Aalto University
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Cost-optimal energy retrofitting of apartment buildings

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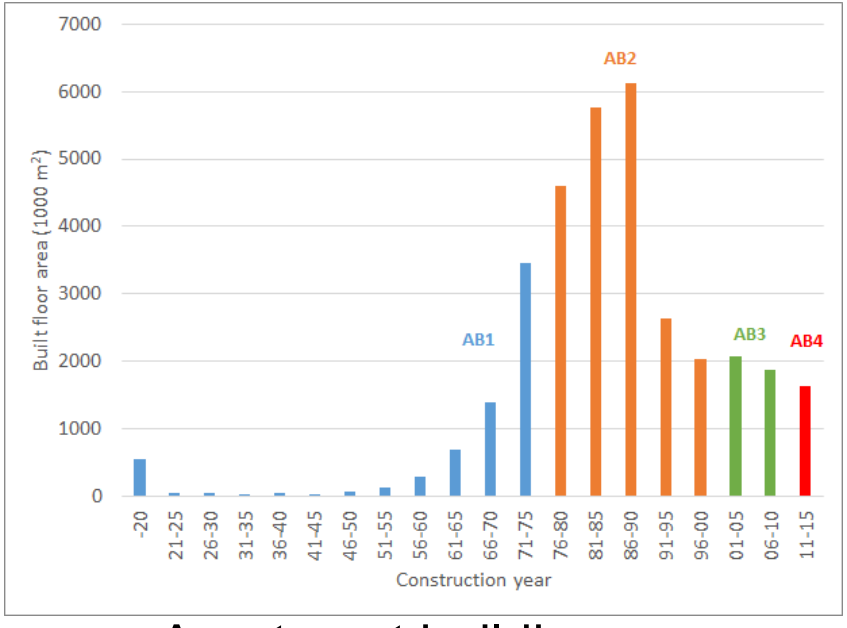
Background

- **EU targets: significant emissions reductions needed**
  - -40% by 2030
  - -80% by 2050
- **Energy Performance of Buildings Directive (EPBD)**
  - nZEB requirements
- **Most buildings have been built in the 1970s and 1980s**

→ Energy renovation



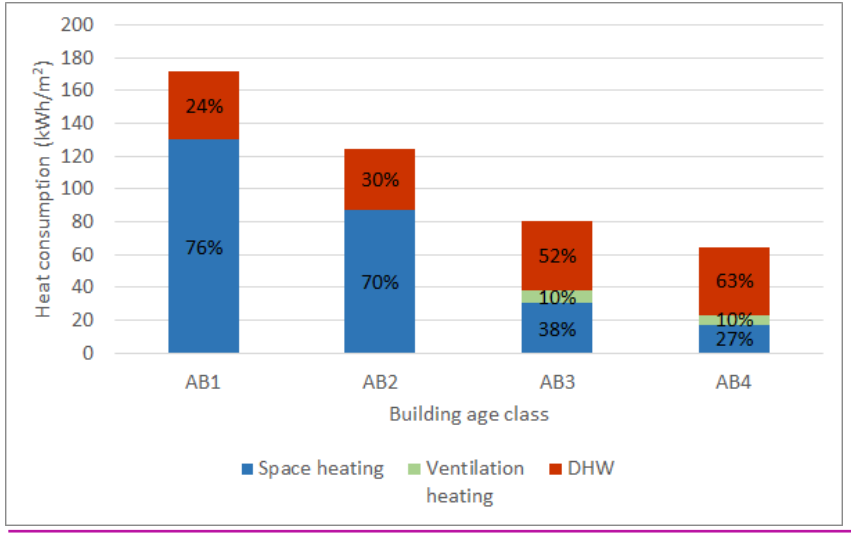
Apartment building ages

Research questions

- **How much can emissions be reduced in Finnish apartment buildings by doing energy renovation?**
- **What are the cost-optimal and maximum performance solutions?**
  - Thermal insulation, heat recovery, solar energy, windows?
- **How do the solutions differ with respect to building age?**

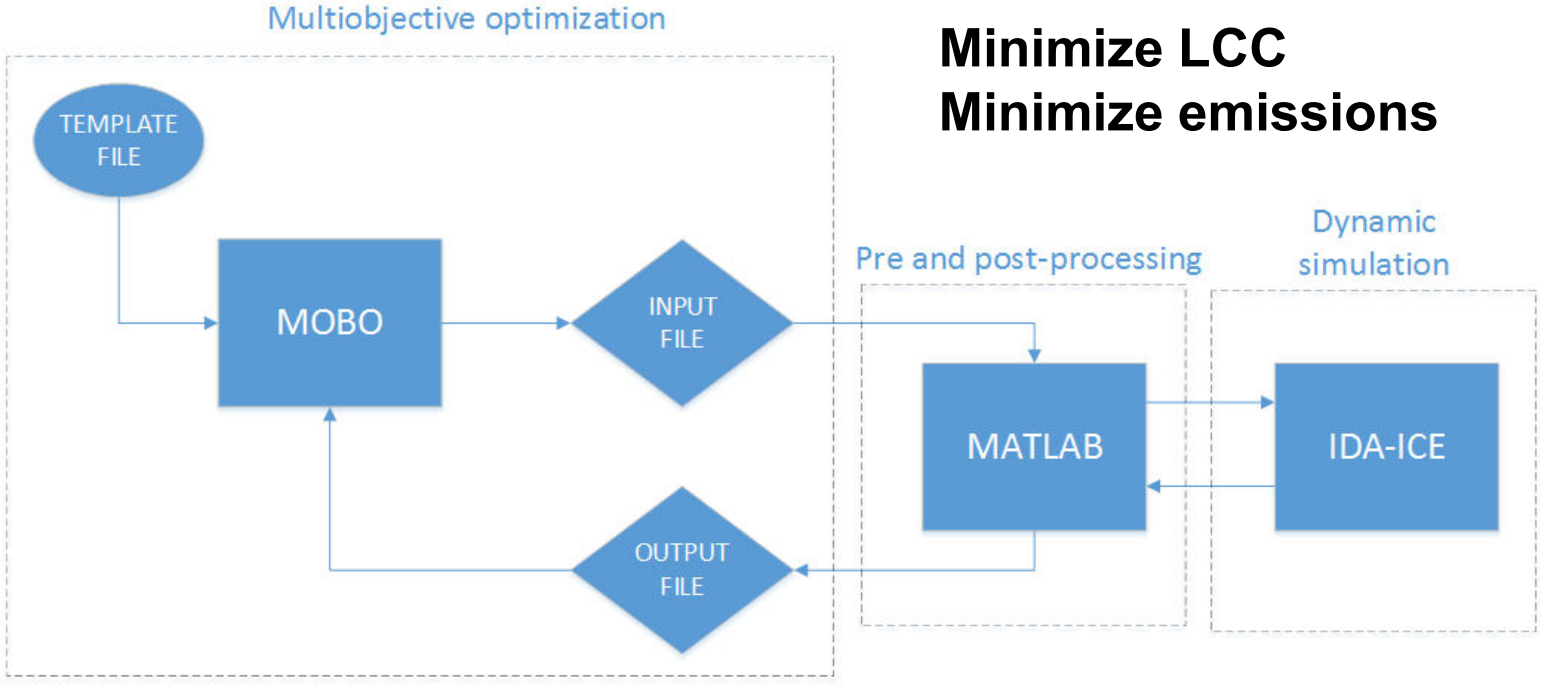
Building information

AB1: <1976 – Mechanical exhaust ventilation, no heat recovery
AB2: 1976-2002 – Mechanical exhaust ventilation, no heat recovery
AB3: 2003-2009 – Mechanical supply-exhaust ventilation, heat recovery
AB4: 2010< – Mechanical supply-exhaust ventilation, heat recovery

