INDUSTRY – MORE THAN JUST PROCESSES: A COMBINED STOCK-MODEL APPROACH TO QUANTIFY THE ENERGY SAVING POTENTIAL FOR SPACE HEATING IN EUROPEAN INDUSTRY

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Fraunhofer ISI

Agenda

I. Motivation & Objective

II. Methodology

III. Results

IV. Conclusion

Motivation & Objective

Motivation & Objective

- Space heating accounts for around 10% of the industrial final energy demand in Europe ~1.500PJ – more than some energy-intensive sectors
  - But studies mostly focus on residential & tertiary sector
- It can be considered as „cross-cutting-technology“ in a heterogeneous sector as the industry
- Potential for fuel switch & entry of new technologies (e.g. heat pumps, solar thermal, biomass etc.)

- **Quantify the space heating saving potential** in the European industry until 2030 by taking into account the dynamics and restrictions of the existing building stock
- **Improve the understanding** of the underlying dynamics

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Major challenges determine model choice

Major Challenges

- **Detailed technology modelling** required to make statements about technology dynamics
- The **age structure** determines the efficiency and thereby the final energy use
- The **heterogeneity** of industry and the lack of available data
- Endogenous simulation of the the **technology choice** of companies investing in new heating systems

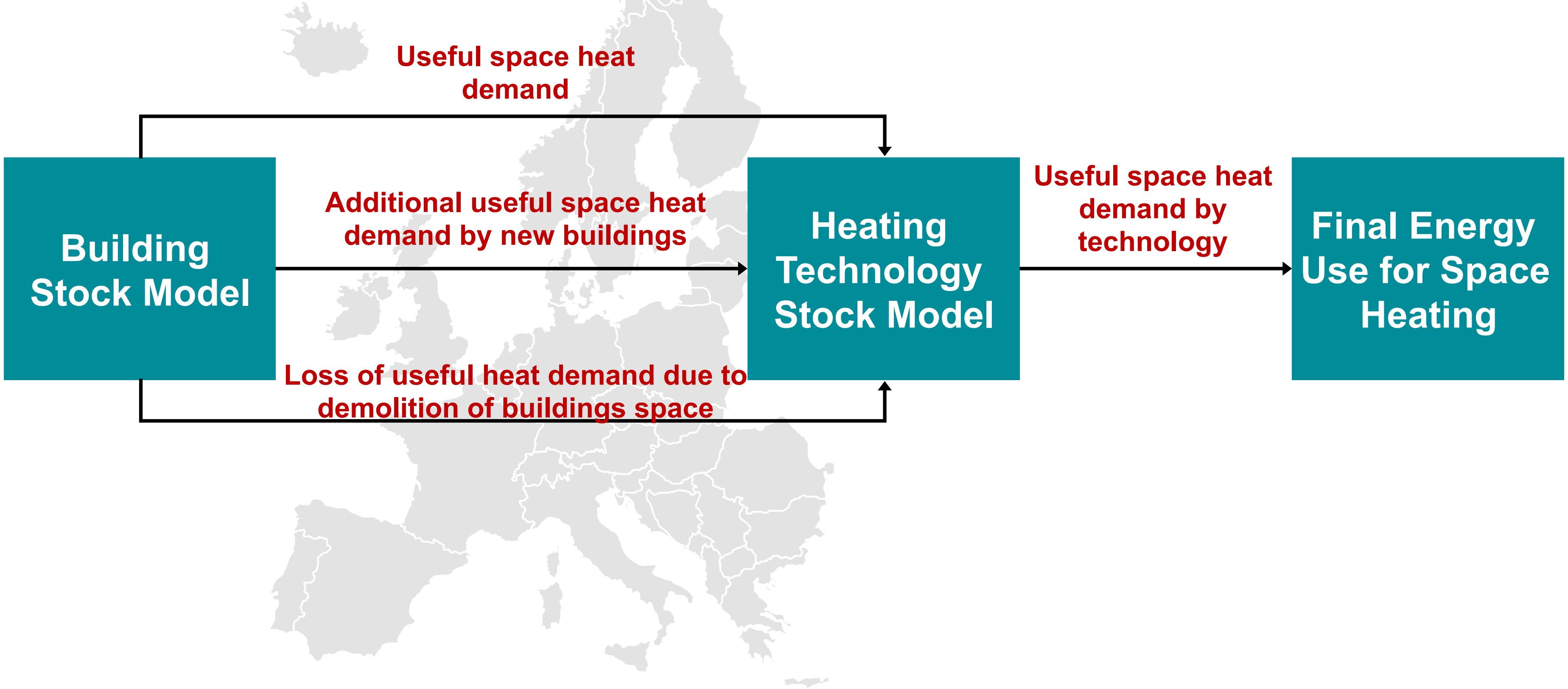
→

- **Bottom-up model** to allow different technologies
- **Stock model** to distinct between individual „vintages“
- **Distribution functions** to cover heterogeneity and to overcome lack of data
- **Myopical cost-based logit approach & path-dependent approach** to model technology choice

