

Appendix 5. Technology characteristics

Technology	Name	Source	Type	Combined heat and power (CHP)	Fuel	Investment mil. \$/MW-heat	Fixed O&M \$/MW-heat/year
Air source heat pump	Air source heat pump-commercial		commercial	no	Electricity-Commercial	0.41	2395
Ground source heat pump	Ground source heat pump-commercial		commercial	no	Electricity-Commercial	0.78	2395
Gas boiler	Gas boiler-commercial		commercial	no	Natural gas-Commercial	0.07	2335
Oil boiler	Oil boiler-commercial		commercial	no	Oil-Commercial	0.07	2525
Gas fired absorption heat pump	Gas fired absorption heat pump-commercial		commercial	no	Natural gas-Commercial	0.27	2395
Electric heating	Electric heating-commercial		commercial	no	Electricity-Commercial	0.09	1389
Oil fired absorption heat pump	Oil fired absorption heat pump-commercial		commercial	no	Natural gas-Commercial	0.27	2395
Air cooled chiller	Air cooled chiller-commercial		commercial	no	Electricity-Commercial	0.28	2360
Wood pellet boiler	Wood pellet boiler-commercial		commercial	no	Natural gas-Commercial	0.57	0
TTES	TTES-commercial		commercial	no	Natural gas-Commercial	180	0
Kendal (DH)	Kendal (DH)-commercial		commercial	yes	Natural gas-Commercial	1.07	31859
Harvard district heating	Harvard district heating-commercial		commercial	yes	Natural gas-Commercial	0.76	0
MIT district heating	MIT district heating-commercial		commercial	yes	Natural gas-Commercial	0.76	0
None	None-commercial		commercial	no	Natural gas-Commercial	0.07	2335
Electric heating	Electric heating-residential		residential	no	Electricity-Residential	0.09	1389
Harvard district cooling	Harvard district cooling-commercial		commercial	no	Natural gas-Commercial	0.28	2360
MIT district cooling	MIT district cooling-commercial		commercial	no	Natural gas-Commercial	0.28	2360
No cooling	No cooling-commercial		commercial	no	Natural gas-Commercial	0.28	2360
Biomass plant	Biomass plant-commercial		commercial	yes	Wood chips-Commercial	2.12	65332
VGS-HP	VGS-HP-residential		residential	no	Electricity-Residential	1.78	2395
ATES-cool	ATES-cool-residential		residential	no	Electricity-Residential	0.00	0
ATES-heat	ATES-heat-residential		residential	no	Electricity-Residential	0.78	2395
Air source heat pump	Air source heat pump-residential		residential	no	Electricity-Residential	0.41	2395
Ground source heat pump	Ground source heat pump-residential		residential	no	Electricity-Residential	1.95	2395
Gas boiler	Gas boiler-residential		residential	no	Natural gas-Residential	0.22	17045
Oil boiler	Oil boiler-residential		residential	no	Oil-Residential	0.13	22727
Air-to-water heat pump	Air-to-water heat pump-residential		residential	no	Electricity-Residential	0.45	2395
Unknown	Unknown-commercial		commercial	no			
	-			no			
Solar PV	Solar PV-			no		1.48	14750
Solar thermal	Solar thermal-			no		0.23	0

Appendix 5. Technology characteristics

Technology	Name	Variable O&M \$/MWh-heat	Lifetime year	CV	CB	Technology Cost Estimates		
						Electric efficiency CHP MW-el/MW-fuel	Efficiency MW-heat/MW-fuel	Electric efficiency condensing MW-el/MW-fuel
Air source heat pump	Air source heat pump-commercial	2.16	25	0.00	0.00	0%	200%	0%
Ground source heat pump	Ground source heat pump-commercial	2.16	25	0.00	0.00	0%	350%	0%
Gas boiler	Gas boiler-commercial	1.32	25	0.00	0.00	0%	85%	0%
Oil boiler	Oil boiler-commercial	1.90	25	0.00	0.00	0%	80%	0%
Gas fired absorption heat pump	Gas fired absorption heat pump-commercial	2.16	25	0.00	0.00	0%	150%	0%
Electric heating	Electric heating-commercial	0.64	20	0.00	0.00	0%	99%	0%
Oil fired absorption heat pump	Oil fired absorption heat pump-commercial	2.16	25	0.00	0.00	0%	130%	0%
Air cooled chiller	Air cooled chiller-commercial	2.12	25	0.00	0.00	0%	450%	0%
Wood pellet boiler	Wood pellet boiler-commercial	3.41	20	0.00	0.00	0%	85%	0%
TTES	TTES-commercial	0.00	30	0.00	0.00	0%	0%	0%
Kendal (DH)	Kendal (DH)-commercial	0.68	30	0.00	0.75	30%	40%	30%
Harvard district heating	Harvard district heating-commercial	4.35	25	0.00	0.78	30%	38%	30%
MIT district heating	MIT district heating-commercial	4.35	25	0.00	0.67	30%	45%	30%
None	None-commercial	1.32	25	0.00	0.00	0%	103%	0%
Electric heating	Electric heating-residential	0.64	20	0.00	0.00	0%	99%	0%
Harvard district cooling	Harvard district cooling-commercial	2.12	25	0.00	0.00	0%	70%	0%
MIT district cooling	MIT district cooling-commercial	2.12	25	0.00	0.00	0%	70%	0%
No cooling	No cooling-commercial	2.12	25	0.00	0.00	0%	70%	0%
Biomass plant	Biomass plant-commercial	2.34	40	0.00	0.50	30%	60%	30%
VGS-HP	VGS-HP-residential	2.16	25	0.00	0.00	0%	400%	0%
ATES-cool	ATES-cool-residential	0.00	25	0.00	0.00	0%	4000%	0%
ATES-heat	ATES-heat-residential	2.16	25	0.00	0.00	0%	400%	0%
Air source heat pump	Air source heat pump-residential	2.16	25	0.00	0.00	0%	200%	0%
Ground source heat pump	Ground source heat pump-residential	2.16	25	0.00	0.00	0%	350%	0%
Gas boiler	Gas boiler-residential	0.01	22	0.00	0.00	0%	80%	0%
Oil boiler	Oil boiler-residential	0.00	20	0.00	0.00	0%	70%	0%
Air-to-water heat pump	Air-to-water heat pump-residential	2.16	25	0.00	0.00	0%	250%	0%
Unknown	Unknown-commercial	-	-	-	-	-	-	-
Solar PV	Solar PV-	0.00	20	-	-	-	-	-
Solar thermal	Solar thermal-	0.57	30	-	-	-	-	-