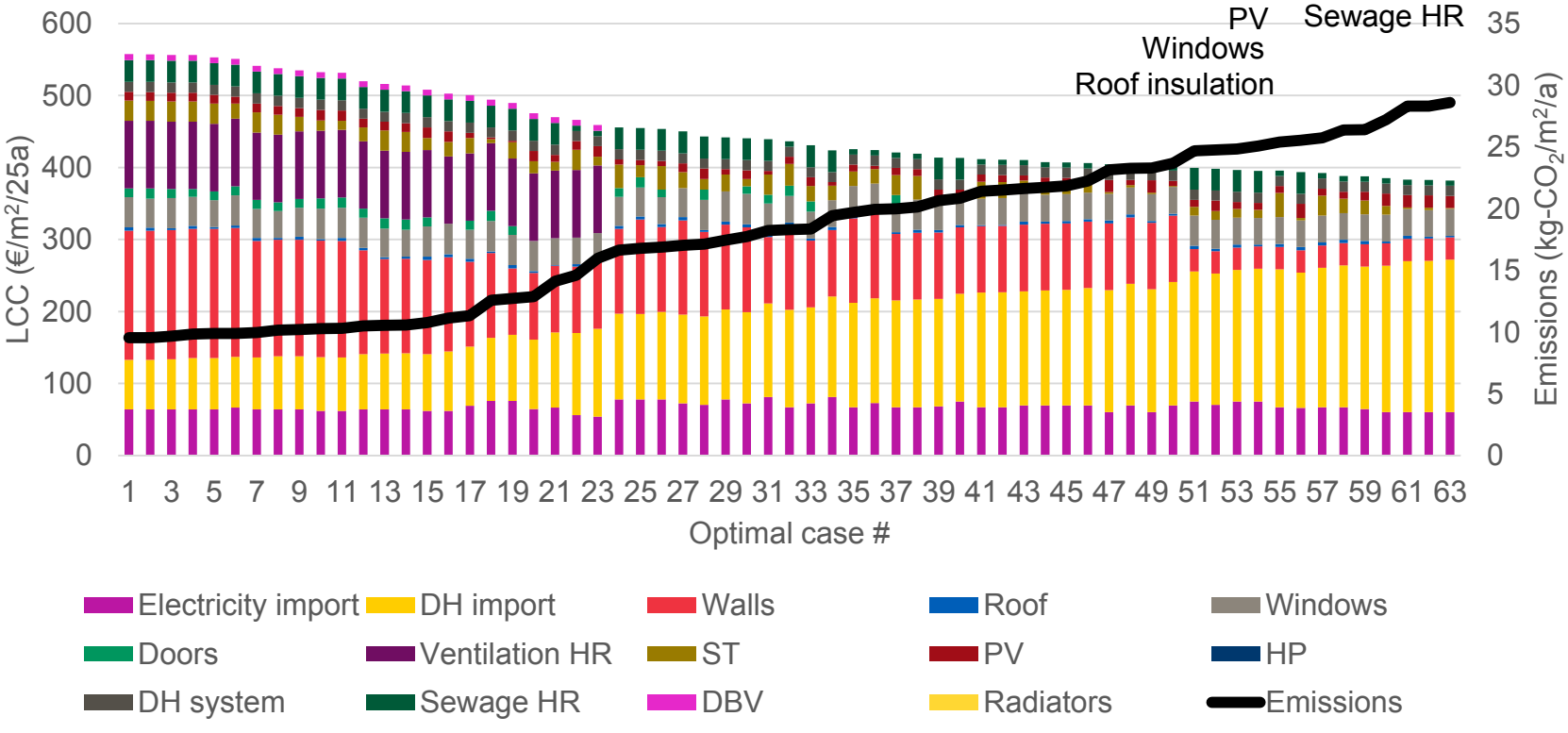


- **Heating system options**
  - District heating
  - GSHP + electric boiler
  - EAHP + district heating

Simulation-based optimization



AB1 – District heating, optimal solutions



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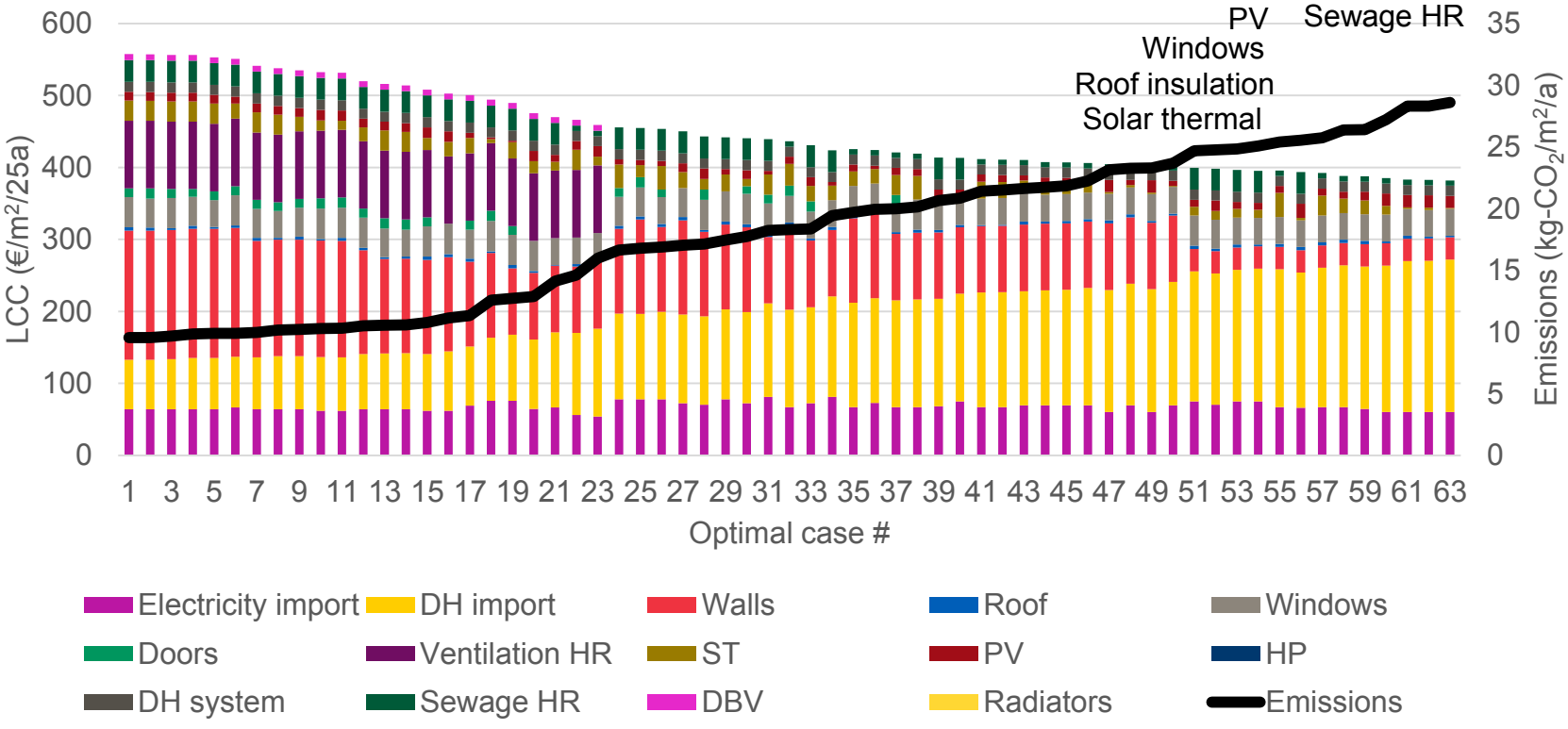

