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Pathway to a competitive European Fuel Cell micro-CHP Market

WP3.2 – Modelling of the µCHP consumer business case

PACE final dissemination event – 26/04/2023

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Background and introduction

Consumer business case for current (2023) and future (installations)

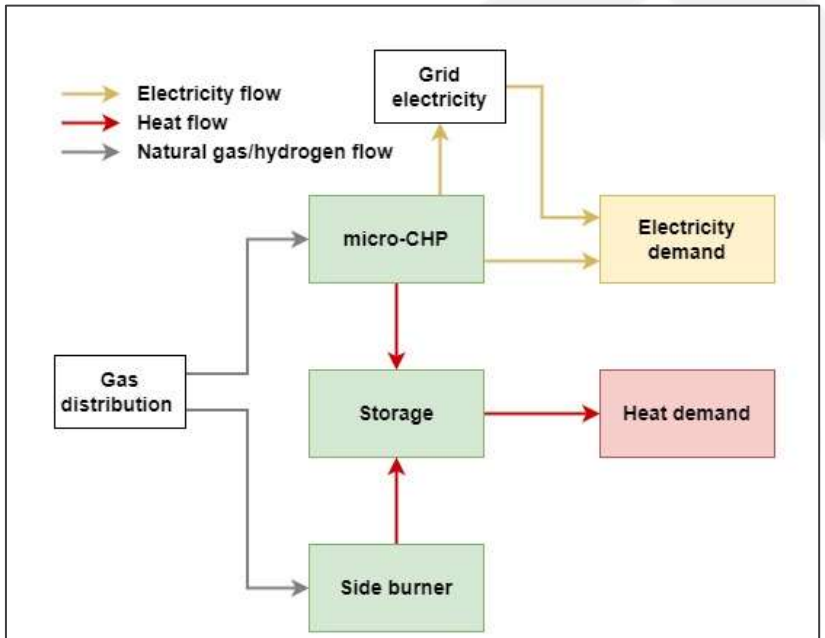
Fuel Cell micro-Combined Heat and Power (FC µCHP) is one of several different options available today for domestic consumers.

Purpose:

- **Discounted lifetime costs** is the key metric to calculate the consumer business case
- **Lifetime emissions** are also compared, as these are an important factor for consumers' decisions

Methodology:

- A short timestep (hourly operation) model simulated a year of operation for each system
- Assumptions made for **fuel price and electricity decarbonisation projections** for each country from a variety of sources
- **Annual average** prices and emissions factors used
- Sensitivity of results to changes in assumptions tested



All possible interactions with the FC µCHP system

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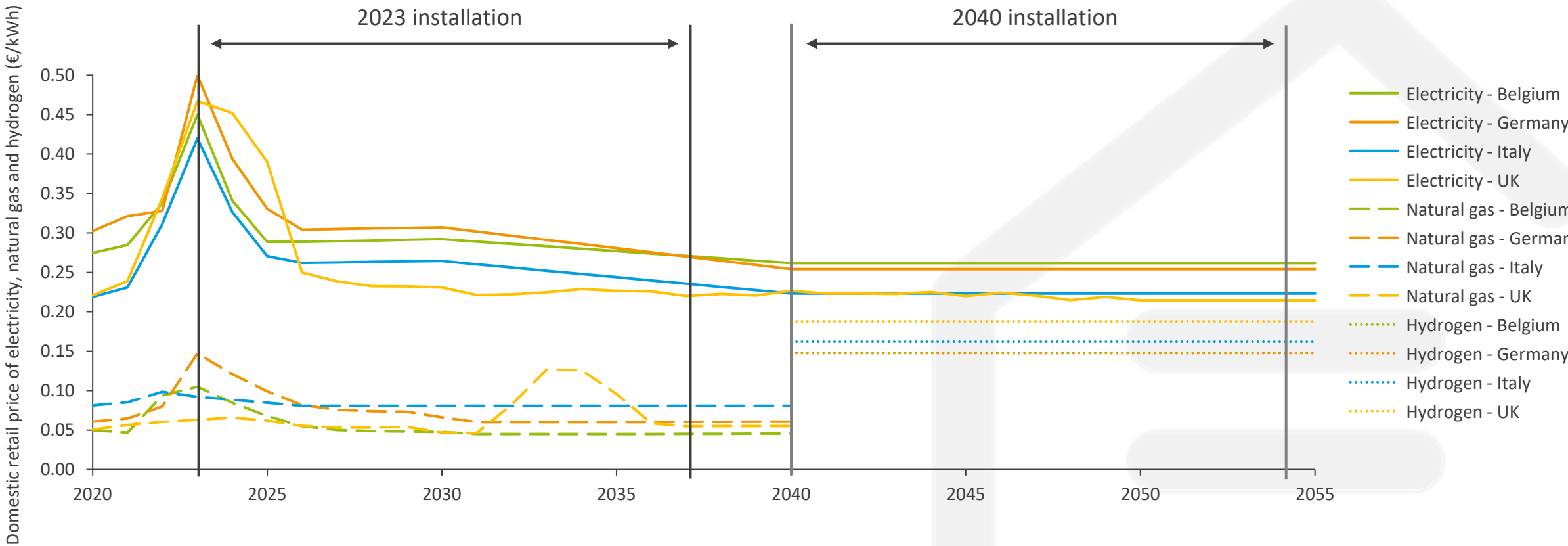
Summary of price projections