Appendix 5. Technology characteristics

Technology	Name	Technology Cost Estimates					
		Emission factor CO2	Emission factor SO2	Emission factor NOx	Emission factor CH4	Emission factor N2O	Emission factor PM2.5
		kg/GJ fuel	g/GJ	g/GJ fuel	g/GJ fuel	g/GJ fuel	g/GJ fuel
Air source heat pump	Air source heat pump-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Ground source heat pump	Ground source heat pump-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Gas boiler	Gas boiler-commercial	57.10	0.40	33.00	1.00	1.00	0.10
Oil boiler	Oil boiler-commercial	79.20	100.00	138.00	0.80	0.30	2.50
Gas fired absorption heat pump	Gas fired absorption heat pump-commercial	57.10	0.40	33.00	1.00	1.00	0.10
Electric heating	Electric heating-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Oil fired absorption heat pump	Oil fired absorption heat pump-commercial	79.20	100.00	138.00	0.80	0.30	2.50
Air cooled chiller	Air cooled chiller-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Wood pellet boiler	Wood pellet boiler-commercial	0.00	11.00	81.00	11.00	4.00	10.00
TTES	TTES-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Kendal (DH)	Kendal (DH)-commercial	57.10	0.40	55.00	1.00	1.00	0.10
Harvard district heating	Harvard district heating-commercial	57.10	0.40	48.00	1.70	1.00	0.05
MIT district heating	MIT district heating-commercial	57.10	0.40	48.00	1.70	1.00	0.05
None	None-commercial	57.10	0.40	33.00	1.00	1.00	0.10
Electric heating	Electric heating-residential	0.00	0.00	0.00	0.00	0.00	0.00
Harvard district cooling	Harvard district cooling-commercial	0.00	0.00	0.00	0.00	0.00	0.00
MIT district cooling	MIT district cooling-commercial	0.00	0.00	0.00	0.00	0.00	0.00
No cooling	No cooling-commercial	0.00	0.00	0.00	0.00	0.00	0.00
Biomass plant	Biomass plant-commercial	0.00	8.35	33.30	0.00	0.00	1.32
VGS-HP	VGS-HP-residential	0.00	0.00	0.00	0.00	0.00	0.00
ATES-cool	ATES-cool-residential	0.00	0.00	0.00	0.00	0.00	0.00
ATES-heat	ATES-heat-residential	0.00	0.00	0.00	0.00	0.00	0.00
Air source heat pump	Air source heat pump-residential	0.00	0.00	0.00	0.00	0.00	0.00
Ground source heat pump	Ground source heat pump-residential	0.00	0.00	0.00	0.00	0.00	0.00
Gas boiler	Gas boiler-residential	57.10	0.40	33.00	1.00	1.00	0.10
Oil boiler	Oil boiler-residential	79.20	100.00	138.00	0.80	0.30	2.50
Air-to-water heat pump	Air-to-water heat pump-residential	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	Unknown-commercial	-	-	-	-	-	-
Solar PV	Solar PV-	-	-	-	-	-	-
Solar thermal	Solar thermal-	-	-	-	-	-	-

Appendix 5. Fuel price projections, commercial

Commercial												
<i>S/MWh</i>	<i>Electricity</i>	<i>Natural gas</i>	<i>Coal</i>	<i>Fueloil</i>	<i>Oil</i>	<i>Straw</i>	<i>Wood chips</i>	<i>Wood pellets</i>	<i>Energy crops</i>	<i>Local biomass</i>	<i>Municipal waste</i>	
<i>Name</i>	Electricity-Commercial	Natural gas-Commercial	Coal-Commercial	Fueloil-Commercial	Oil-Commercial	Straw-Commercial	Wood chips-Commercial	Wood pellets-Commercial	Energy crops-Commercial	Local biomass-Commercial	Municipal waste-Commercial	
<i>Source</i>	--	--	--	--	--	--	--	--	--	--	--	
2017	121	19	9	37	53	24	27	39	28	11	0	
2018	122	19	9	37	54	24	27	40	28	11	0	
2019	122	20	9	37	54	24	27	40	28	11	0	
2020	123	20	9	37	53	25	27	40	28	11	0	
2021	123	20	9	36	53	25	28	40	28	11	0	
2022	123	21	10	37	53	25	28	40	28	11	0	
2023	124	21	10	38	55	25	28	41	28	11	0	
2024	124	21	11	40	56	26	28	41	28	11	0	
2025	124	21	11	42	58	26	29	41	28	11	0	
2026	125	22	11	44	61	26	29	41	28	11	0	
2027	125	22	12	47	63	26	29	41	28	11	0	
2028	125	22	12	50	67	27	29	41	28	11	0	
2029	126	23	13	53	70	27	30	42	28	11	0	
2030	126	23	13	57	74	27	30	42	28	11	0	
2031	126	23	13	58	75	27	30	42	28	11	0	
2032	127	24	14	59	76	27	30	42	28	11	0	
2033	127	24	14	60	77	28	31	42	28	11	0	
2034	128	25	14	61	78	28	31	43	28	11	0	
2035	128	25	14	62	78	28	31	43	28	11	0	
2036	128	25	14	63	79	28	31	43	28	11	0	
2037	129	26	14	64	80	28	32	43	28	11	0	
2038	129	26	14	64	81	29	32	43	28	11	0	
2039	129	26	14	65	82	29	32	44	28	11	0	
2040	130	27	14	66	83	29	32	44	28	11	0	