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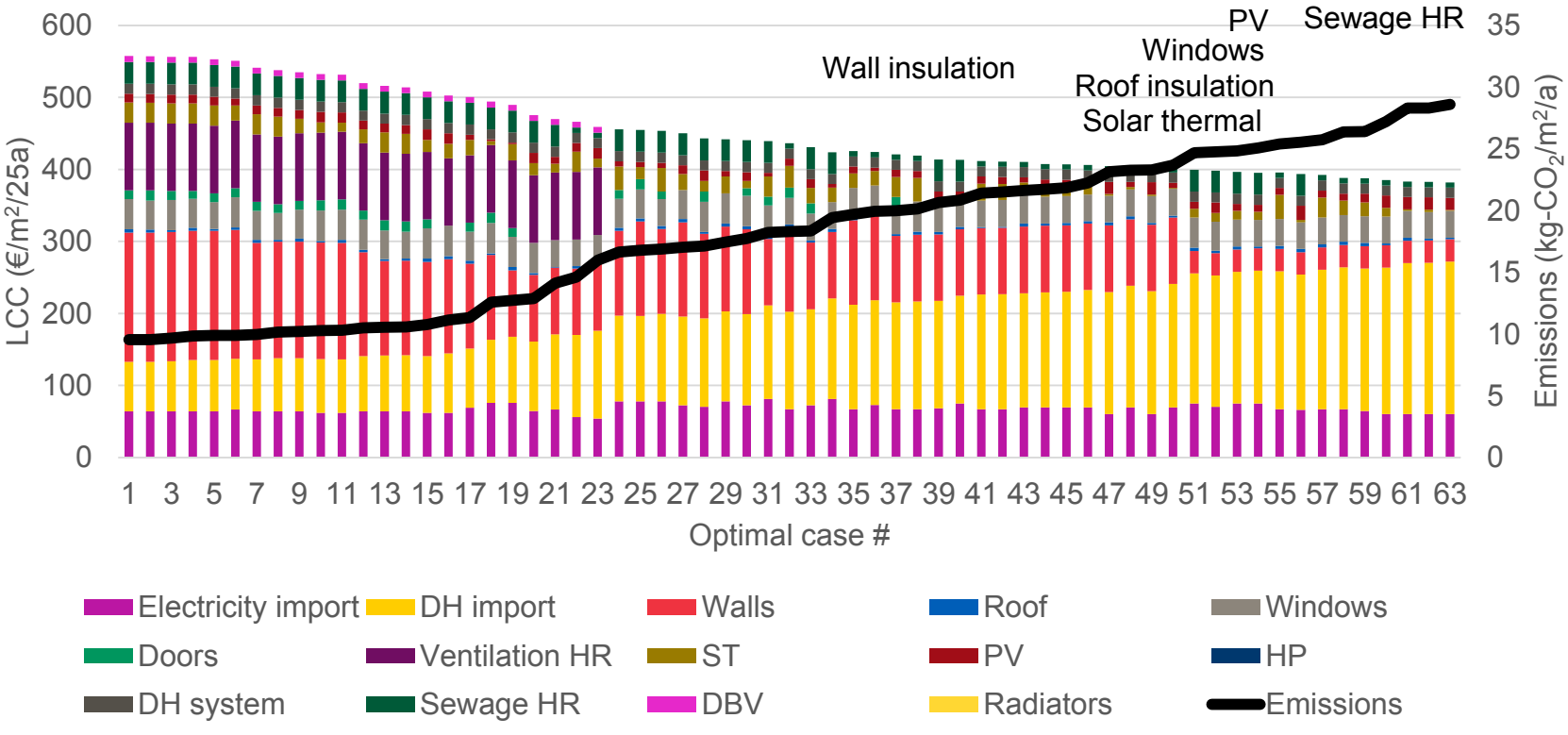

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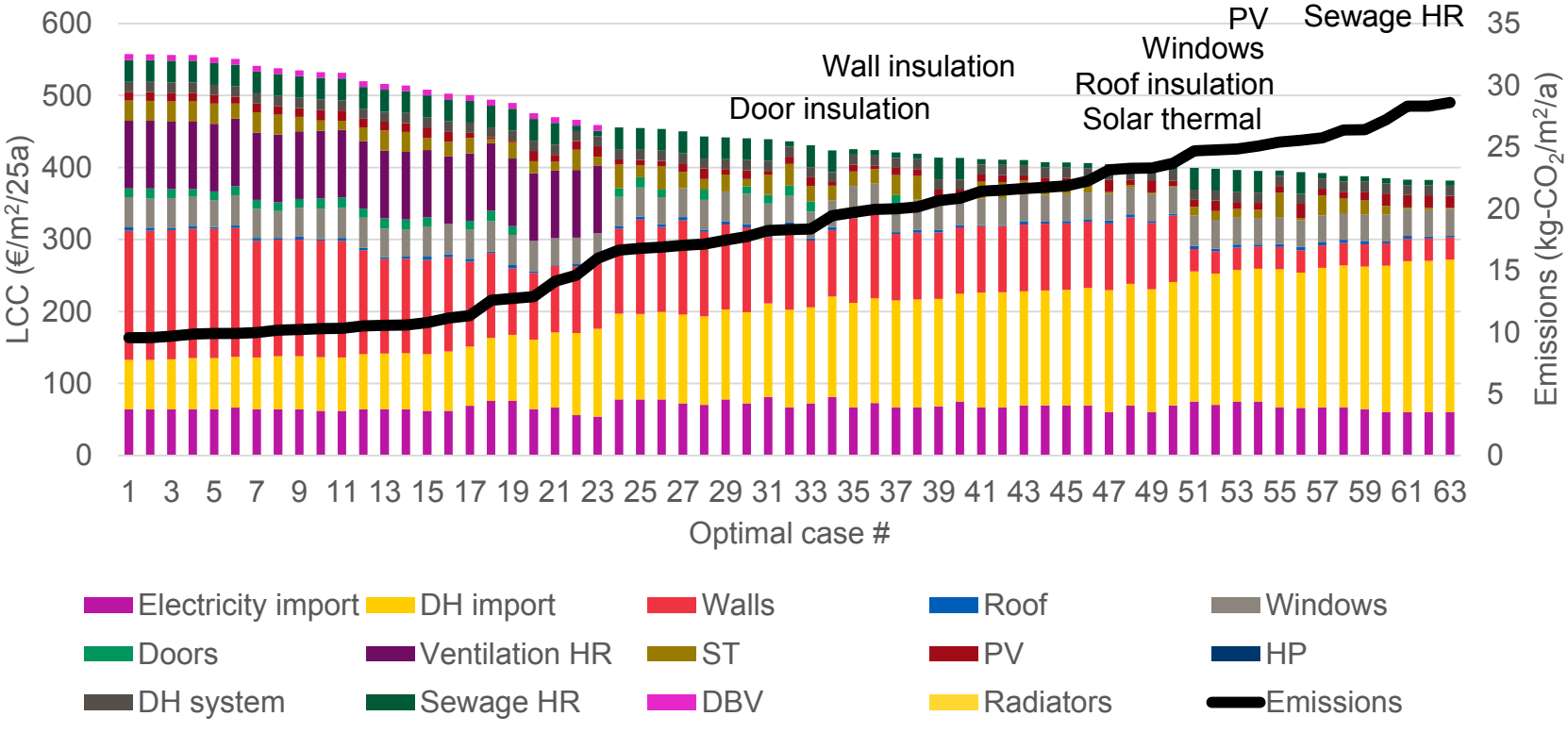