By combining two stock models final energy use for space heating is determined

Interaction between building and heating stock model

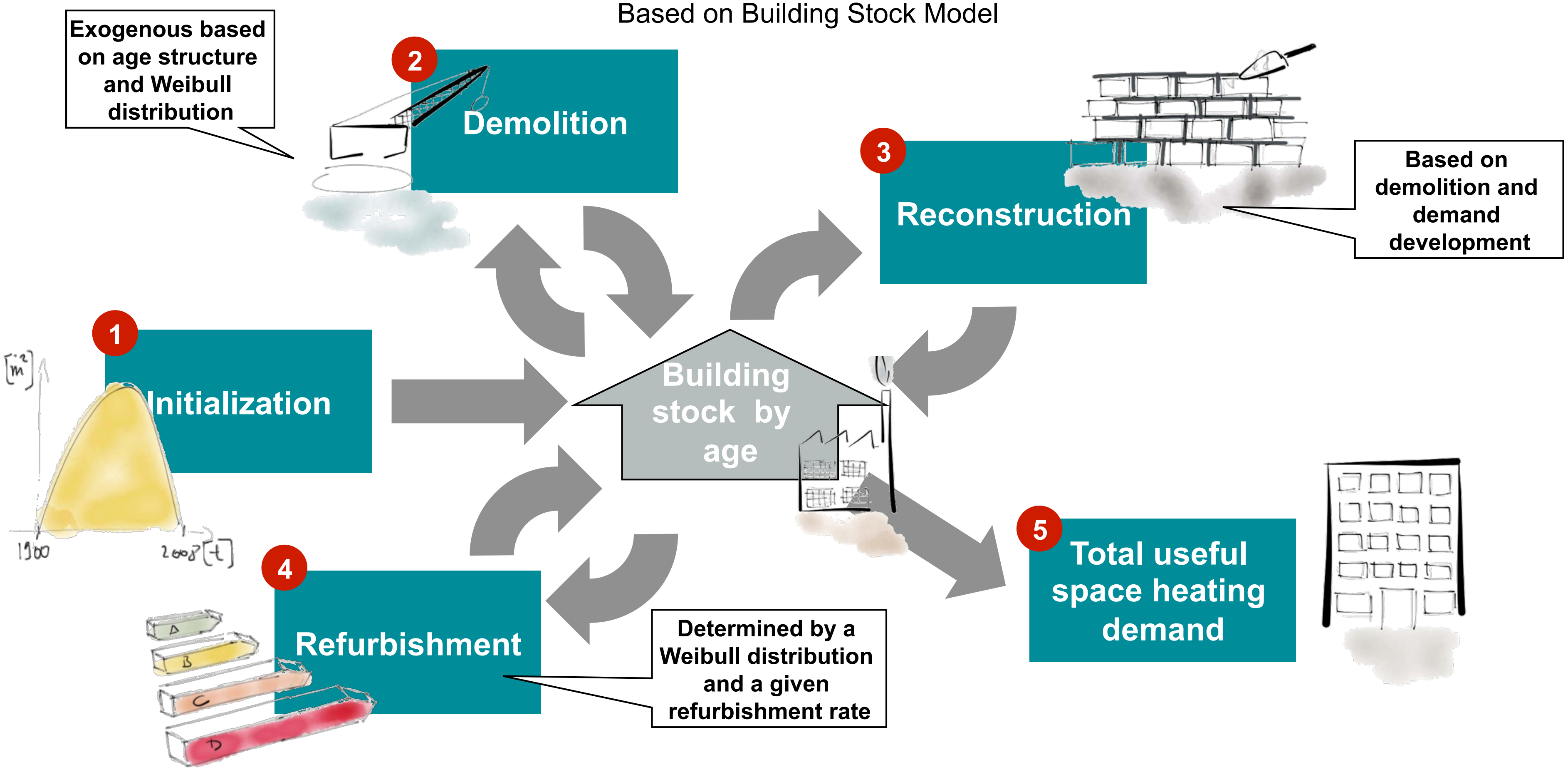
ISI-Industry Forecast 4



Conceptual approach to derive total useful space heating demand

Calculation of Total Useful Space Heating Demand

Based on Building Stock Model



1 Initialization

2 Demolition

3 Reconstruction

4 Refurbishment

5 Total useful space heating demand

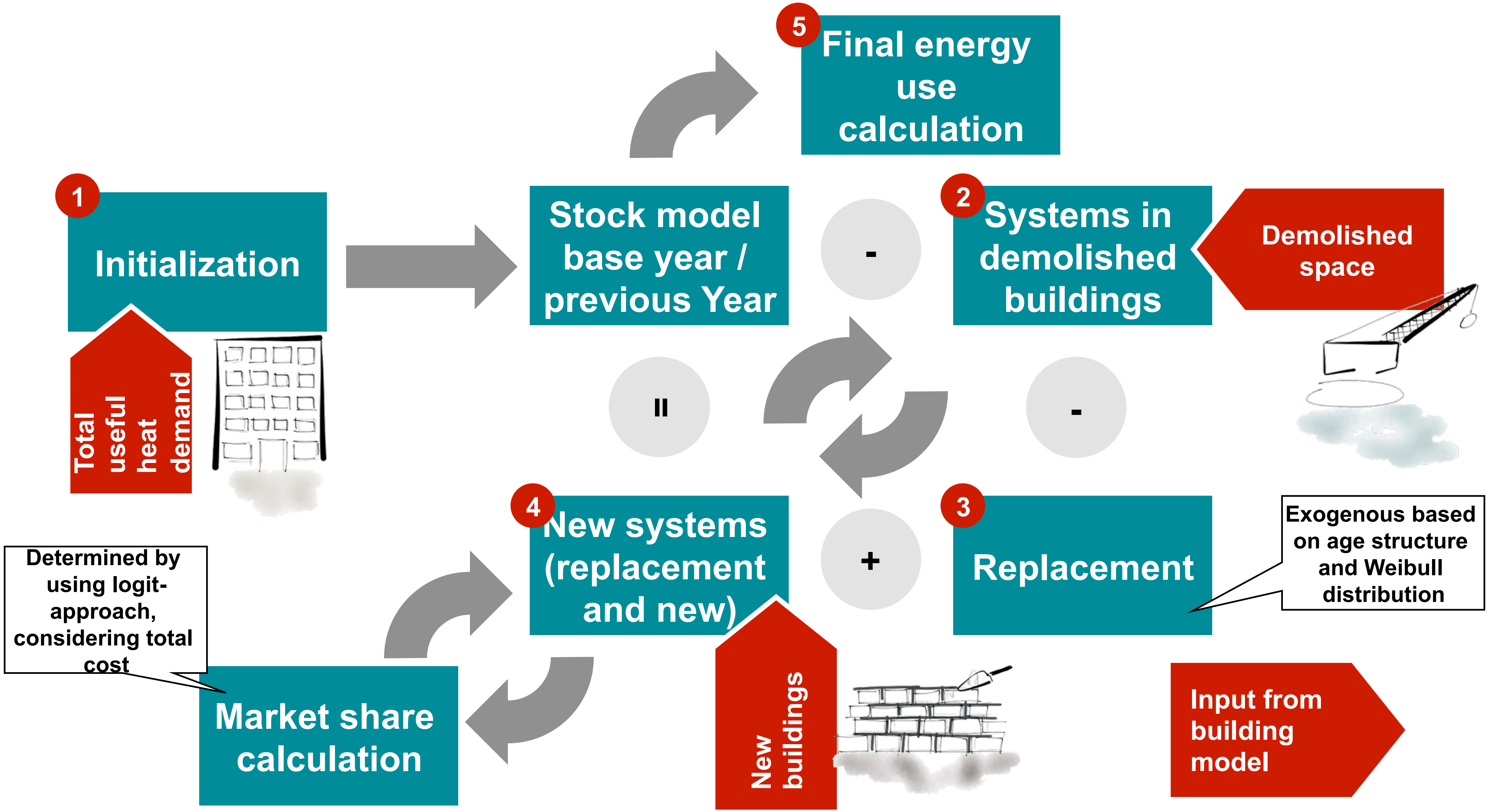