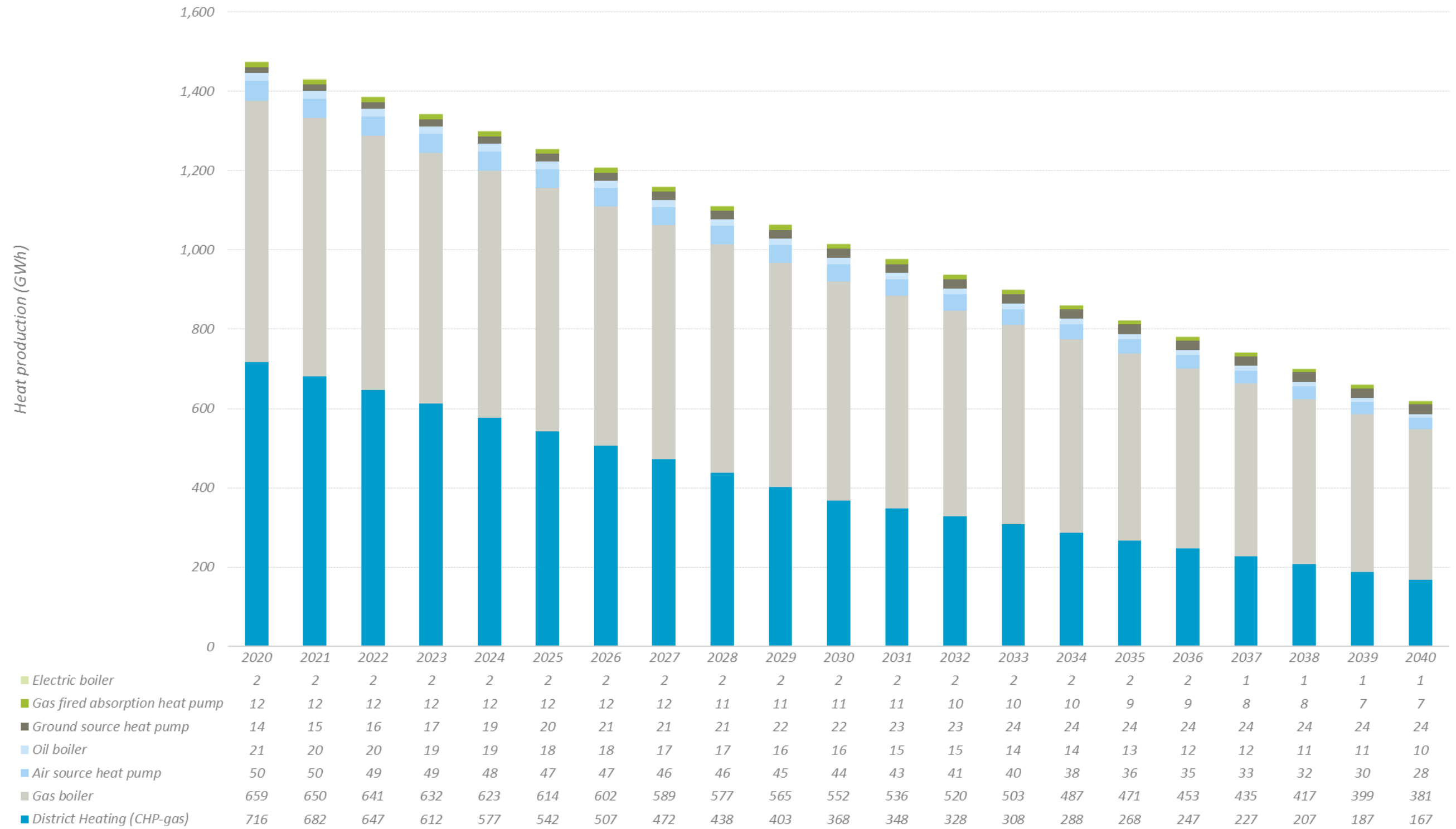
NOTE: Electricity price includes average of delivery prices