Fuel price projections for the 2023 and 2040 business cases



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Scope of study

The consumer business case was determined for selected scenarios relying on house archetypes to profile consumers

Fuel Cell micro-Combined Heat and Power (FC µCHP) is one of several different options available today for domestic consumers.

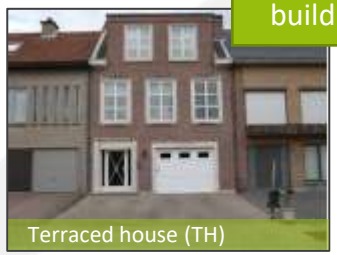

FC µCHP systems

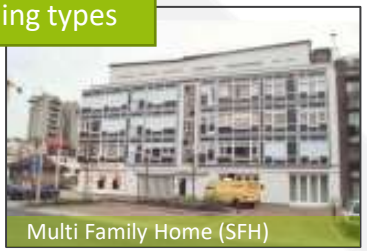

Gas boiler


ASHP

3-5 different heating systems


Single Family Home (SFH)


Terraced house (TH)

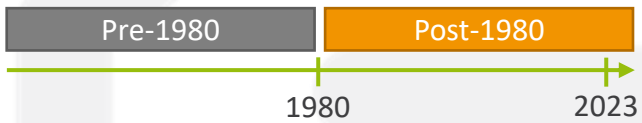

Multi Family Home (SFH)

3 different building types

4 different countries

2023: Natural gas / biomethane as µCHP/boiler fuel
2040: hydrogen as µCHP/boiler fuel

2 different installation dates



2 different house ages

Total of 192 scenarios and cases evaluated for discounted lifetime costs and lifetime emissions