Building stock by age

Exogenous based on age structure and Weibull distribution

Based on demolition and demand development

Determined by a Weibull distribution and a given refurbishment rate

Conceptual approach to derive end energy demand based on a heating stock model



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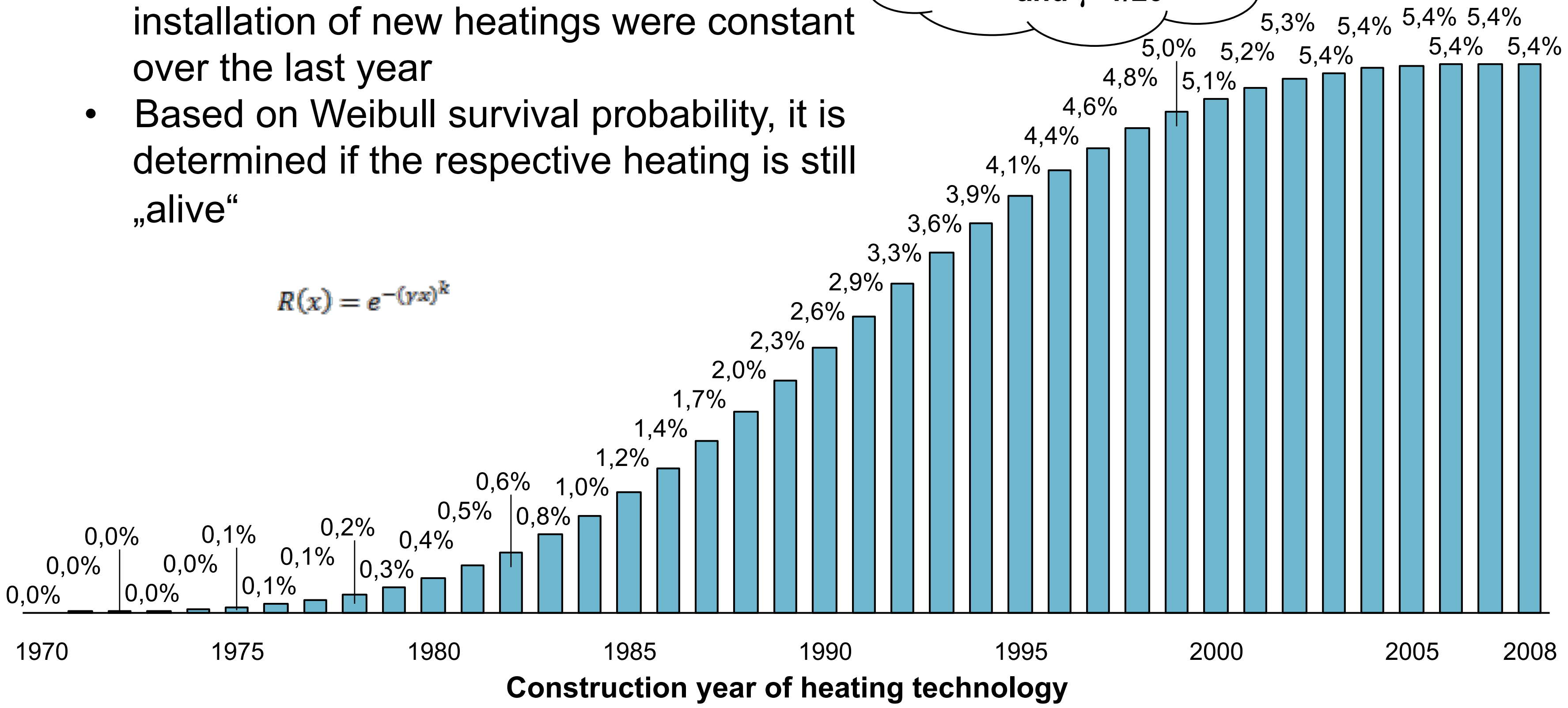
Initialization heating stock model

Weibull-survival probability determines age structure

I.