Appendix 5. Fuel price projections, residential

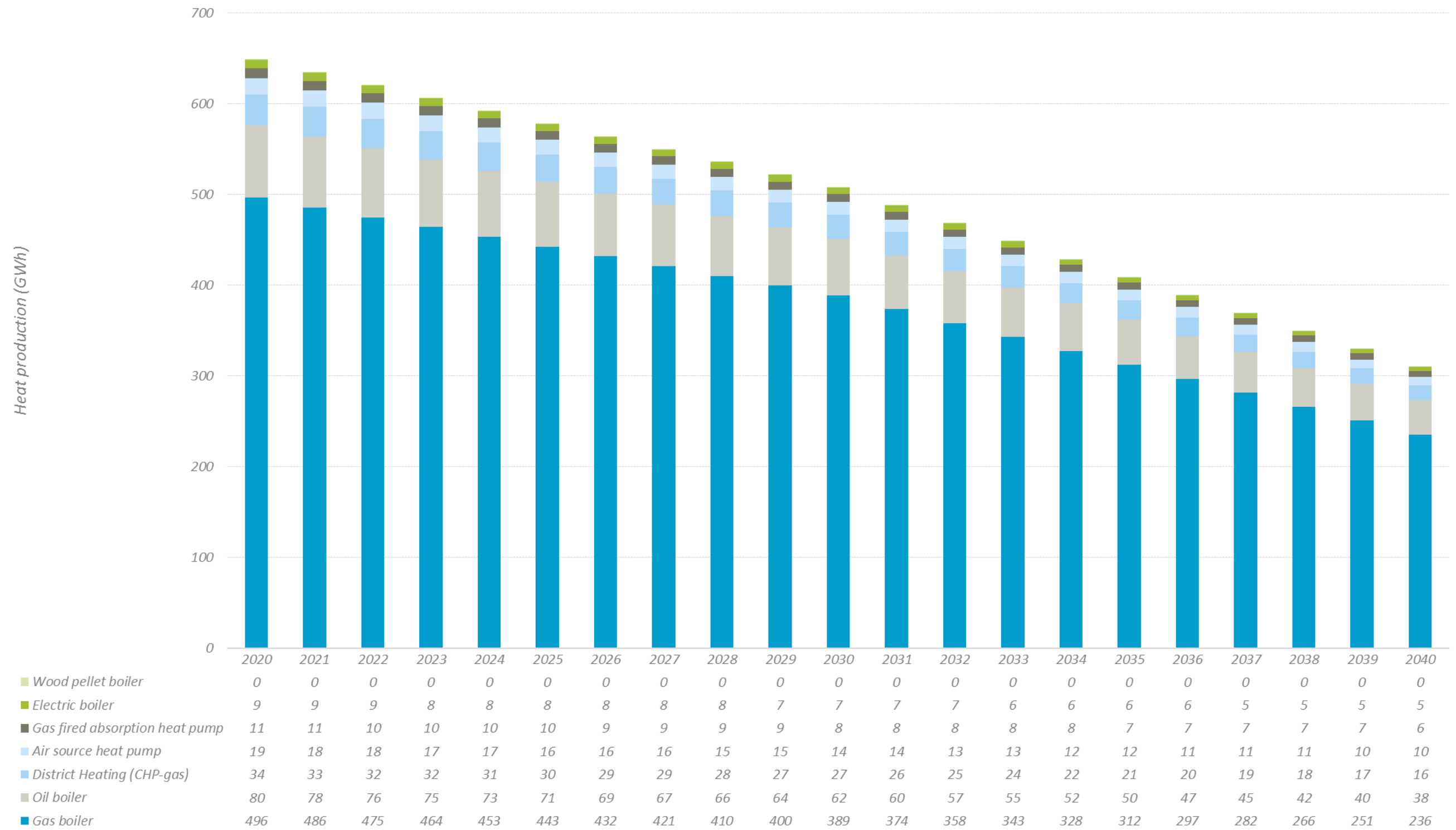
Residential												
<i>S/MWh</i>	<i>Electricity</i>	<i>Natural gas</i>	<i>Coal</i>	<i>Fueloil</i>	<i>Oil</i>	<i>Straw</i>	<i>Wood chips</i>	<i>Wood pellets</i>	<i>Energy crops</i>	<i>Local biomass</i>	<i>Municipal waste</i>	
---	Electricity-Residential	Natural gas-Residential	Coal-Residential	Fueloil-Residential	Oil-Residential	Straw-Residential	Wood chips-Residential	Wood pellets-Residential	Energy crops-Residential	Local biomass-Residential	Municipal waste-Residential	
<i>Source</i>	---	---	---	---	---	---	---	---	---	---	---	
2017	251	39	9	37	53	24	27	39	28	11	0	
2018	254	40	9	37	54	24	27	40	28	11	0	
2019	257	40	9	37	54	24	27	40	28	11	0	
2020	259	41	9	37	53	25	27	40	28	11	0	
2021	262	41	9	36	53	25	28	40	28	11	0	
2022	265	42	10	37	53	25	28	40	28	11	0	
2023	268	42	10	38	55	25	28	41	28	11	0	
2024	271	43	11	40	56	26	28	41	28	11	0	
2025	274	43	11	42	58	26	29	41	28	11	0	
2026	277	44	11	44	61	26	29	41	28	11	0	
2027	280	44	12	47	63	26	29	41	28	11	0	
2028	283	45	12	50	67	27	29	41	28	11	0	
2029	286	45	13	53	70	27	30	42	28	11	0	
2030	289	46	13	57	74	27	30	42	28	11	0	
2031	292	46	13	58	75	27	30	42	28	11	0	
2032	295	47	14	59	76	27	30	42	28	11	0	
2033	298	47	14	60	77	28	31	42	28	11	0	
2034	301	48	14	61	78	28	31	43	28	11	0	
2035	304	48	14	62	78	28	31	43	28	11	0	
2036	308	49	14	63	79	28	31	43	28	11	0	
2037	311	49	14	64	80	28	32	43	28	11	0	
2038	314	50	14	64	81	29	32	43	28	11	0	
2039	318	50	14	65	82	29	32	44	28	11	0	
2040	321	51	14	66	83	29	32	44	28	11	0	