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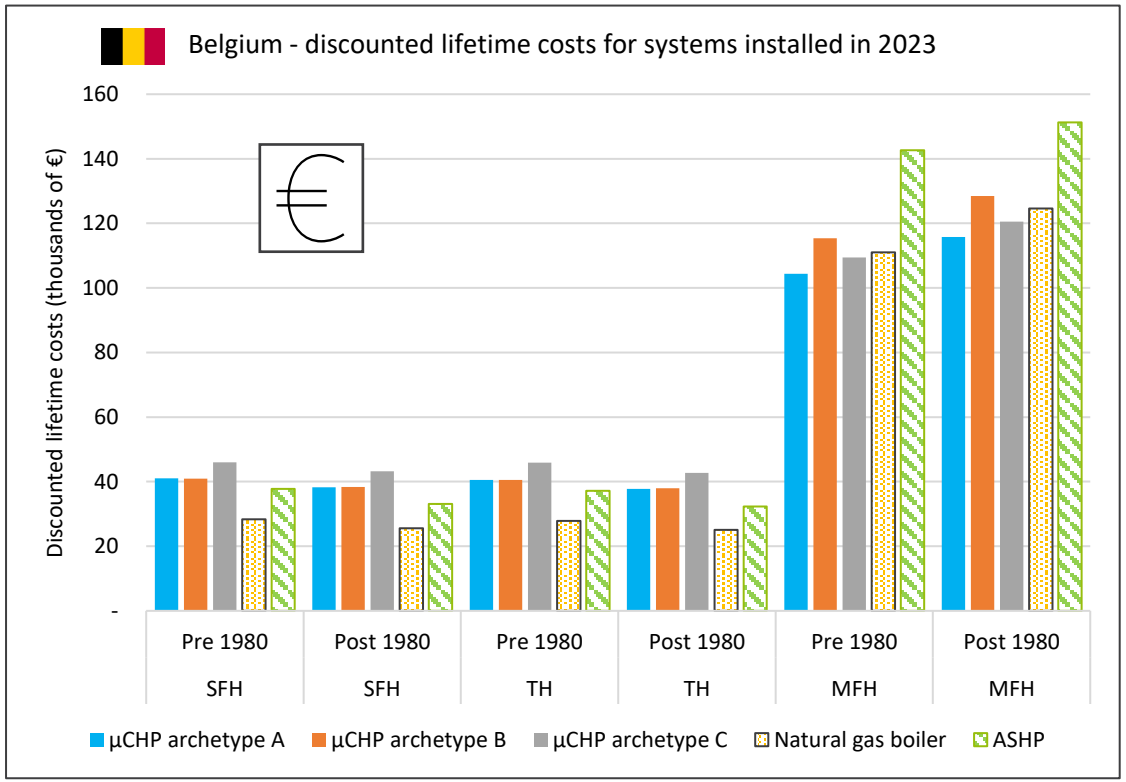
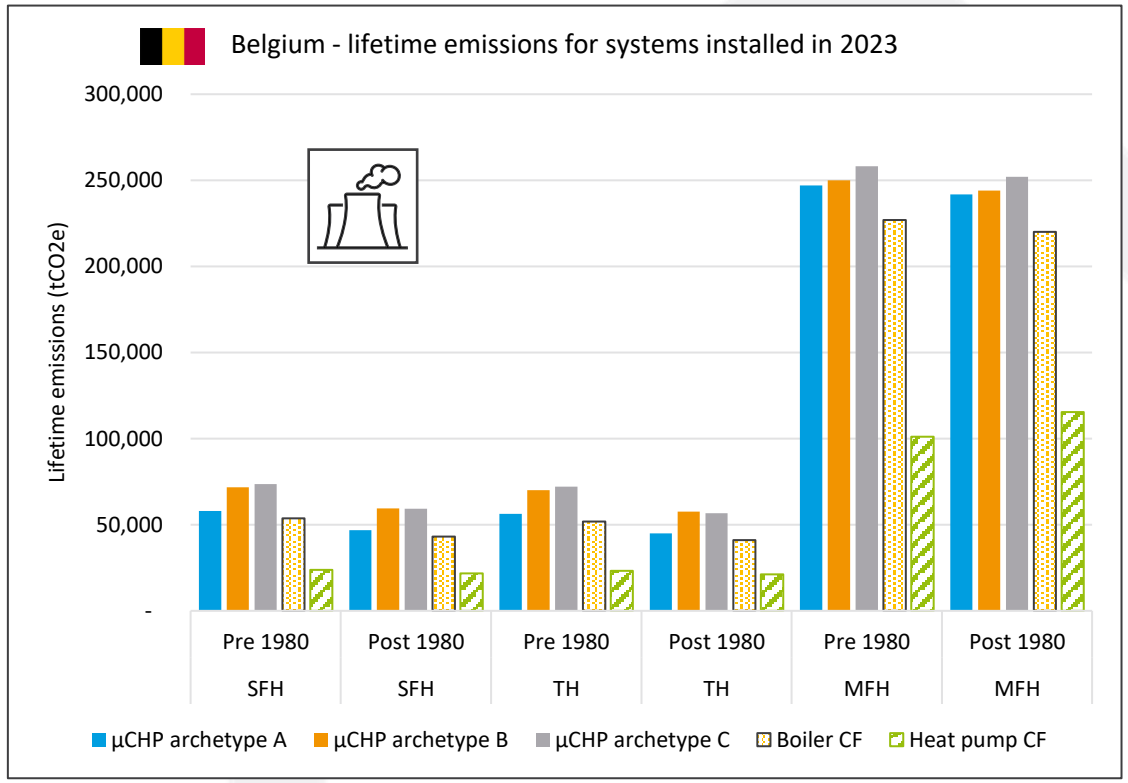
Results for 2023 installations

Discounted lifetime costs and lifetime emissions in Belgium

FC µCHPs incurred lower lifetime costs than its counterfactuals in larger homes, but the decarbonisation of grid electricity reduces its environmental benefits