- As start solution, it is assumed, that installation of new heatings were constant over the last year
- Based on Weibull survival probability, it is determined if the respective heating is still „alive“

$$R(x) = e^{-(\gamma x)^k}$$



Illustrative heating stock model for k= 3, and γ=1/20

4

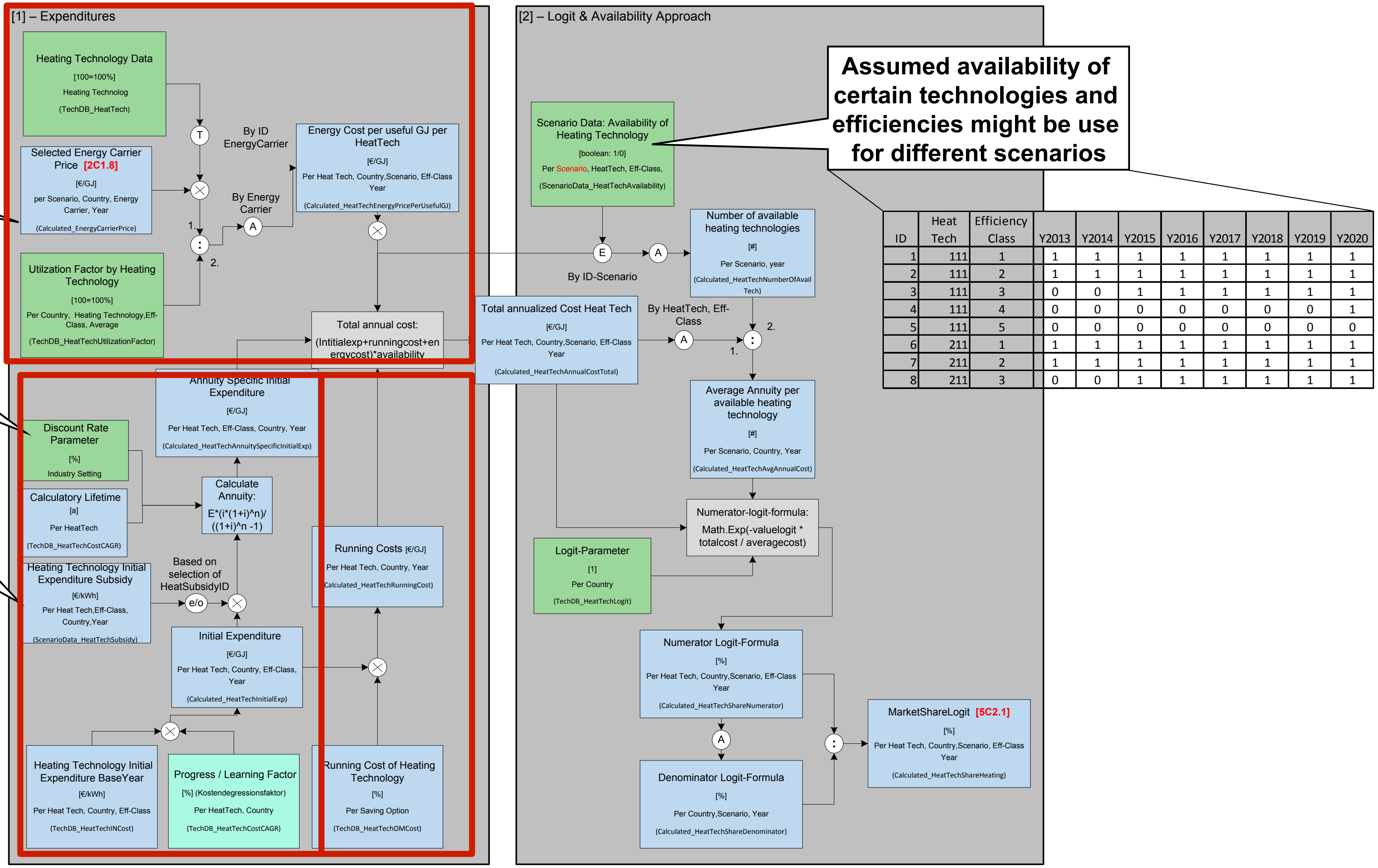
New heatings from replacement and new building

Logit-approach considering all cost is used to receive the new market share

Scenario-specific energy carrier prices are included

Discount rate influences annuity

Subsidies can be considered for certain scenarios



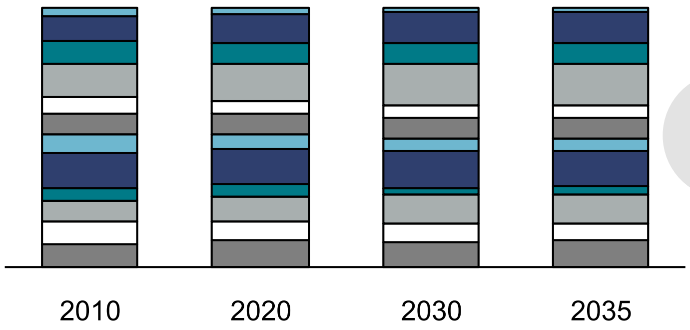
Assumed availability of certain technologies and efficiencies might be use for different scenarios

ID	Heat Tech	Efficiency Class	Y2013	Y2014	Y2015	Y2016	Y2017	Y2018	Y2019	Y2020
1	111	1	1	1	1	1	1	1	1	1
2	111	2	1	1	1	1	1	1	1	1
3	111	3	0	0	1	1	1	1	1	1
4	111	4	0	0	0	0	0	0	0	1
5	111	5	0	0	0	0	0	0	0	0
6	211	1	1	1	1	1	1	1	1	1
7	211	2	1	1	1	1	1	1	1	1
8	211	3	0	0	1	1	1	1	1	1