NOTE: Electricity price includes average of delivery prices

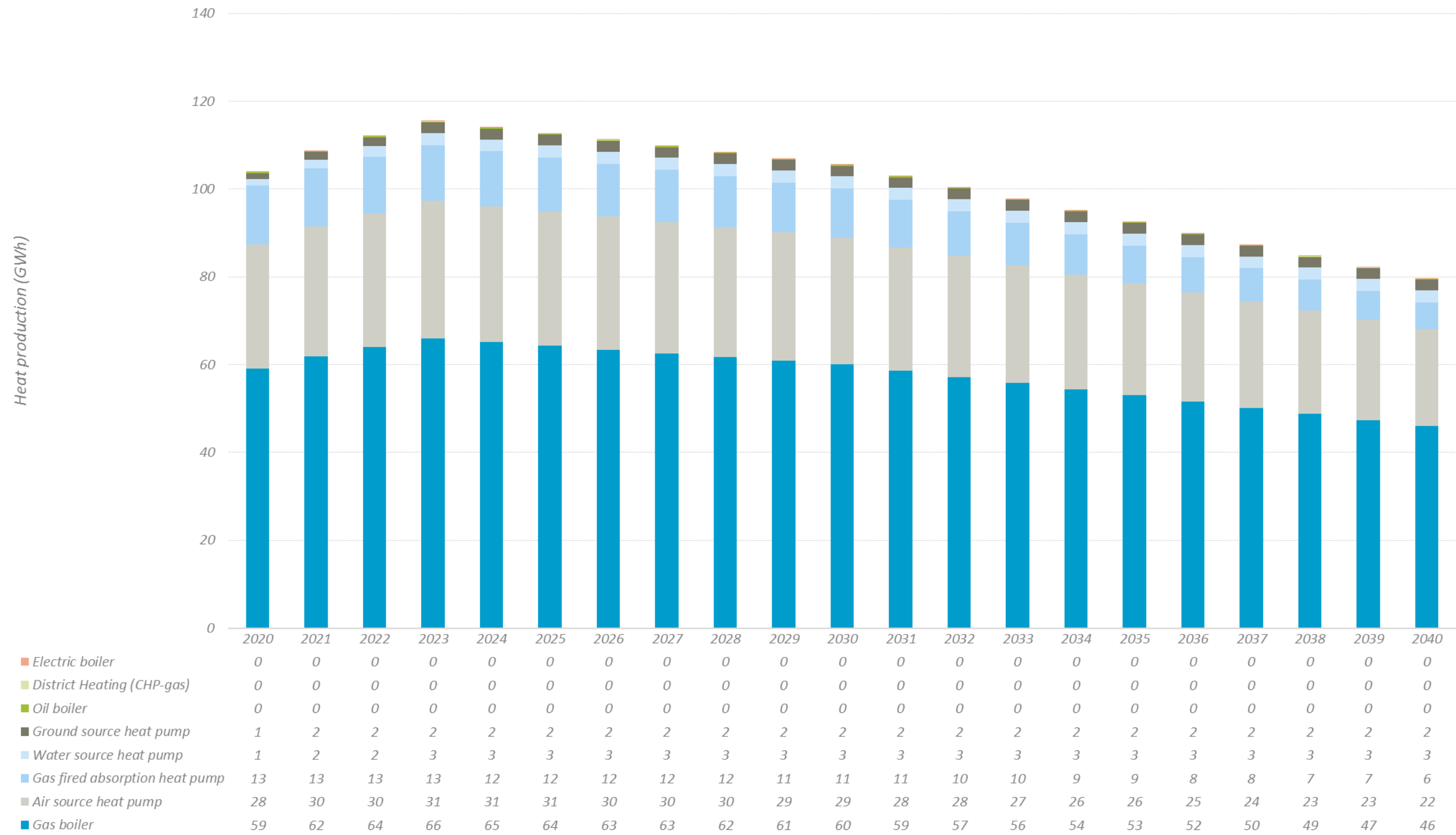
Appendix 5. Development of heat demand in zone 1 for BaU scenario.



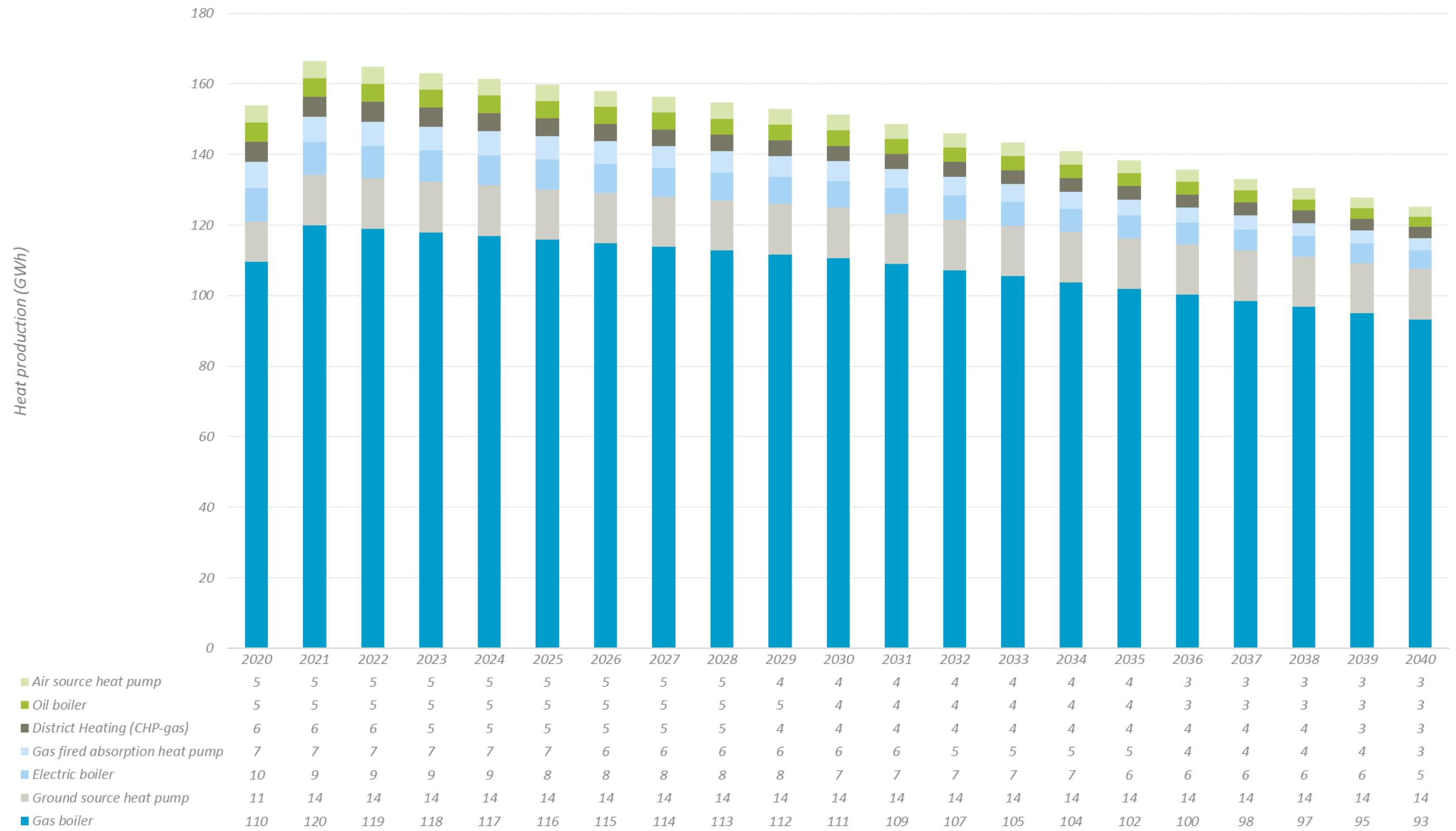
Appendix 5. Development of heat production in zone 2 for BaU scenario