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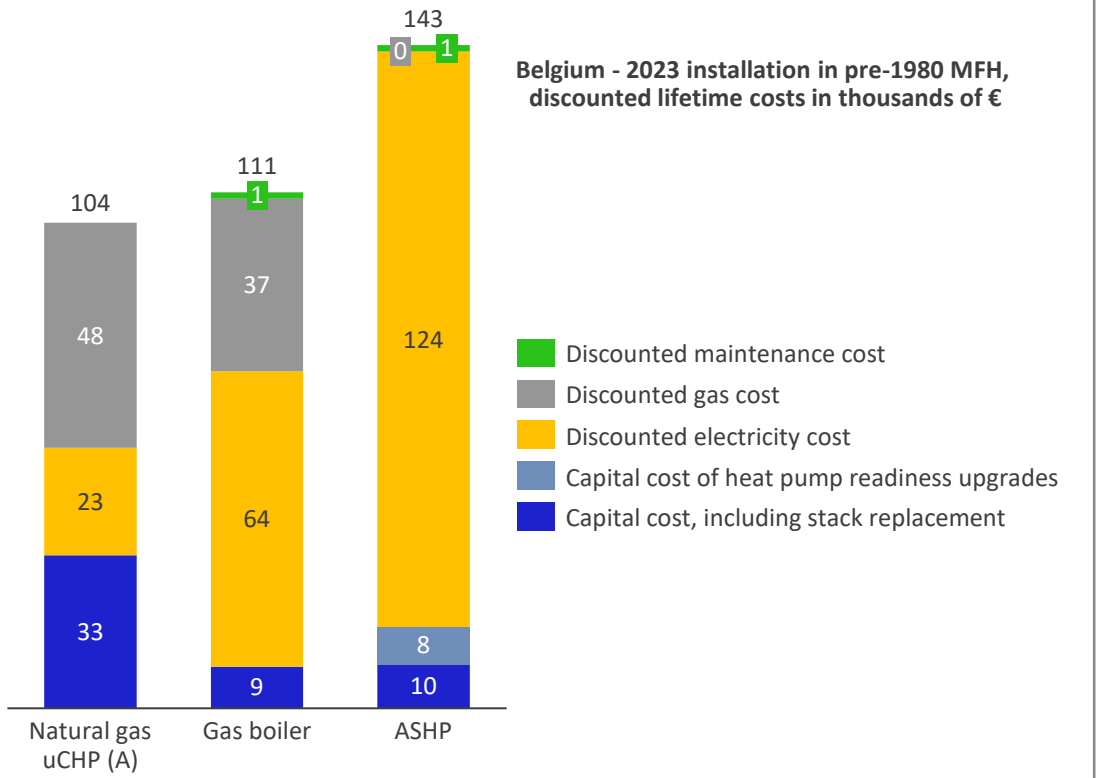
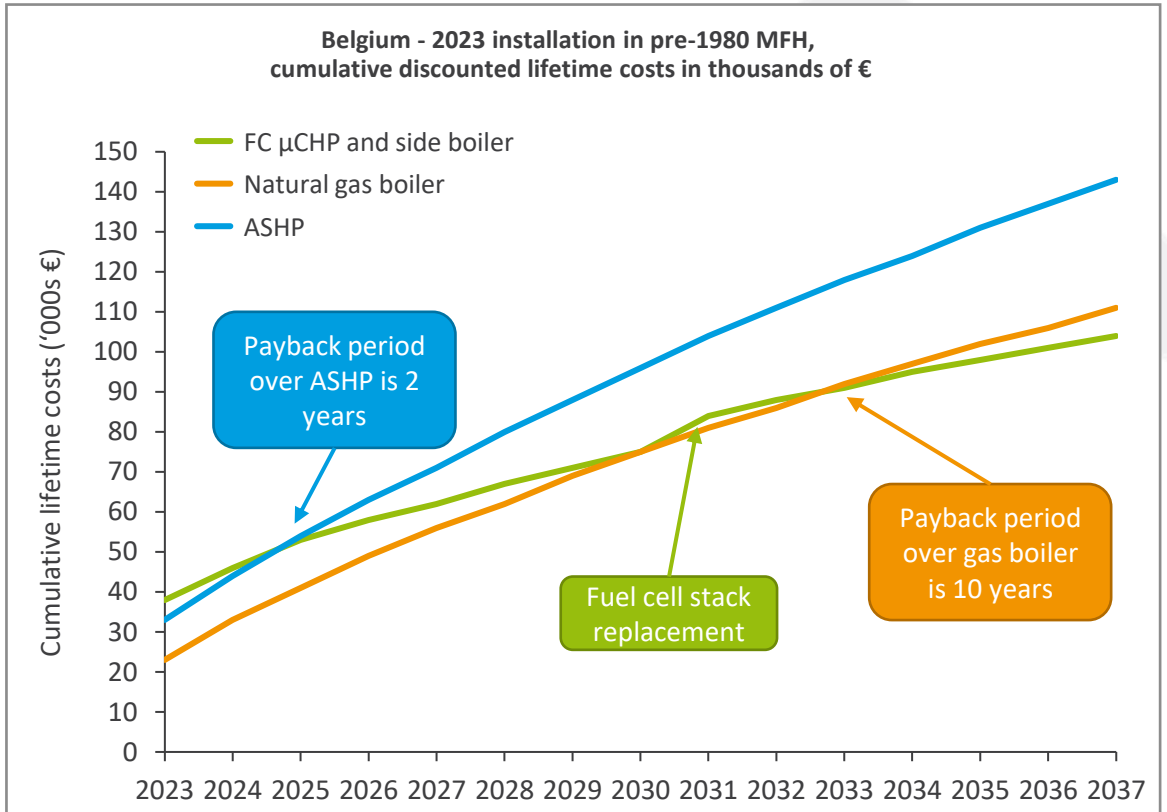
Results for 2023 installations