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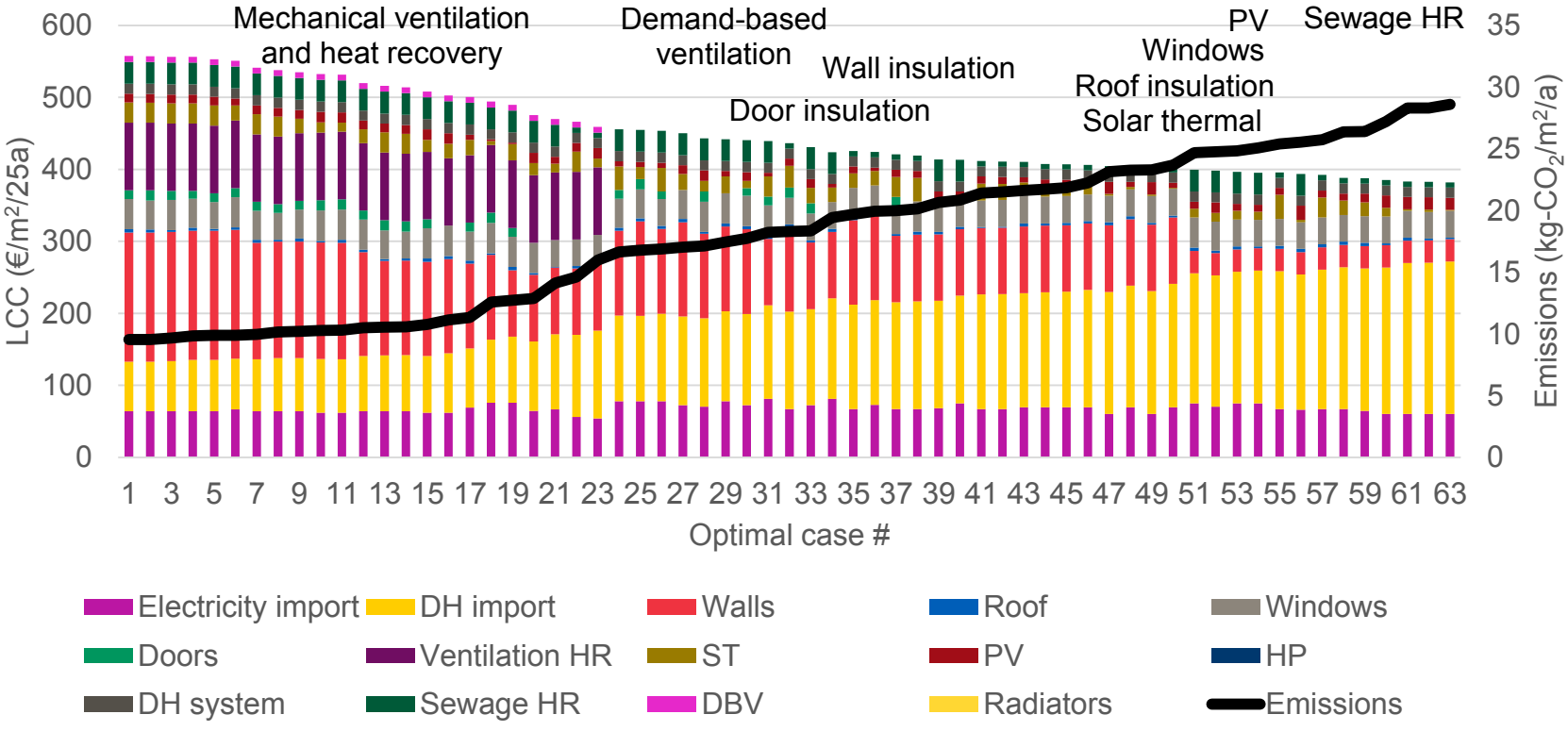
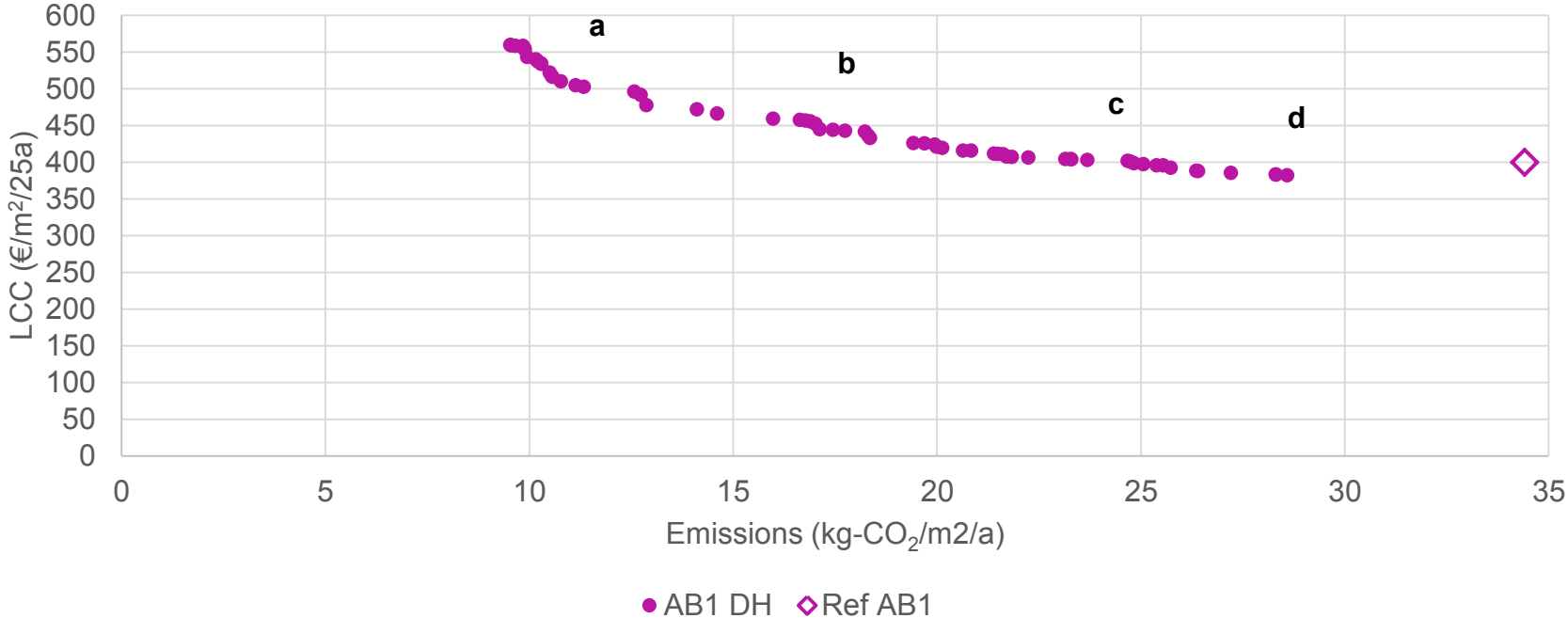
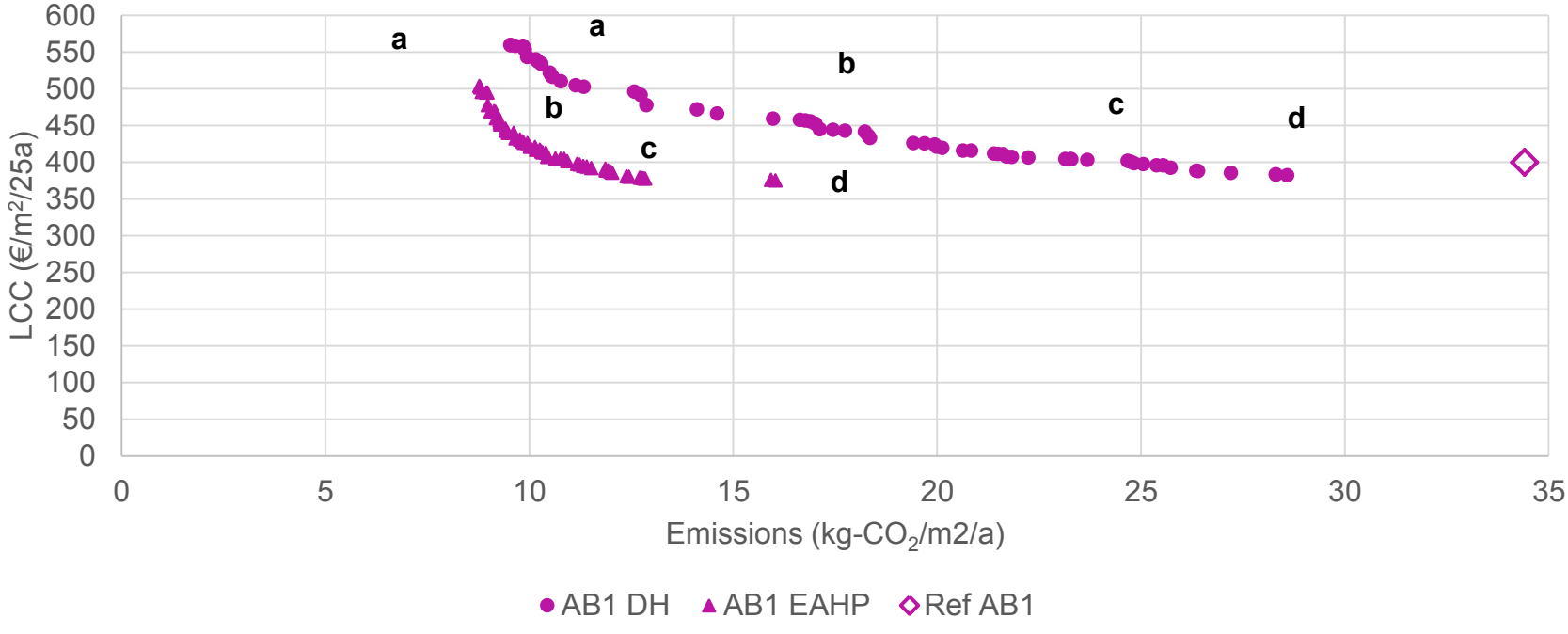