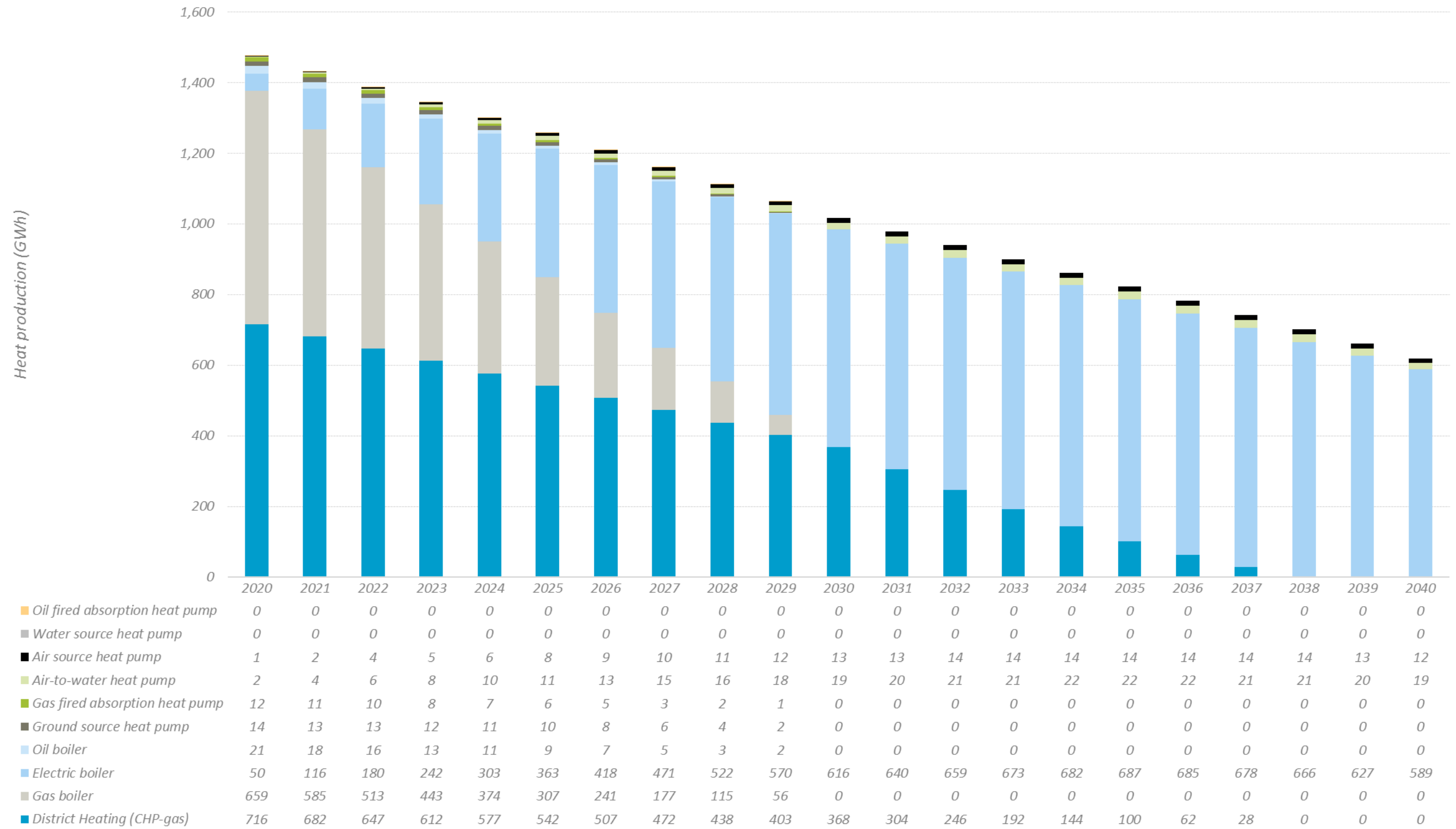
Appendix 5. Development of heat production in zone 3 for BaU scenario