4 **New heatings from replacement and new building**

Technology share is gained by weighting logit-approach and replaced heatings

Technology share based on logit-approach



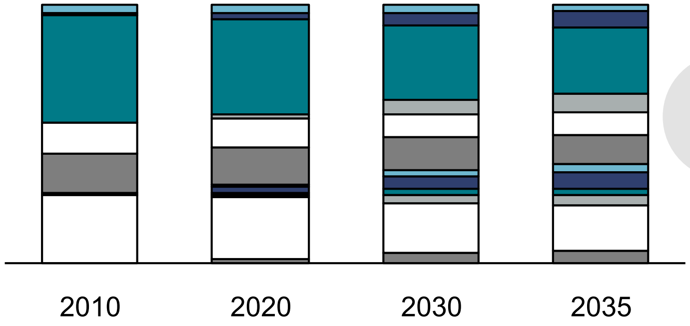
x

Different weighting parameter for different scenarios

α

+

Technology share based on exchanged heatings

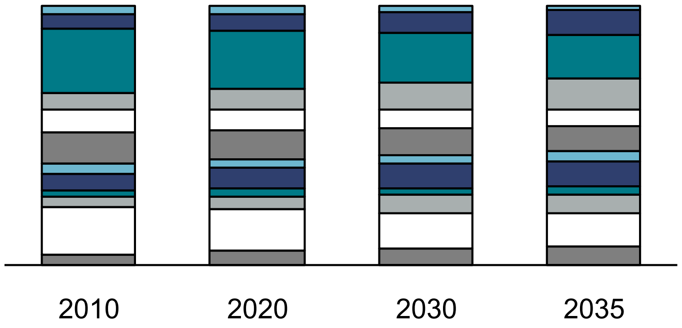


x

$(1-\alpha)$

Illustrative for weigthing parameter 0.5

Resulting new share based on weighting



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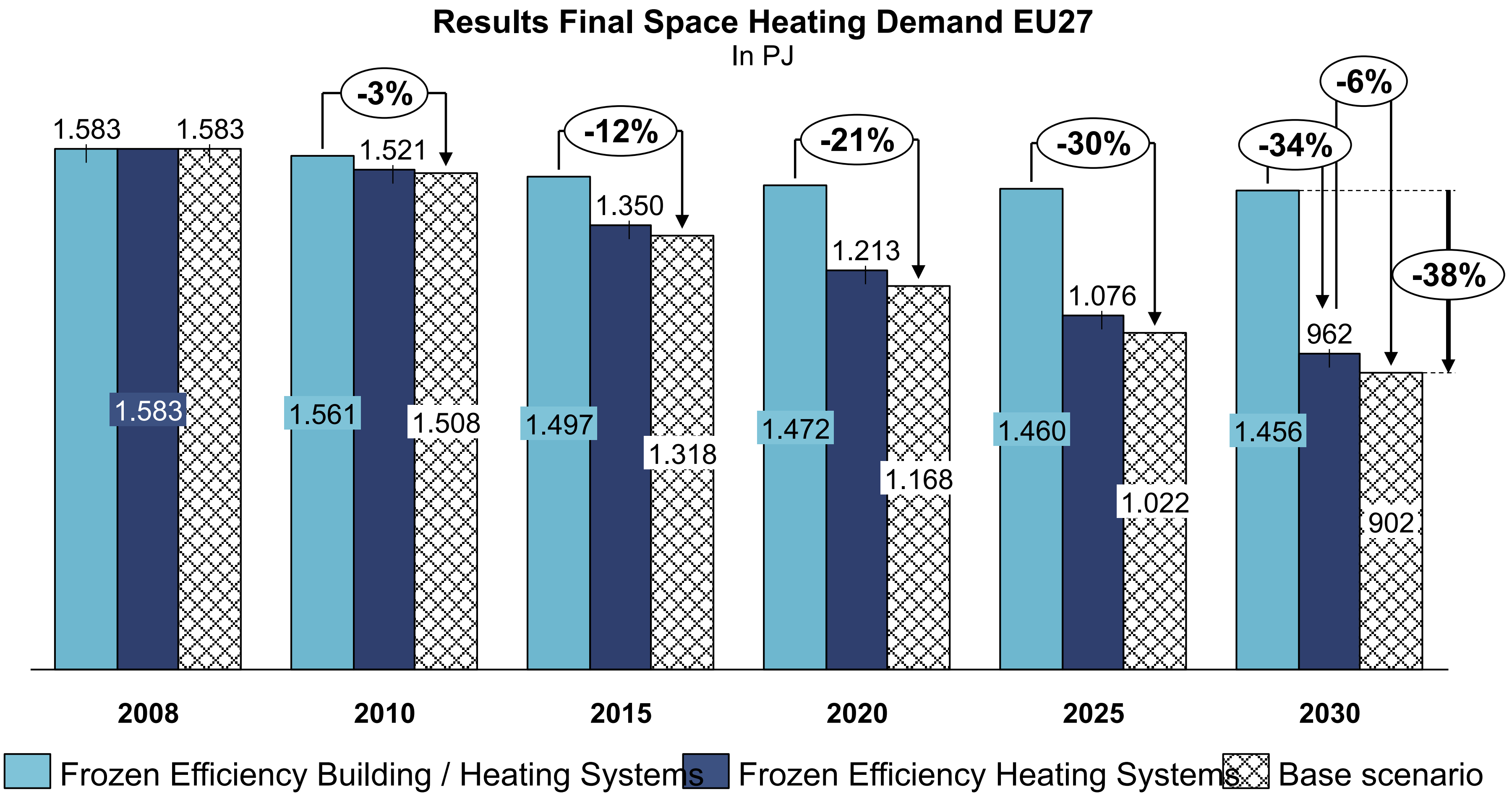
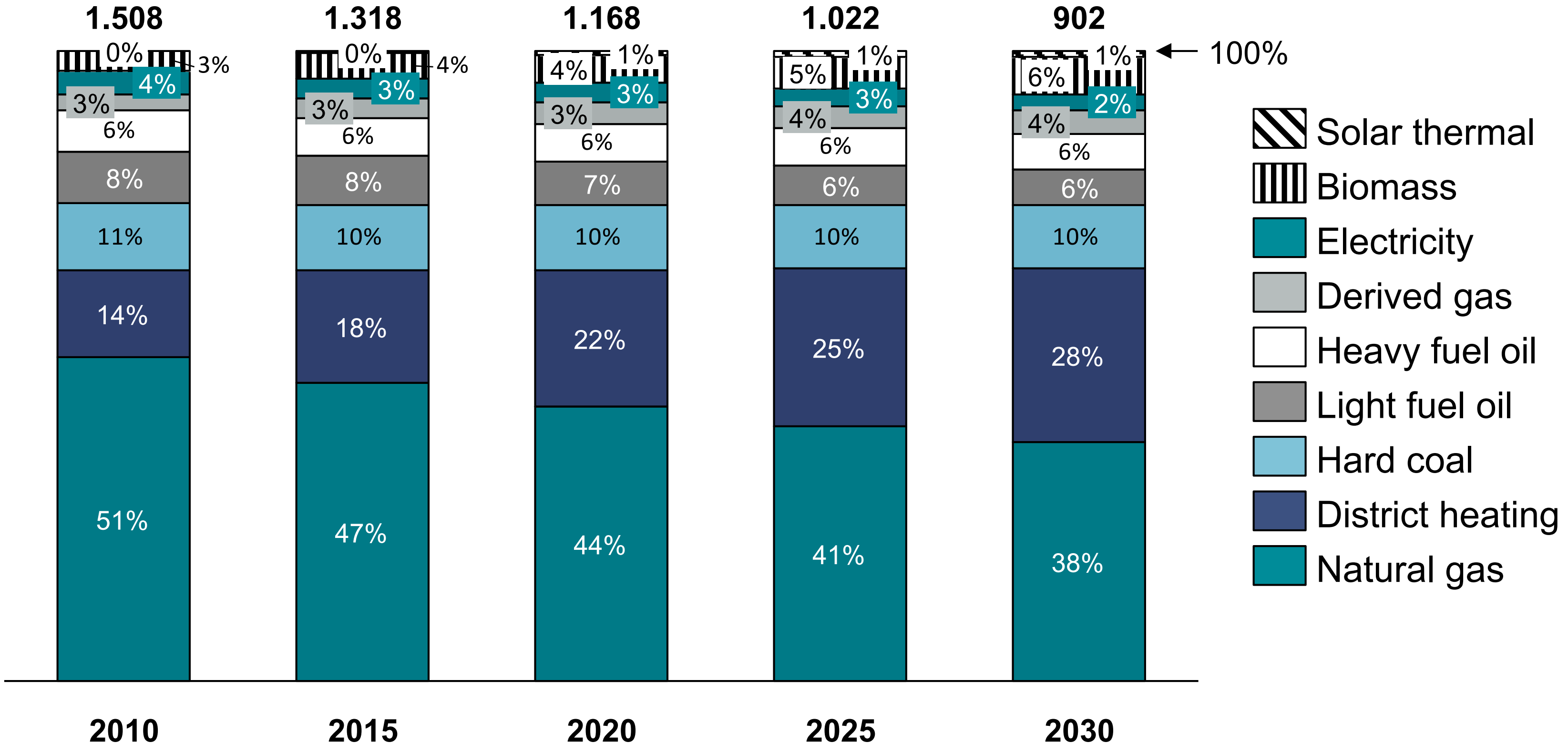
Final Space Heating Demand can be reduced by 38% accounting for ~550 PJ