	(kg-CO_2/ m^2/a)	(kg-CO_2/ m^2/a)	(%)	(€-LCC/ kg-CO_2/ m^2/a)	(€/m^2/ 25a)	(€/m^2)	U-values (W/m^2K)				(m^2)	(kW_p)	(kW_{th})		(°C)	
Solution type	Emissions	Emission reduction	Relative reduction	Reduction cost	LCC	Investment cost	Walls	Roof	Doors	Windows	ST	PV	HP	Ventilation	Radiators	Sewage HR
Apartment building (AB1) with district heating (DH)																
a	9.5	24.9	72	6.41	559	498	0.1	0.06	1	0.6	125	25	0	HR+DBV	70/40	Active HR
b	16.0	18.4	54	3.21	459	339	0.36	0.08	2.2	0.8	55	30	0	HR+DBV	70/40	Passive HR
c	24.7	9.7	28	0.07	400	156	0.81	0.08	2.2	0.7	55	30	0	No HR	70/40	Active HR
d	28.6	5.8	17	-3.04	382	122	0.81	0.1	2.2	0.8	5	35	0	No HR	70/40	Passive HR
Ref	34.4				399		0.81	0.47	2.2	1.7	0	0	0	No HR	70/40	No HR
Apartment building (AB1) with an exhaust air heat pump (EAHP) and district heating backup																
a	8.8	25.6	75	4.05	504	399	0.1	0.06	0.7	0.6	90	30	39	No HR	45/35	Active HR
b	9.3	25.1	73	2.06	451	338	0.13	0.06	0.7	0.6	75	30	39	No HR	70/40	Active HR
c	10.9	23.5	68	0.07	401	265	0.23	0.1	1	0.8	0	40	35	No HR	70/40	Active HR
d	17.7	16.8	49	-2.68	355	143	0.81	0.19	2.2	0.8	0	35	35	No HR	70/40	Active HR
Apartment building (AB1) with a ground-source heat pump (GSHP) and electric backup heating																
a	4.9	29.5	86	5.46	561	545	0.1	0.06	0.7	0.6	145	20	115	HR+DBV	45/35	Passive HR
b	5.5	28.9	84	2.70	478	443	0.23	0.1	0.7	0.8	0	35	115	HR+DBV	45/35	Passive HR
c	7.0	27.4	80	-0.10	397	296	0.36	0.08	0.7	0.7	60	35	110	No HR	45/35	Active HR
d	9.6	24.8	72	-3.37	316	155	0.81	0.13	2.2	0.8	0	30	135	No HR	70/40	Passive HR