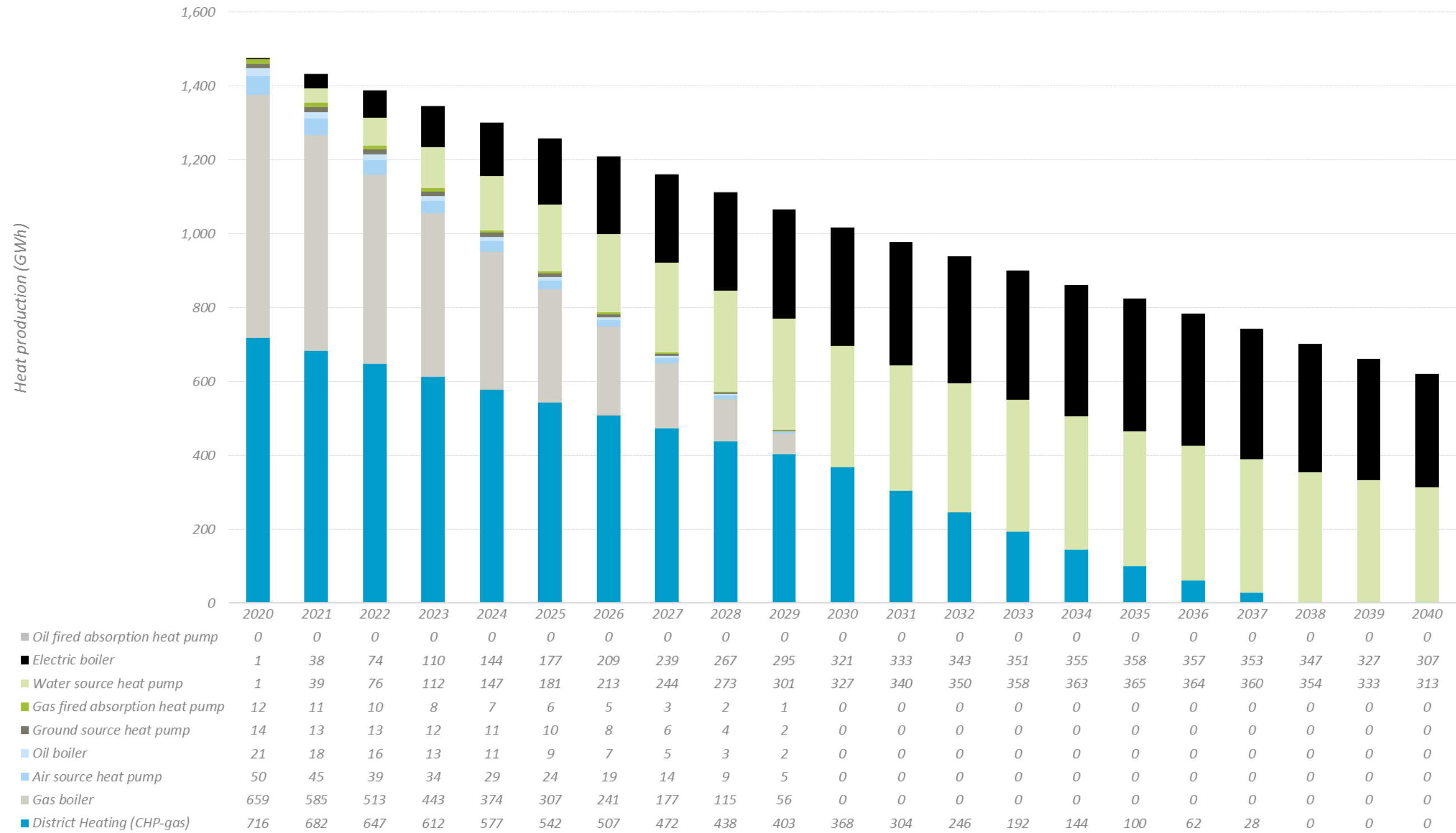
Appendix 5 Development of heat production in zone 4 for BaU scenario



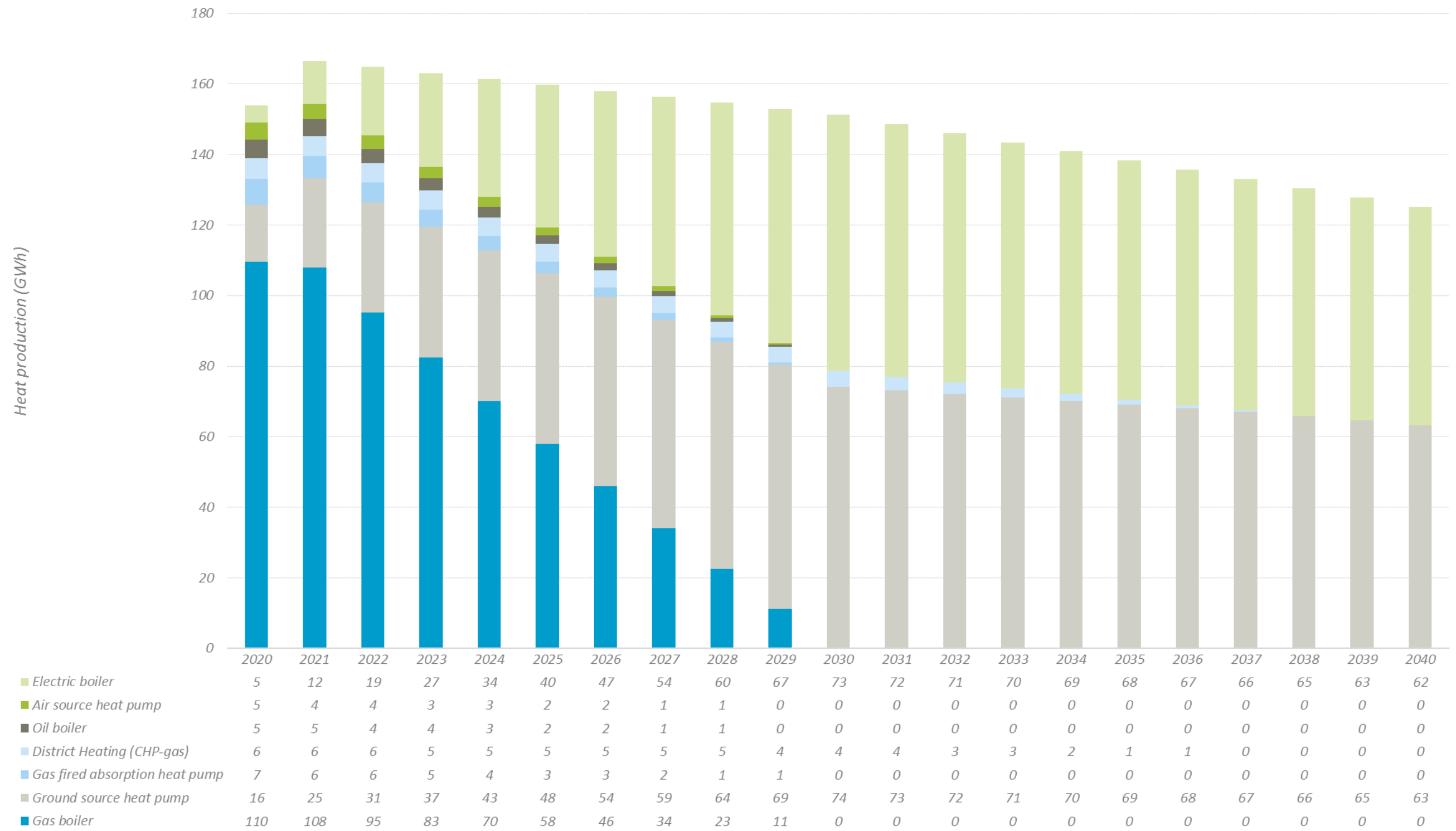
Appendix 5. Development of heat demand in zone 1 for scenario 1.



