Appendix B Technology database

Below in tables B.1 – B.13 an overview of future technologies included in TIMES-Europe is given. The data sources used in compiling this database are included in the main text of the paper.

Table B.1 Techno-economic parameters of investable renewable electricity generation technologies based on solar, wind, geothermal heat and hydro energy included in TIMES-Europe.

Technology	**Input**	**Output**	**Start year**	**Technical lifetime (yr)**	**Investment cost [M€/GW]**	**Fixed O&M Costs [% of Inv. cost]**
PV - Residential	Solar	Electricity	2020	30	2020: 1080 2030: 942 2040: 764 2050: 655	2%
PV - Commercial	Solar	Electricity	2020	30	2020: 905 2030: 790 2040: 640 2050: 549	2.5%
PV - Utility - Field - fixed orientation	Solar	Electricity	2020	30	2020: 810 2030: 707 2040: 573 2050: 491	1.7%
PV - Utility - Field - tracking	Solar	Electricity	2020	30	2020: 889 2030: 776 2040: 629 2050: 539	2.3%
CSP Parabolic Trough	Solar	Electricity	2020	30	2020: 4414 2030: 3727 2040: 3433 2050: 3335	3%
CSP Solar Tower	Solar	Electricity	2020	30	2020: 6451 2030: 5447 2040: 5017 2050: 4873	3%
Hydrothermal Flash plant	Geothermal heat	Electricity	2020	30	2020: 3364 2030: 3193 2040: 3103 2050: 3005	2%

Hydrothermal ORC plant	Geothermal heat	Electricity	2020	30	2020: 6623 2030: 6286 2040: 6109 2050: 5916	2%
Enhanced Geothermal System - ORC plant	Geothermal heat	Electricity	2020	30	2020: 11204 2030: 10633 2040: 10334 2050: 10007	2%
Wind Onshore - Low Capacity factor	Wind	Electricity	2020	25	2020: 1038 2030: 1001 2040: 964 2050: 939	1%
Wind Onshore - Medium Capacity factor	Wind	Electricity	2020	25	2020: 1285 2030: 1240 2040: 1195 2050: 1164	1%
Wind Onshore - High Capacity factor	Wind	Electricity	2020	25	2020: 1761 2030: 1699 2040: 1637 2050: 1595	1%
Wind Offshore fixed pole	Wind	Electricity	2020	25	2020: 2487 2030: 2368 2040: 2289 2050: 2198	2.5%
Wind Offshore floating	Wind	Electricity	2020	25	2020: 4559 2030: 4342 2040: 4197 2050: 4029	2%
Hydropower - impoundment	Hydro energy	Electricity	2020	75	1380	2%
Hydropower - run of river	Hydro energy	Electricity	2020	75	2940	2%
Tidal stream	Tidal	Electricity	2025	20	2020: 7095 2030: 5784 2040: 4697 2050: 4036	6%
Tidal range (dam)	Tidal	Electricity	2025	20	2020: 5574 2030: 4544	6%

					2040: 3691 2050: 3171	
Wave energy converter	Wave	Electricity	2025	20	2020: 7158 2030: 5835 2040: 4739 2050: 4072	4%

Table B.2 Techno-economic parameters of investable thermal electricity generation technologies based on natural gas, biomass, municipal waste, hydrogen and uranium included in TIMES-Europe.

Technology	**Input**	**Output**	**Efficiency**	**CO_2 capture efficiency**	**Start year**	**Technical lifetime (yr)**	**Investment costs [M€/GW]**	**Fixed O&M Costs [% of Inv. cost]**	**Variable O&M Costs [€/GJ]**
Fluidized Bed Biomass Boiler + steam turbine	Biomass	Electricity	2020: 36% 2030: 37% 2040: 38% 2050: 39%		2020	30	2020: 3334 2030: 3242 2040: 3171 2050: 3057	2%	1.1
Biomass Integrated gasification Combined Cycle	Biomass	Electricity	2020: 37% 2030: 43% 2040: 47% 2050: 48%		2025	30	2020: 4909 2030: 4773 2040: 4669 2050: 4501	2%	2.3
Fluidized Bed Biomass Boiler / steam turbine + post comb. CCS	Biomass	Electricity	2020: 25% 2030: 26% 2040: 27% 2050: 28%	88%	2025	25	2020: 4248 2030: 3956 2040: 3684 2050: 3452	2.6%	2.2
Biomass Integrated gasification Combined Cycle + post comb. CCS	Biomass	Electricity	2020: 29% 2030: 37% 2040: 41% 2050: 42%	88%	2030	25	5700	2.5%	2.6
Power plant on Biogas	Biogas	Electricity	2020: 38% 2030: 40% 2040: 42% 2050: 45%		2020	30	2020: 2871 2030: 2792 2040: 2731 2050: 2632	4%	0.9
Hydrogen fuel cell electricity plant	Hydrogen	Electricity	50%		2025	25	2025: 2001 2030: 1485	10%	1.5