Emissions vs. LCC



Emissions vs. LCC



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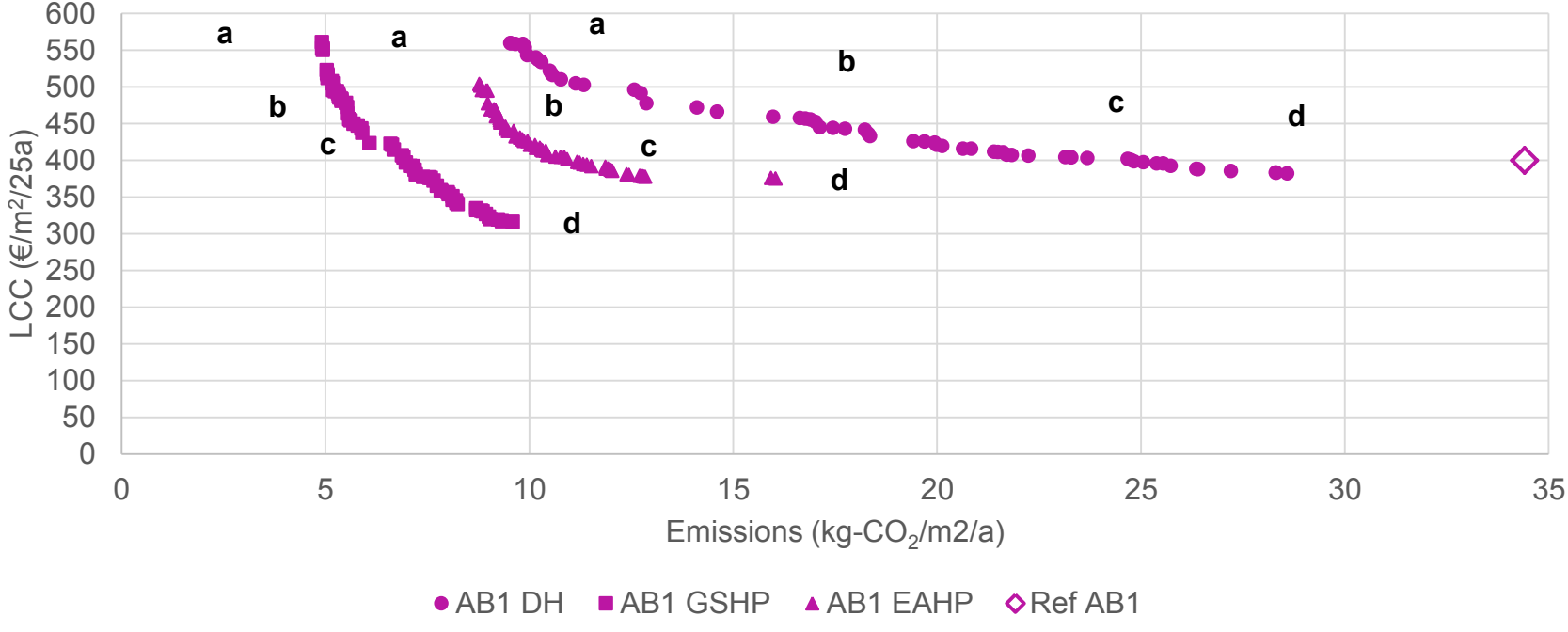

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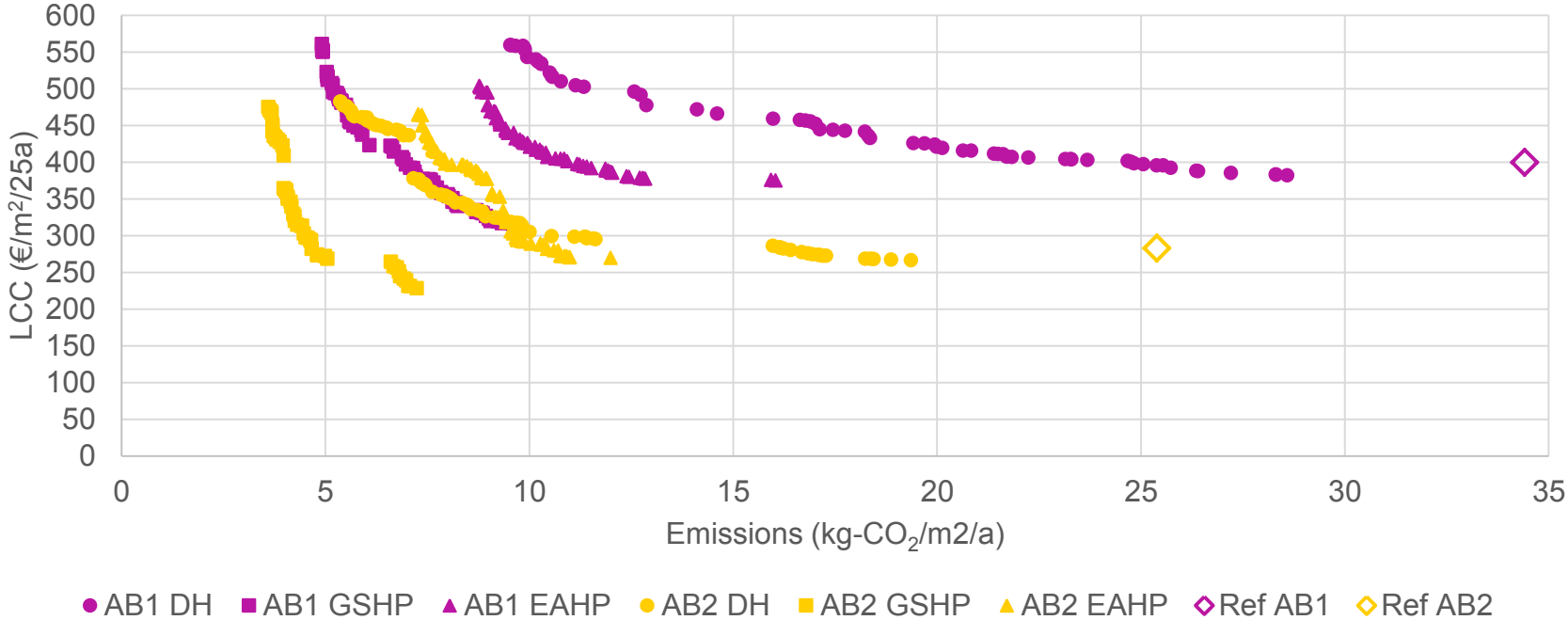