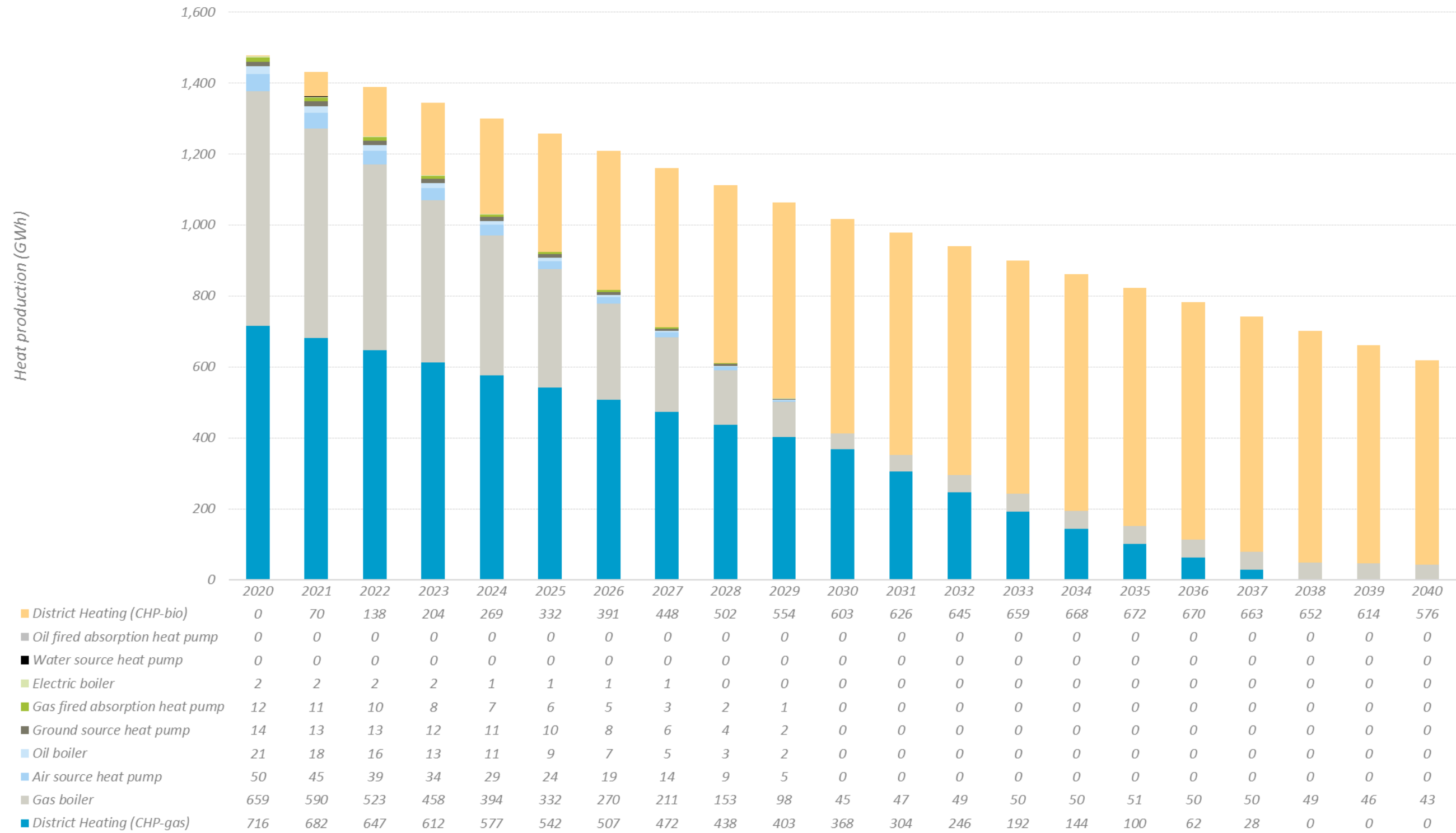
Appendix 5. Development of heat production in zone 1 for scenario 2.



Appendix 5. Development of heat demand in zone 4 for scenario 2 and 4



Appendix 5. Development of heat production in zone 1 for scenario 4.



Appendix 5. Development of heat demand in zone 3 for scenario 4