Natural gas - Internal combustion	Natural gas	Electricity	50%		2020	30	2020: 1052 2030: 1030	1.4%	0.6
Natural gas - Advanced combined cycle gas turbine	Natural gas	Electricity	2020: 60% 2030: 62% 2040: 62% 2050: 64%		2020	30	856	2.5%	0.6
Natural gas Advanced combined cycle gas turbine + flue gas CO_2 removal	Natural gas	Electricity	2020: 52% 2030: 55%	86%	2025	30	1480	2.6%	1.1
Nuclear PWR Electricity Plant	Uranium	Electricity	31%		2028	60	4350	2%	0.8

Table B.3 Techno-economic parameters of investable thermal combined heat and power (CHP) plants based on natural gas, biomass, municipal waste and biogas included in TIMES-Europe.

Technology	**Input**	**Output**	**Electrical Efficiency**[1]	**CO_2 capture efficiency**	**Start year**	**Technical lifetime (yr)**	**Investment costs [M€/GW]**	**Fixed O&M Costs [% of Inv. cost]**	**Variable O&M Costs [€/GJ]**
CHP Natural gas Combined Cycle Gas Turbine	Natural gas	Electricity Heat	2020: 47% 2030: 48% 2040: 51%		2020	25	2020: 961 2030: 890	2.6%	2.2
CHP Natural gas Combined Cycle pre comb. CCS	Natural gas	Electricity Heat	2020: 43% 2030: 45%	86%	2020	25	1555	2.5%	2.6
CHP Biogas internal combustion	Biogas	Electricity Heat	40%		2020	25	2020: 1708 2030: 1675	2%	2.5
CHP municipal waste Steam Turbine	Municipal waste	Electricity Heat	2020: 33% 2030: 34%		2020	25	2020: 2228 2030: 1773	2%	2.9
CHP Biomass gasification	Biomass	Electricity Heat	34%		2020	25	2020: 5159 2030: 5015 2040: 4902 2050: 4727	2%	2.3

[1] CHPs are modelled as installations with a flexible heat and electricity output. The electricity lost per unit of heat gained is defined in the range of 0.2 – 0.25.

Table B.4 Techno-economic parameters of investable electricity storage options included in TIMES-Europe.

Technology	**Input**	**Output**	**Storage Efficiency**	**Start year**	**Technical lifetime (yr)**	**Investment costs [M€/GW]**	**Fixed O&M Costs M€/GW]**	**Variable O&M Costs [€/GJ]**
Li-Ion Network Battery E2P 2h	Electricity	Electricity	86%	2020	13	2020: 1023 2030: 428 2040: 298 2050: 260	2020: 6.3[1] 2030: 5.0 2040: 4.7 2050: 4.6	2020: 0.5 2030: 0.4
Li-Ion Network Battery E2P 4h	Electricity	Electricity	86%	2020	13	2020: 1742 2030: 728 2040: 507 2050: 443	2020: 6.3[1] 2030: 5.0 2040: 4.7 2050: 4.6	2020: 0.5 2030: 0.4
Li-Ion Network Battery E2P 8h	Electricity	Electricity	86%	2020	13	2020: 3180 2030: 1330 2040: 925 2050: 809	2020: 6.3[1] 2030: 5.0 2040: 4.7 2050: 4.6	2020: 0.5 2030: 0.4
Pumped Hydro Storage E2P 8h	Electricity	Electricity	80%	2020	50	1442	6.5	0.2
Pumped Hydro Seasonal Storage E2P 32h/64h/128h	Electricity	Electricity	80%	2020	50	32h: 3007 64h: 5093 128h: 9266	6.5	0.2
Diabatic Compressed Air energy storage E2P 8h	Electricity Natural gas	Electricity	54%[2]	2020	30	964	11.4	0.5
Diabatic Compressed Air seasonal energy storage E2P 32h/64h/128h	Electricity Natural gas	Electricity	54%[2]	2020	30	32h: 1727 64h: 2744 128h: 4779	11.4	0.5
Adiabatic Compressed Air energy storage E2P 8h	Electricity	Electricity	75%	2025	30	1598	11.4	0.45
Adiabatic Compressed Air seasonal energy storage E2P 32h/64h/128h	Electricity	Electricity	75%	2025	30	32h: 4611 64h: 8628 128h: 16662	11.4	0.45

[1] 50% of the annual fixed operational and maintenance are assumed to follow the cost reductions estimated for the investment costs (section A.2).

[2] For D-CAES the efficiency refers to the energy efficiency defined as the electrical energy output divided by the sum of the electrical energy input and the fuel (natural gas) consumption.

Table B.5 Techno-economic parameters of investable low-carbon processes enabling decarbonization of the iron and steel production included in TIMES-Europe.