Deep dive into the lifetime costs of centrally installed pre-1980 MFHs

Belgium has the most favourable market conditions – in MFH, the lower operating costs make up for higher capital costs



Breakdown of discounted lifetime costs in a pre-1980 MFH in Belgium



Breakdown of discounted lifetime costs in a pre-1980 MFH in Belgium

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Results for 2023 installations

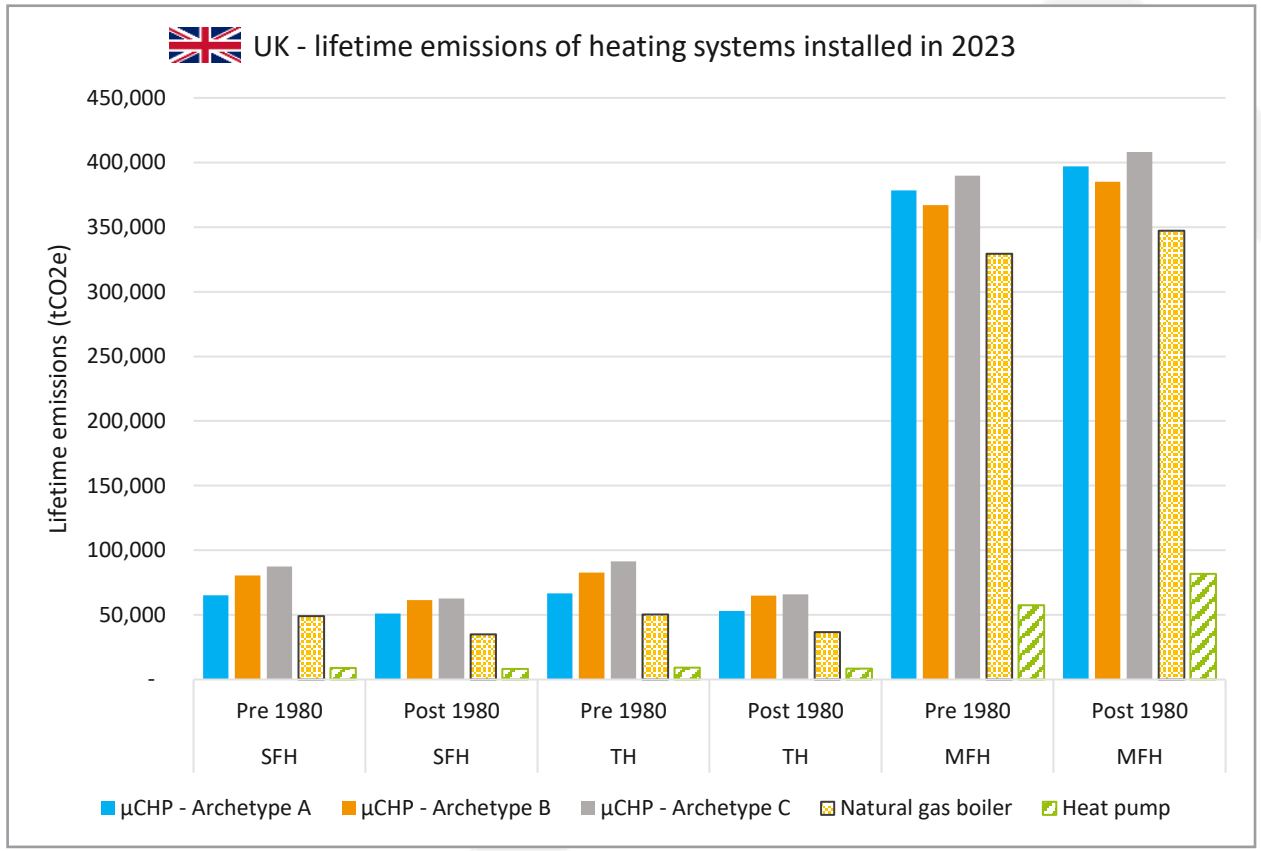
Deep dive into the lifetime emissions of systems

Emissions from µCHP systems in profit-maximising modes are projected to produce more emissions than both counterfactual technologies

- Using annual emissions factors, FC µCHP produced the most emissions
- Rapidly decarbonising power reduces the value of self-generated electricity from µCHP systems

