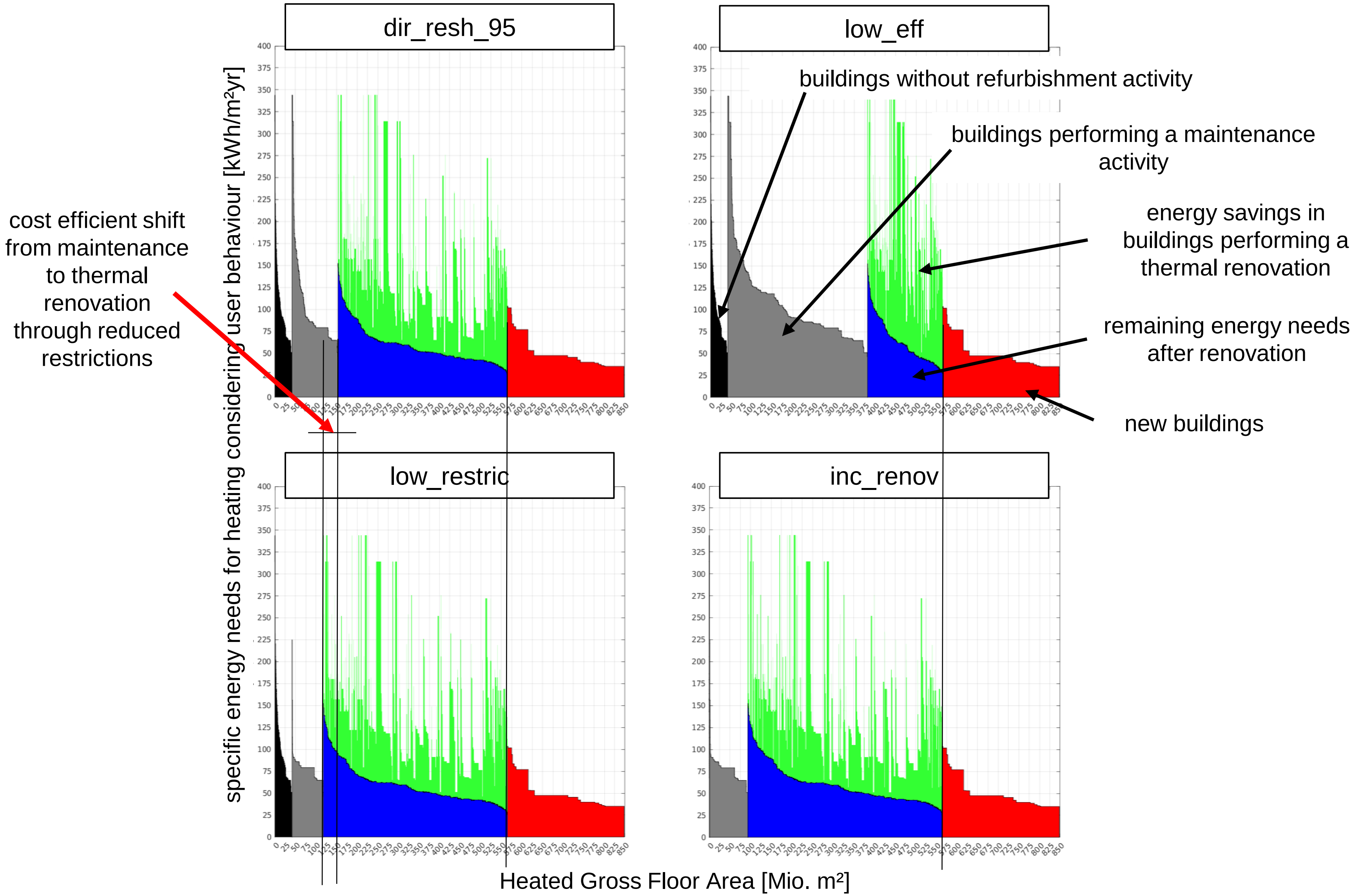
Resource restriction for the decentral biomass utilization

	Decentral biomass utilization [TWh]	Share of decentral biomass on final energy demand for space heating and domestic hot water preparation	Decentral biomass resource potential (= full resource potential) [TWh]	Decentral biomass potential on final energy demand for space heating and domestic hot water assuming a decreasing in related final energy demand of 50%	Ratio of biomass resource potential 2050 on biomass utilization in base year	Biogas resource potential for use in the space heating and hot water sector [TWh]	Bi re pc fo th he ar w se [T
	Base year		2050				
AT	20.8	25%	13.8	33%	66%	1.6	
BE	7.1	6%	12.3	21%	172%	1.1	
BG	8.8	38%	3.8	33%	43%	1.1	
CY	0.2	5%	0.5	20%	216%	0.0	
CZ	21.0	22%	16.1	33%	77%	1.6	
DE	85.8	12%	97.1	27%	113%	11.0	
DK	10.8	18%	9.9	33%	91%	1.0	
EE	4.5	35%	2.1	33%	47%	0.5	
ES	30.7	19%	26.5	33%	86%	6.0	
FI	13.5	18%	12.5	33%	92%	1.5	
FR	81.6	15%	82.6	30%	101%	13.8	
GR	9.5	18%	8.7	33%	91%	1.5	
HR	12.5	45%	4.6	33%	37%	1.3	
HU	20.0	24%	13.9	33%	70%	2.7	
IE	0.5	2%	2.7	17%	503%	0.8	
IT	76.8	19%	67.2	33%	87%	7.4	
LT	5.6	33%	2.9	33%	51%	0.8	
LU	0.3	3%	0.8	18%	302%	0.0	
LV	6.0	39%	2.6	33%	43%	0.7	
MT	0.0	2%	0.1	17%	519%	0.0	
NL	5.2	3%	14.7	18%	282%	1.9	
PL	31.7	13%	34.7	28%	109%	4.6	
PT	8.8	29%	5.0	33%	57%	0.9	
RO	34.2	42%	13.6	33%	40%	3.9	
SE	11.4	11%	13.6	26%	120%	1.7	
SI	5.2	39%	2.2	33%	42%	0.3	
SK	0.5	1%	3.3	16%	610%	1.1	
EU-27	**513**	**16%**	**468**	**29%**	**91%**	**69**	

Key assumptions on energy carrier prices

Energy Carrier	Assumptions on prices and CO_2 factor
Gas	Composition: 2% natural gas, 10% methane, 10% hydrogen, rest biogas EU average of national wholesale prices for biogas around 70 EUR/MWh (Nuffel et al., 2020: Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure), for methane around 93 EUR/MWh (from modelling with Enertile) and for hyrogen around 55 EUR/MWh (also from Enertile) Grid charge is increasing with decreasing gas consumption
Fuel oil	Composition: 5% fossil heating oil, 85% bio liquids, 10% e-liquids EU average of national wholesale prices for bio liquids around 87 EUR/MWh (+25% compared to biogas) and for e-liquids around 103 EUR/MWh (+10% compared to e-gases)
Biomass	Are assumed to remain constant
Electricity	Nearly full decarbonisation of supply infrastructure Modelling of wholesale prices at national level with the Enertile model EU average of national wholesale prices around 55 EUR/MWh in 2050
District heating	Nearly full decarbonisation of supply infrastructure Modelling of future wholesale prices at national level with the Enertile model Current wholesale prices according to literature Difference between current and future wholesale prices based on difference in modelled supply costs

Renovation vs. maintenance – Austria



Final energy demand – EU27