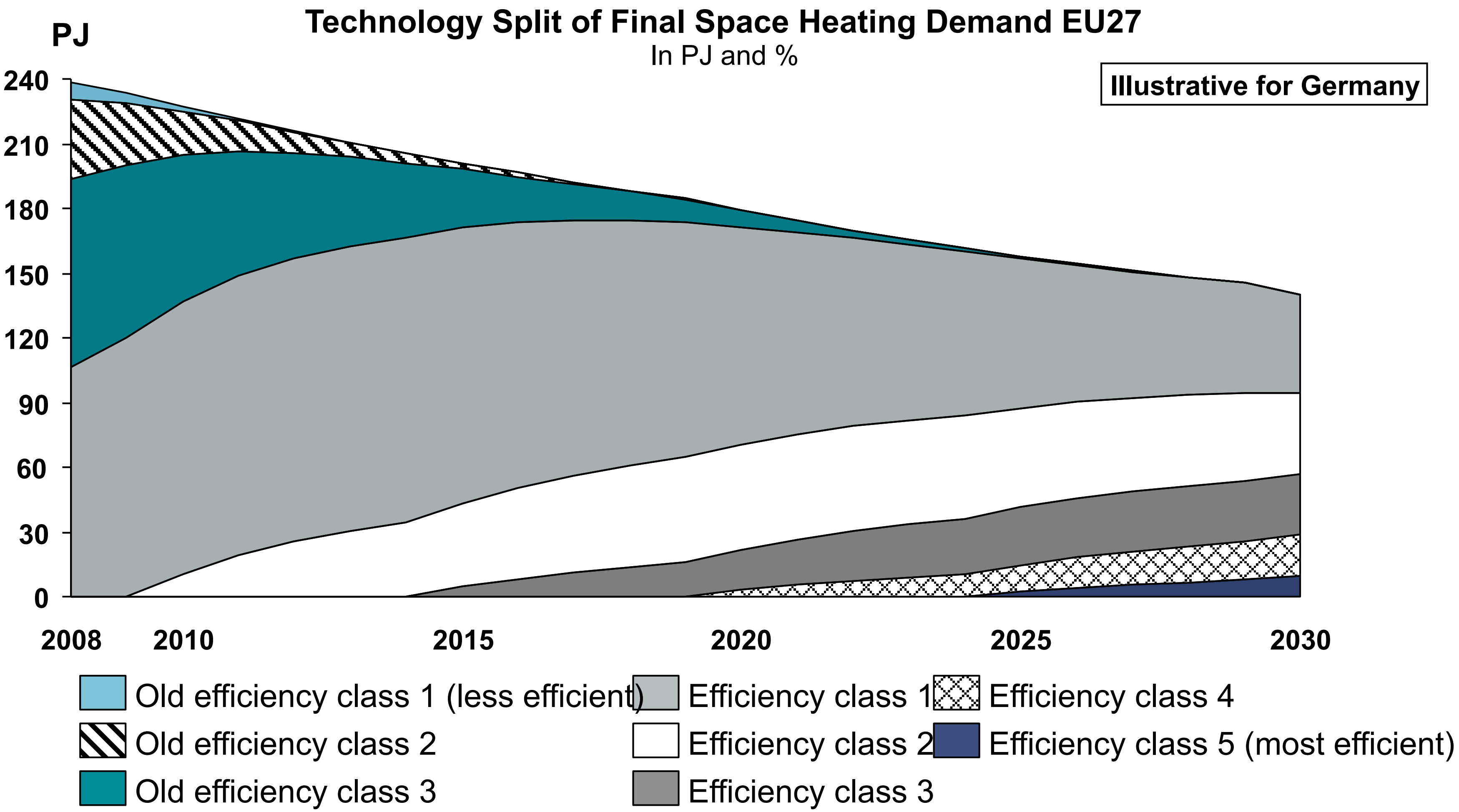
Under this scenario, biomass and solar thermals remain a niche technology