Levers to narrow emissions gap

- Grid electricity decarbonises slower based on different assumptions → **potential in other countries**
- **Using hourly emissions factors** to ensure the µCHP only operates when it is environmentally optimal to do so → **lowers technology load factor**
- Consider **biomethane use → increases blended gas price**



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Impact of biomethane use on lifetime emissions

Scenarios compare the lifetime emissions of µCHP and ASHP for blended gas and electricity emissions factors

Biomethane use and increasing demand-weighted grid electricity emissions factors has the potential to reduce µCHP lifetime emissions

Increasing amounts of biomethane used to displace fossil natural gas

Result from study

Line defining emissions parity between µCHP and ASHP

Belgium - 2023 installation in pre-1980 MFH
Lifetime emissions difference between an ASHP and a uCHP, in tCO2e
Red = uCHP higher emissions, Green = uCHP lower emissions

	Blended gas carbon intensity factor (kgCO2e/kWh)	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
Unabated gas carbon factor, used in study	0.213	-117	-110	-104	-98	-92	-86	-80	-73	-67	-61	-55	-49	-43
	0.2	-107	-100	-94	-88	-82	-76	-70	-63	-57	-51	-45	-39	-32
	0.18	-91	-85	-79	-72	-66	-60	-54	-48	-42	-35	-29	-23	-17
25% of input gas is biomethane	0.16	-75	-69	-63	-57	-51	-44	-38	-32	-26	-20	-14	-7	-1
	0.14	-60	-54	-47	-41	-35	-29	-23	-17	-10	-4	2	8	14
	0.12	-44	-38	-32	-26	-19	-13	-7	-1	5	11	18	24	30
53% of input gas is biomethane	0.10	-29	-22	-16	-10	-4	2	8	15	21	27	33	39	45
	0.08	-13	-7	-1	6	12	18	24	30	36	43	49	55	61
	0.06	3	9	15	21	27	33	40	46	52	58	64	70	77
	0.04	18	24	31	37	43	49	55	61	68	74	80	86	92
	0.02	34	40	46	52	58	65	71	77	83	89	95	102	108
	0.00	49	56	62	68	74	80	86	93	99	105	111	117	123
Electricity carbon intensity (kgCO2e/kWh) ->		0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40

Average grid carbon factor used in study

Increasing demand-weighted lifetime average grid electricity

Lifetime emissions for different scenarios in Belgium

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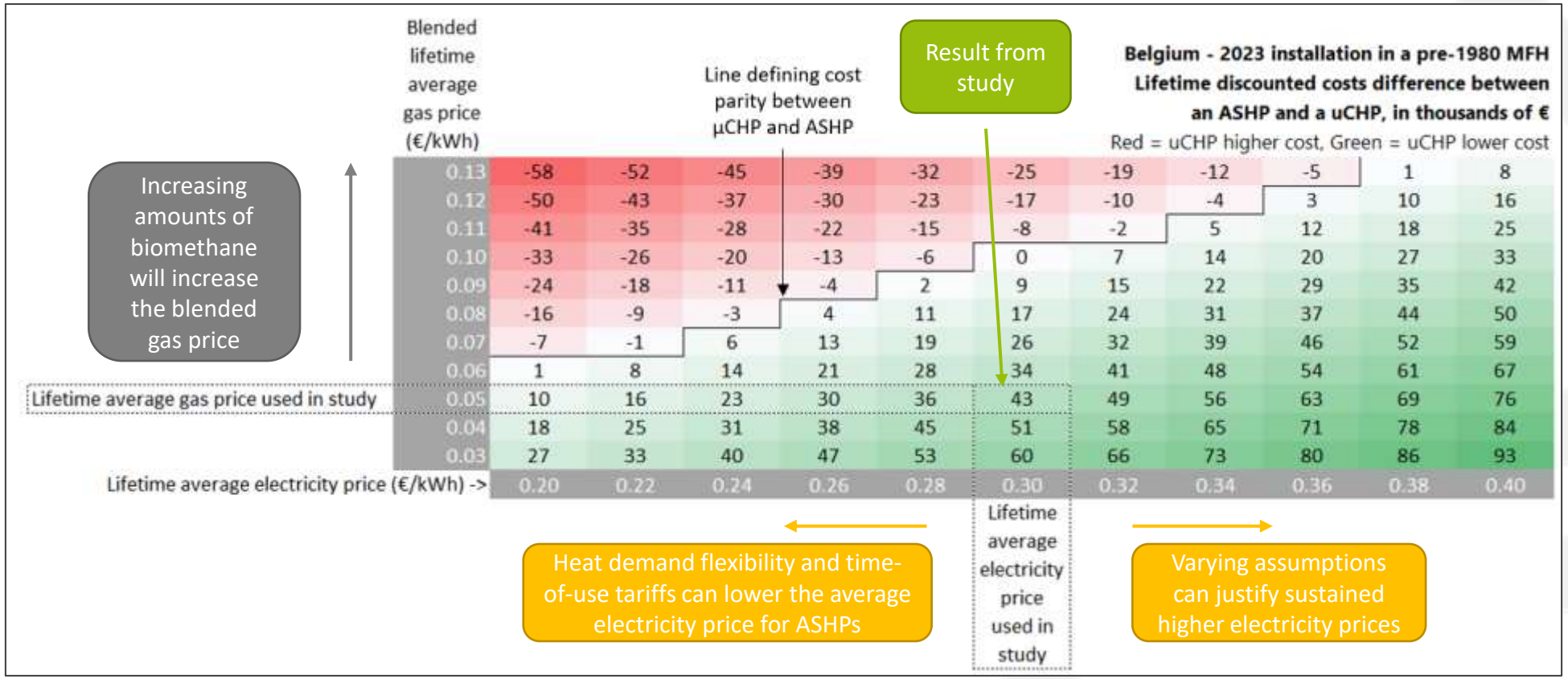
Impact of biomethane use on lifetime costs