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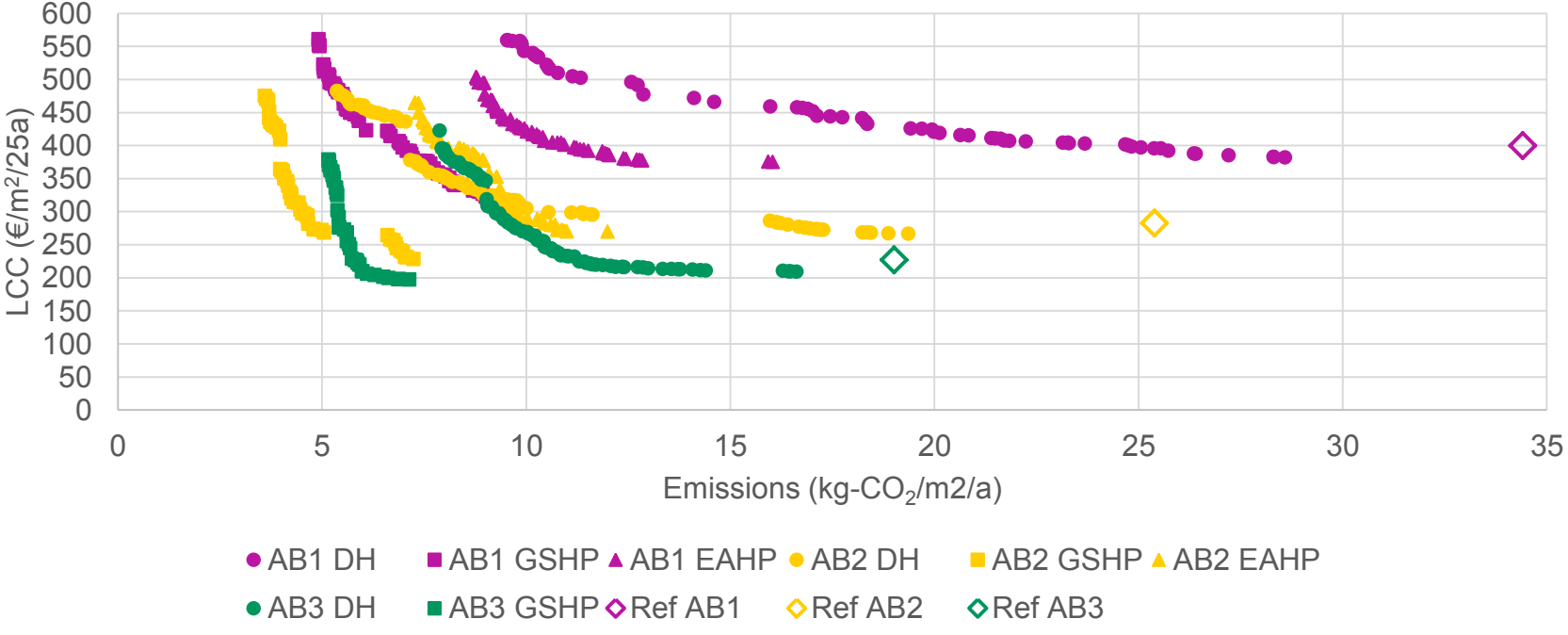