Technology Split of Final Space Heating Demand EU27

In PJ and %



Model allows detailed analysis of results

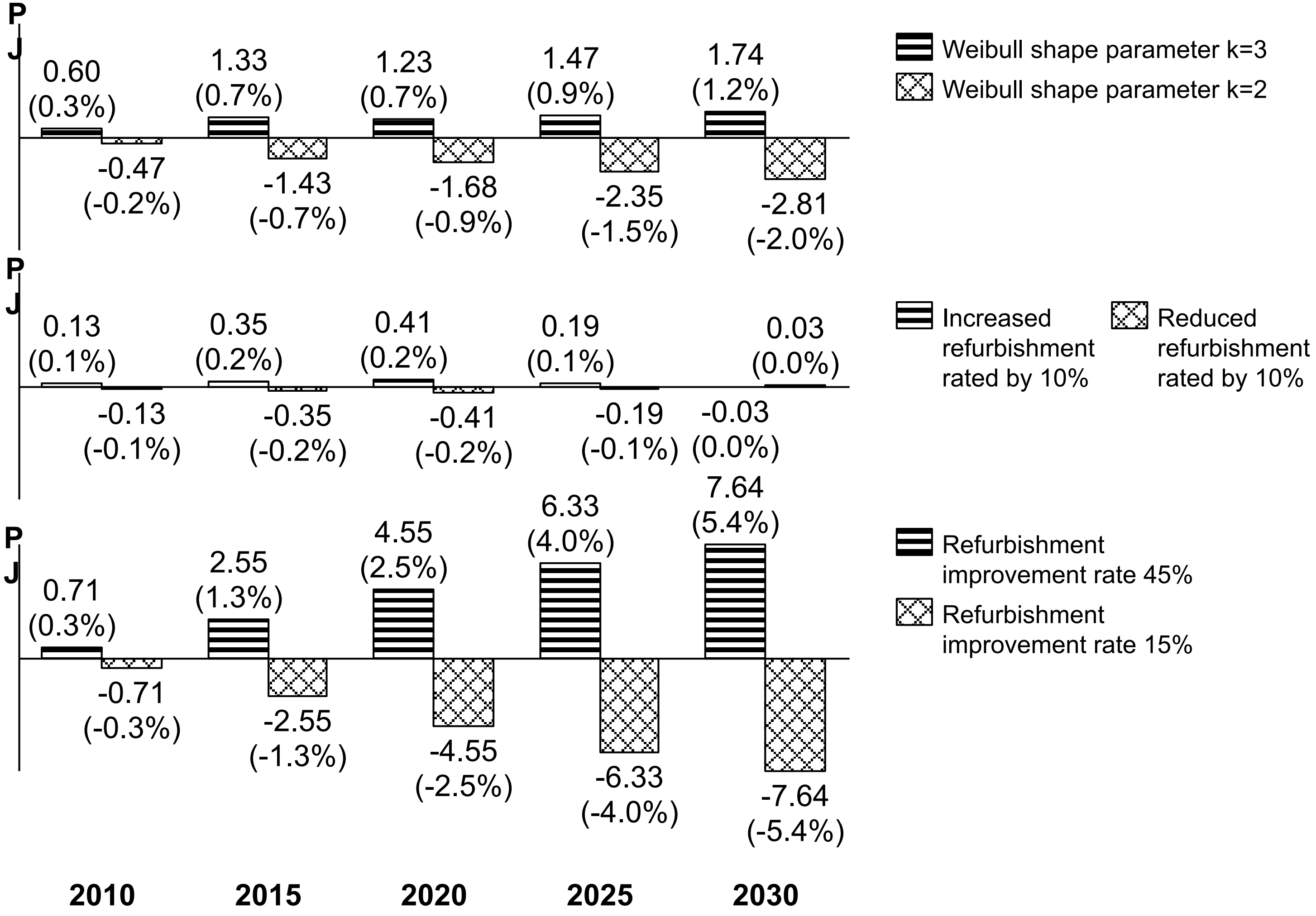


Sensitivity analysis: Building Stock

Weibull shape parameter k to endogenously determine demolition

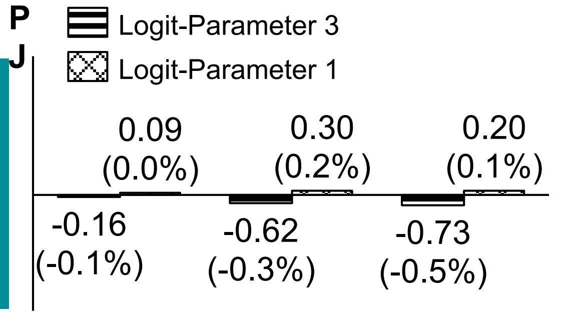
Refurbishment rate

Quality of refurbishment

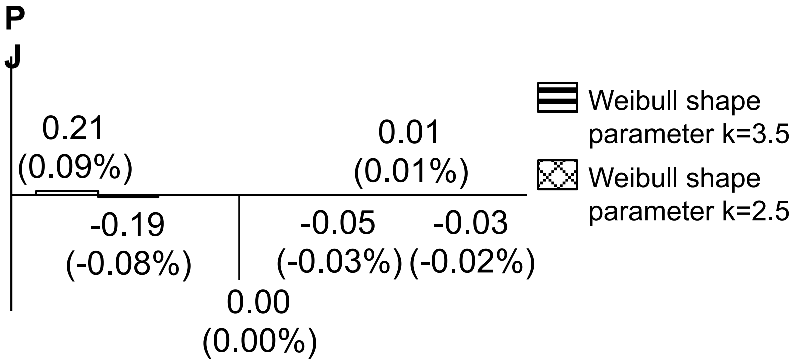


Sensitivity analysis: Heating Stock

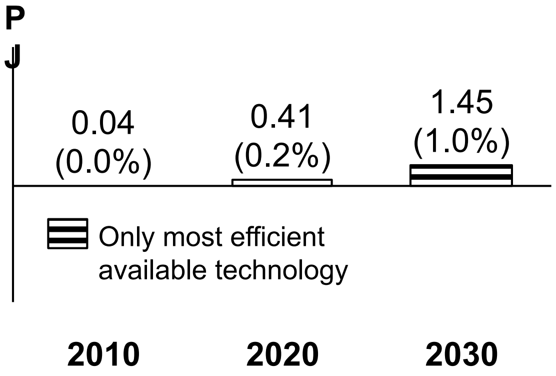
Logit-Parameter (driving cost-sensitivity)



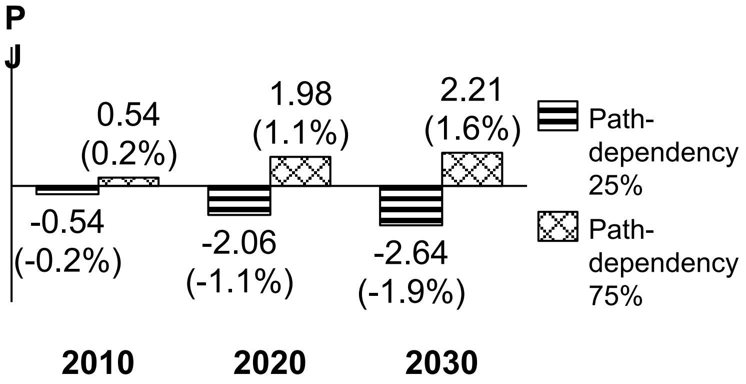
Weibull shape k-parameter (Demolition)



Minimum requirements



Weigting Factor (to reflect Path-dependency)



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Conclusion

- Substantial energy saving potential in the industry building sector – under this scenario assuming a strict EPBD – around 490 PJ are predicted till 2030
- Further 60 PJ can be saved by more efficient heating technologies
- Sensitivity analysis show that policy measures such as specificing the minimum efficiency for heating technologies or minimum refurbishment quality can further increase the saving potential
- As saving potential proved to be significant, further improvement of data availability might be worthwhile

APPENDIX

Assumptions (1/4)

Variable	Assumption & Explanation	Source:
Employees	by branch, kept constant after 2011	Eurostat
Sqm per employee	Use for calibration to meet demand in base year	Derived from diverse studies and calibrated for every country based on Eurostat and base year energyconsumption and kept constant
Employment split	Split between white & blue collar worker	Derived from internal numbers (Fraunhofer ISI)
Hot water consumption	6.4 kWh/sqm	Müller & Biermayr(2011)
Refurbishment rate	between 0.5% & 1.5% in 2008, increasing to 0.9% to 1.65% till 2020 to reflect efforts due to EPBD	assumption
Refurbishment improvemnt α	30%	Antanaius et al. (2013)
Market share heating technology (base year)	Derived from energy carrier split	based on Eurostat(2006) energy carrier split for space heating industry