Scenarios compare the discounted lifetime costs of µCHP and ASHP for blended gas and electricity prices

Biomethane use and increasing demand-weighted grid electricity emissions factors has the potential to reduce µCHP lifetime emissions



Blended lifetime average gas price (€/kWh)	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.13	-58	-52	-45	-39	-32	-25	-19	-12	-5	1	8
0.12	-50	-43	-37	-30	-23	-17	-10	-4	3	10	16
0.11	-41	-35	-28	-22	-15	-8	-2	5	12	18	25
0.10	-33	-26	-20	-13	-6	0	7	14	20	27	33
0.09	-24	-18	-11	-4	2	9	15	22	29	35	42
0.08	-16	-9	-3	4	11	17	24	31	37	44	50
0.07	-7	-1	6	13	19	26	32	39	46	52	59
0.06	1	8	14	21	28	34	41	48	54	61	67
0.05	10	16	23	30	36	43	49	56	63	69	76
0.04	18	25	31	38	45	51	58	65	71	78	84
0.03	27	33	40	47	53	60	66	73	80	86	93

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Conclusions of 2023 installations

Results were completed for all 4 focus countries

µCHPs installed in larger consumer types can offer economic advantages, but lifetime emissions need to be addressed by the use of biomethane or consideration of slower decarbonisation of grid electricity.

µCHPs offer economic benefits to its users in larger MFHs for all countries.

- Consumers with high heat demands that are consistent (non-seasonal) benefit the most from µCHPs.

µCHPs need biomethane to reach emissions parity with ASHPs.

- This may be reduced with hourly marginal emissions factors
- With current assumptions, biomethane must cover 63% (Belgium) to 88% (UK) of natural gas use to reach emissions parity with ASHPs.
- In MFHs, the blended gas price can increase by between 19% (Italy) and 100% (Belgium) to still maintain economic parity with ASHPs.
- Countries with slower electricity decarbonisation pathways offer greater potential for the environmental benefits of µCHP

Country	FC µCHP lifetime costs difference to ASHP (%)	Fraction of biomethane required for ASHP parity (%)	Maximum blended gas price to maintain parity with ASHP (€/kWh)	Maximum price uplift from biomethane use (%)
Belgium	- 27%	63%	0.10 €/kWh	+ 100%
Germany	- 16%	71%	0.10 €/kWh	+ 25%
Italy	- 7%	67%	0.09 €/kWh	+ 19%
UK	- 14%	88%	0.11 €/kWh	+36%

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Overview of 2040 scenario

Impact of changes from 2040 installations, compared to 2023 scenario

Green hydrogen replaces natural gas as µCHP fuel, other changes to system costs and efficiencies

Changes in core assumptions from 2023 scenario	Impact to FC µCHP	Impact to hydrogen boiler	Impact to ASHP
Capital costs of equipment and installation			
Fuel costs			
Emissions of input fuels			
System efficiencies			
Widespread benefits			
Demand flexibility and time-of-use tariffs			