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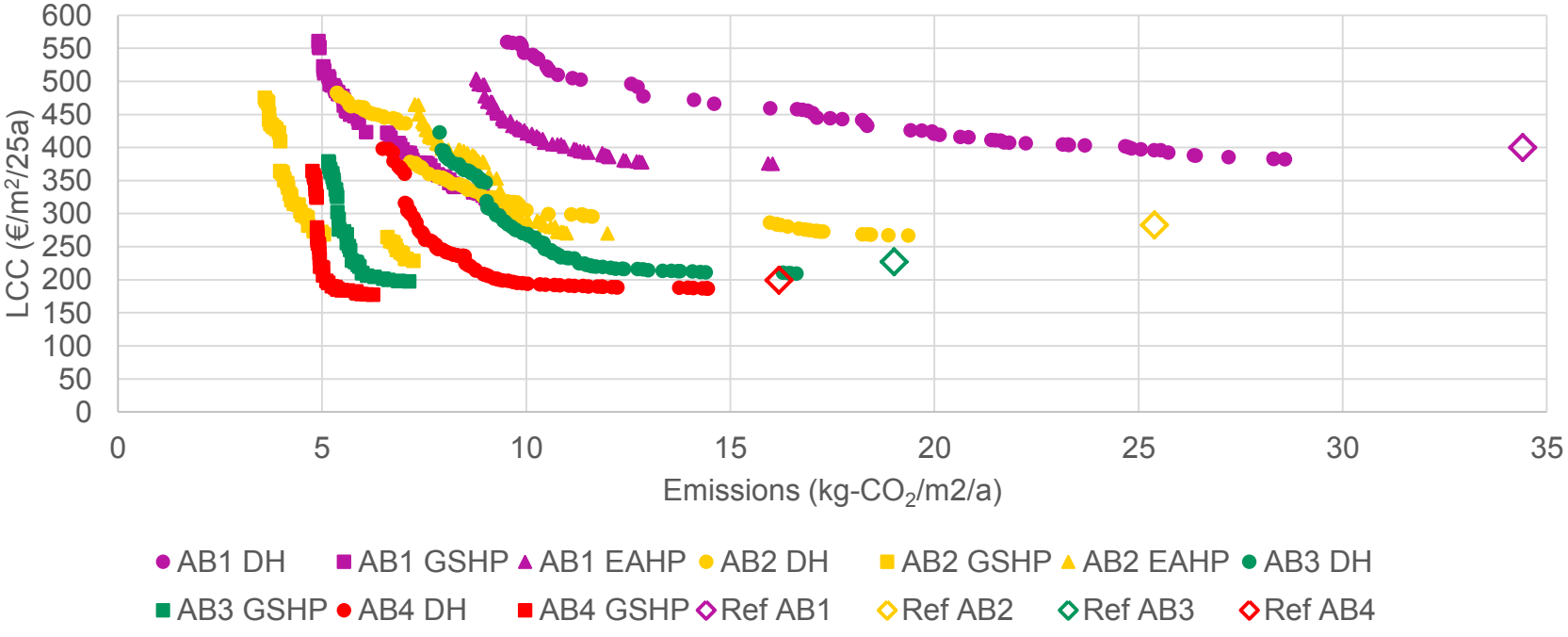
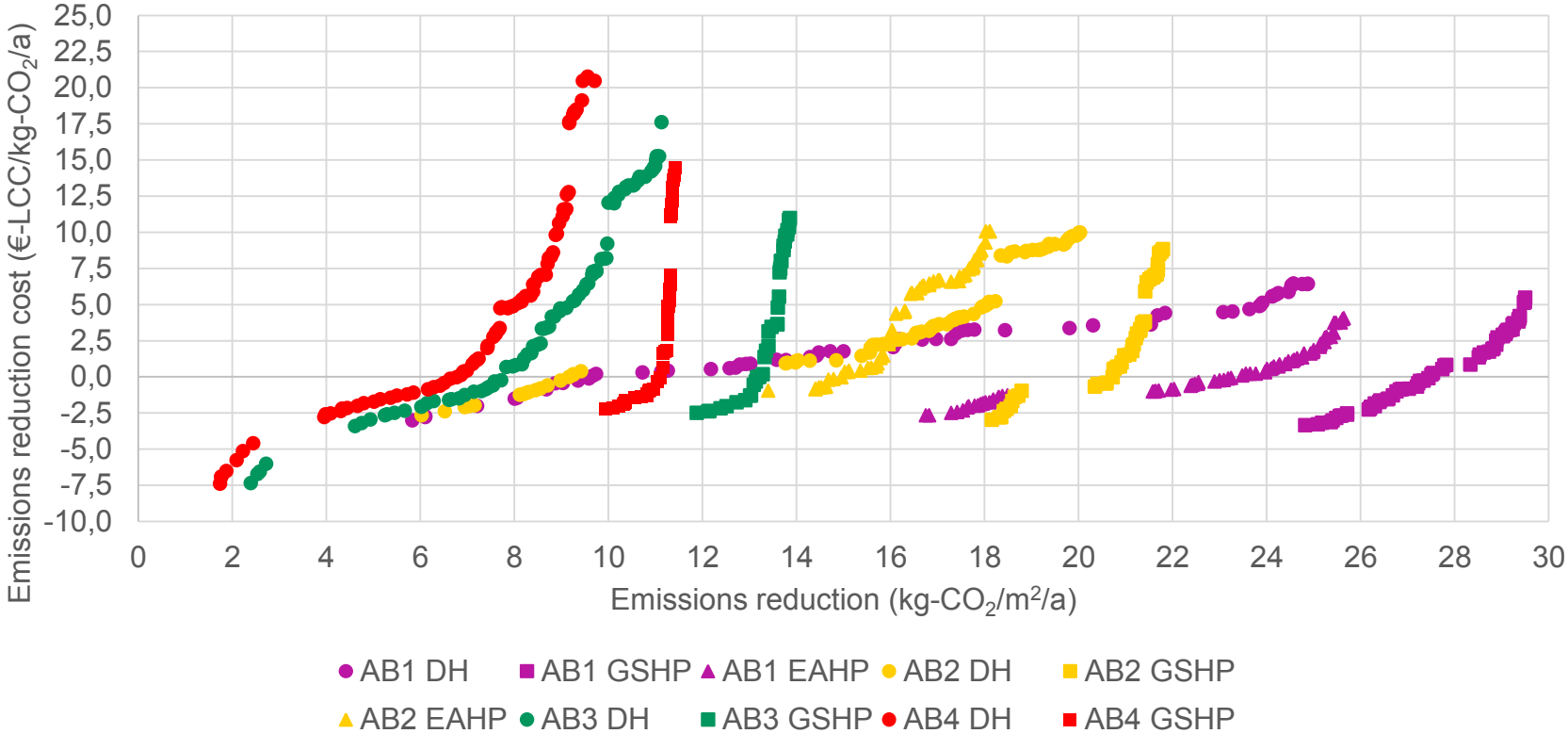
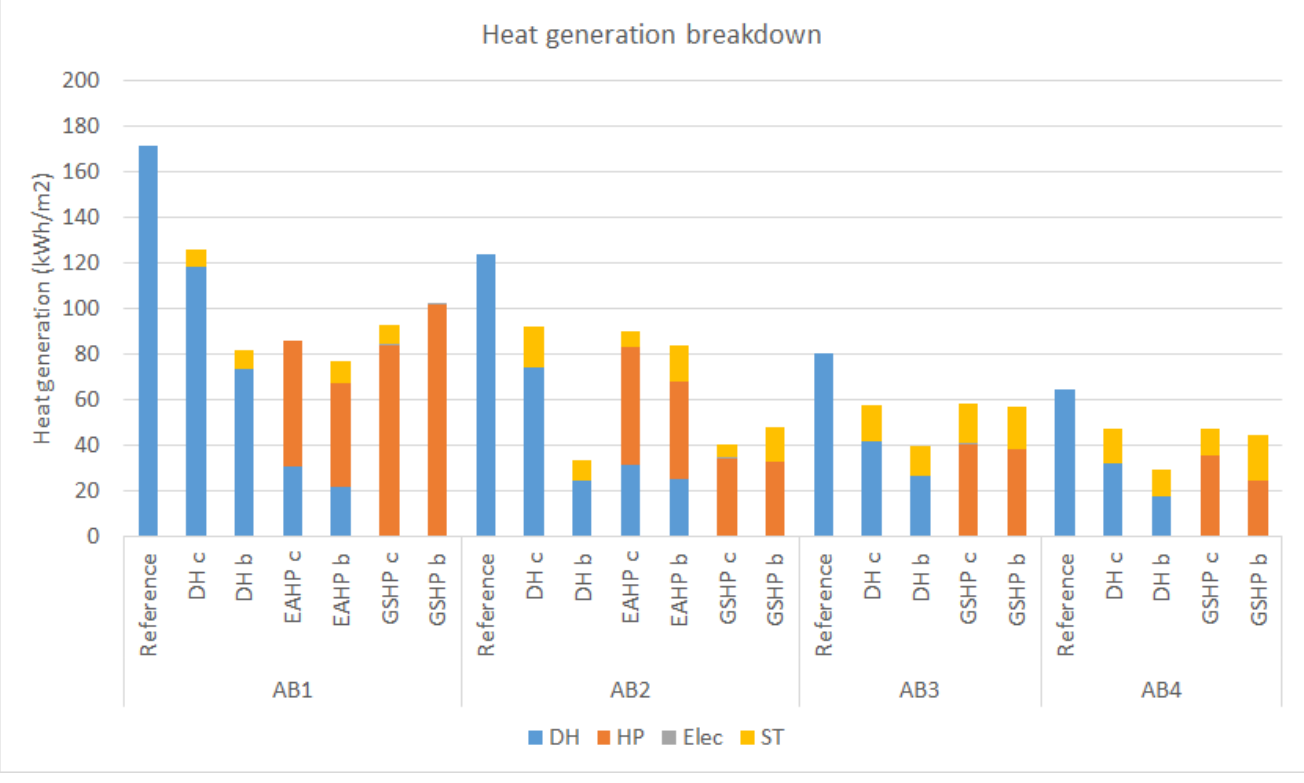


Emission reduction vs. reduction cost



Heat generation of chosen solutions



Conclusions

- **Apartment building emissions can be reduced by 70-80%**
  - Investment cost 270 – 500 €/m²
    - *Typical pipe renovation cost 250 – 1200 €/m²*
  - District heated houses can reduce emissions by 30% without raising life cycle costs
    - *Investment cost 60 – 160 €/m²*
  - Heat pump solutions allow cost-effective reduction of 60-80%
    - *Investment cost 100 – 300 €/m²*
- **Cost-effective retrofit solutions**
  - All buildings: Solar energy and sewage heat recovery
  - Old buildings: Roof insulation, window retrofit
  - New buildings: Demand-based ventilation