Discount rate heating system i	35%	Rivers & Jaccard (2006)
Depreciation time n	analogue to lifetime	assumption
Full load hours	2000	For Germany (Blesl 2009), other derived based on heating degree days (Eurostat) and EHI factor (Werner 2006)
Logit value	2	Assumption
Weighting factor	50%	Based on Henkel (2011)
Heating degree days		Entranze, country-specific
Calibration heating technology		Eurostat, country-specific

Assumptions (2/4)

Process Step	Parameter	Offices	Production	Source
Intialization / Demolition	liftetime of buildings	60	40	assumption, all countries
Intialization / Demolition	Weibull *k* -shaping parameter	2.5	2.5	assumption, all countries
Refurbishment	T= 1/γ (already classified)	10	10	assumption, all countries
Refurbishment	Weibull k-shaping parameter	2	2	assumption, all countries

Building Age Class	Unit	Production	Offices
before	kwh/sqm*a	243	260
1950-1959	kwh/sqm*a	243	270
1960-1969	kwh/sqm*a	243	240
1970-1979	kwh/sqm*a	243	180
1980-1989	kwh/sqm*a	213	140
1990-1999	kwh/sqm*a	151	120
2000-2009	kwh/sqm*a	90	100
2010-1019	kwh/sqm*a	29	55
2020-2029	kwh/sqm*a	21	55
2030-2039	kwh/sqm*a	21	20

Assumptions (3/4)

Heating Technology	Investment Cost 2008 in EUR/kW	Running Cost in % of Invest	CAGR Investment Cost	Utilization Rate
Coal / Lignite boiler	166	3.5%	0.0%	83.7%
Gas boiler	200	2.5%	0.0%	96.5%
Oil boiler	320	4.5%	0.0%	94.2%
Solar thermal combined with gas	252	3.5%	-1.0%	97.0%
Solar thermal combined with electricity	252	2.5%	-1.0%	98.3%
Biomass boiler	440	4.5%	-0.5%	90.2%
Electricity Heat Pump	1000	3.5%	-1.0%	354.8%
Gas-fueled Heat Pump	1100	3.5%	-0.5%	325.0%
District Heating	151	3.5%	-0.5%	97.7%

Process Step	Parameter	Offices	Production	Source
Initialization	Weibull *k* -shaping parameter	3	3	assumption, all countries
Replacement	Weibull *k* -shaping parameter	3	3	assumption, all countries
Replacement	Lifetime *n* heating in years	20	25	assumption, all countries

Assumptions (4/4)