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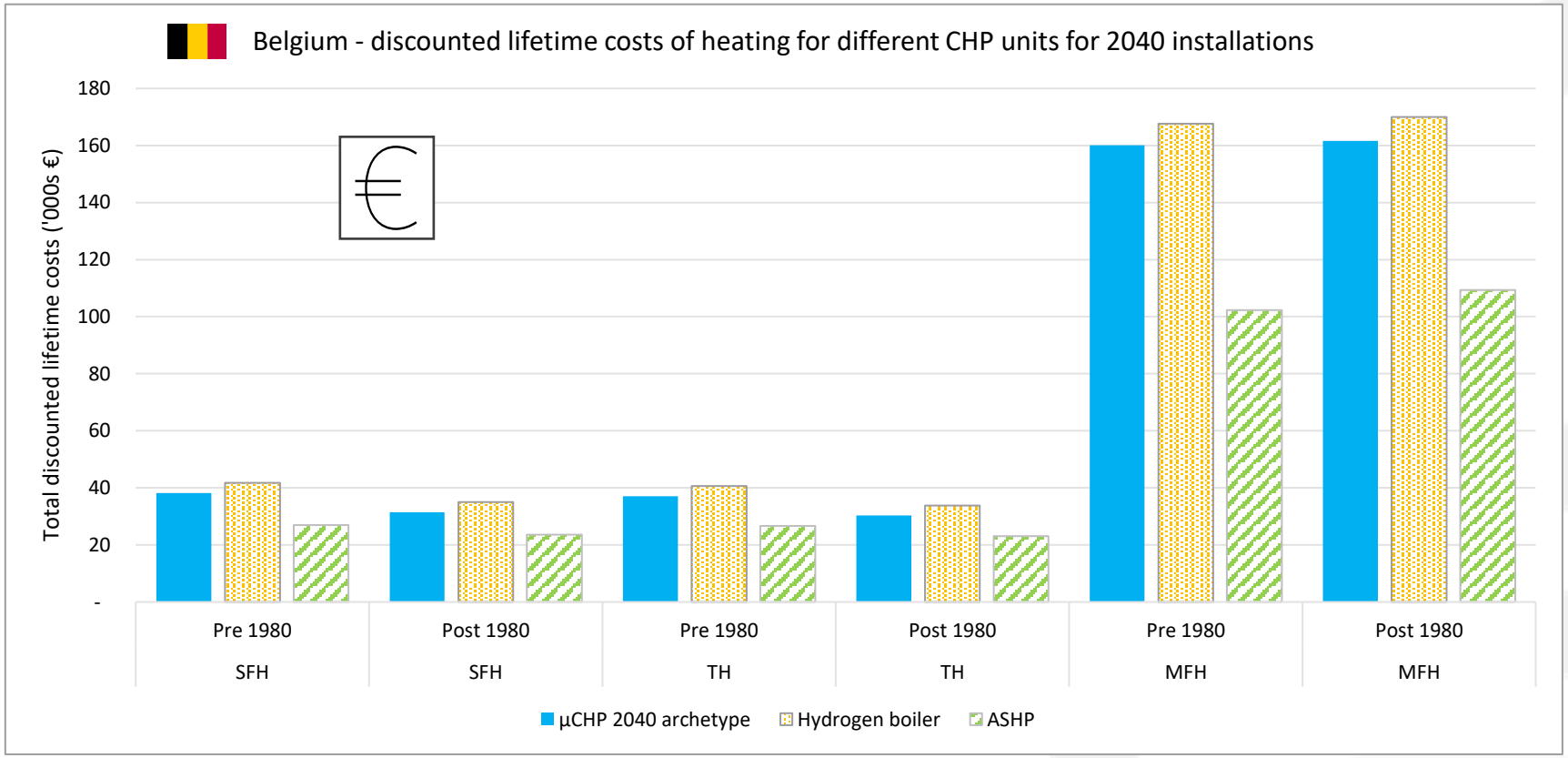
Results for 2040 installations

Discounted lifetime costs in Belgium

FC µCHPs provide an alternative to hydrogen boilers, but lag behind ASHP in economic performance



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Conclusion

Summary of core study conclusions

2023 installations: µCHP installation requires careful consideration and optimisation

- Installations in high-energy consumers yield the best economic results
- Optimizing operation to reduce emissions will impact the business case
- Biomethane use can be considered to reduce emissions
  - Likely to increase the consumer's fuel prices
  - System-wide optimisation may use biomethane for power
- Decarbonising grid electricity is a significant headwind for low-carbon credentials of natural gas-based systems

2040 installations: µCHP are a competitive alternative to hydrogen boilers

- ASHP is the lowest-cost option in all cases
- Simplified system reduces the need of a reformer for FC µCHP
- FC µCHPs perform strongly against hydrogen boilers in 20 / 24 cases across the focus countries
- **In areas where hydrogen is available, FC µCHPs are a viable alternative to hydrogen boilers**