Technology	**Input [PJ]**	**Output**	**CO_2 capture efficiency**	**Start year**	**Technical lifetime (yr)**	**Investment costs [M€/Mt yr^{-1}]**	**Fixed O&M Costs [M€/Mt]**
I&S Blast Furnace with top gas recycling and CCS	Coal – 4.7 Cokes - 4.8 Coke oven gas – 0.3 Electricity – 1.4	Crude Steel Oxygen Furnace gas – 0.7 PJ	75%	2025	25	856	61
I&S Smelting reduction (HIsarna)	Coal – 13.2 Electricity – 1.4	Crude Steel Oxygen Furnace gas – 0.7 PJ	-	2025	25	725	68
I&S Smelting reduction (HIsarna) with CCS	Coal – 13.2 Electricity – 2.3	Crude Steel Oxygen Furnace gas – 0.7 PJ	90%	2025	25	786	74
I&S Direct iron ore reduction with natural gas with CCS + EAF	Natural gas – 9.2 Electricity – 3 Coal – 1.1	Crude Steel	63%[1]	2025	25	804	62
I&S Direct iron ore reduction with hydrogen + EAF	Hydrogen – 5.6 Electricity – 2.2 Natural gas – 1.4 Coal – 1.1	Crude Steel	-	2030	25	637	62
I&S Direct Iron ore reduction with hydrogen + EAF with biomass	Hydrogen – 5.6 Electricity – 2.2 Biomass – 2.1	Crude Steel	-	2035	25	637	62
I&S low temperature iron ore electrolysis	Electricity – 11.2 Natural gas – 0.5 Coal – 0.8	Crude Steel	-	2040	25	895	72
I&S High temperature iron ore electrolysis	Electricity – 14.2	Crude Steel	-	2050	25	682	54

[1] Here, Vacuum Pressure Swing Absorption + compression and cryogenic separation are considered to be applied to the Natural gas Direct Reduction reactor with 93% capture efficiency. Additional emissions from EAF and pelletizing plant result in an overall lower capture efficiency.

Table B.6 Techno-economic parameters of investable low-carbon technologies for the production of low temperature heat (LTH) (excl. heat pumps), process heat (PHTH) and steam and furnace heat (FHTH) included in TIMES-Europe.

Technology	Input	Output	Efficiency	CO_2 capture efficiency	Start year	Technical lifetime (yr)	Investment costs [M€/GW]	Fixed O&M Costs [M€/GW]
Industrial natural gas boiler	Natural gas	PHTH / steam	92.5%		2020	20	18	1.8
Industrial natural gas boiler with CCS	Natural gas	PHTH / steam	85.5%	75%	2025	20	30	6
Industrial electric boiler	Electricity	PHTH / steam	97.5%		2020	20	115	2.3
Industrial coal fueled boiler with CCS	Coal	PHTH / steam	75%	75%	2025	20	40	5
Industrial biomass fueled boiler	Biomass	PHTH / steam	80%		2020	20	400	5
Industrial biomass fueled boiler with CCS	Biomass	PHTH / steam	75%	75%	2025	20	500	15
Industrial hydrogen fueled boiler	Hydrogen	PHTH / steam	2020: 90% 2050: 95%		2030	20	110	2030: 3.5 2050: 1.5
Industrial natural gas fueled furnace	Natural gas	FHTH	83%		2020	20	630	19
Industrial natural gas furnace fueled with CCS	Natural gas	FHTH	77%	80%	2025	20	790	24
Industrial hydrogen fueled furnace	Hydrogen	FHTH	87%		2025	20	1500	15
Industrial electric furnace	Electricity	FHTH	80%		2025	20	1100	22
Industrial biomass digestion	Biomass	LTH	85%		2020	20	700	40

Table B.7 Techno-economic parameters of investable industrial CHP options included in TIMES-Europe.

Technology	Input	Output	Electrical Efficiency[1]	CO_2 capture efficiency	Start year	Technical lifetime (yr)	Investment costs [M€/GW]	Fixed O&M Costs [% of Inv. cost]
Industrial natural gas fueled CHP	Natural gas	Electricity PHTH / Steam	55%		2020	20	690	6%
Industrial natural gas fueled CHP with CCS	Natural gas	Electricity	49%	80%	2025	20	830	6%
Industrial coal fueled CHP	Coal	Electricity PHTH / Steam	40%		2020	20	1300	6%
Industrial coal fueled CHP with CCS	Coal	Electricity PHTH / Steam	35%	80%	2025	20	1560	6%
Industrial biomass fueled CHP	Biomass	Electricity PHTH / Steam	31%		2020	20	2110	6%
Industrial biomass fueled CHP with CCS	Biomass	Electricity PHTH / Steam	27%	80%	2025	20	2530	6%
Industrial CHP fueled with manufactured gases	Blast furnace gas Coke oven gas Natural gas	Electricity PHTH / Steam	42%		2020	20	1100	6%

[1] CHPs are modelled as installations with a flexible heat and electricity output. The electricity lost per unit of heat gained is defined in the range of 0.2 – 0.25.

Table B.8 Techno-economic parameters of investable industrial heat pump options for the generation of low temperature heat included in TIMES-Europe.

Technology	Input	Output	COP	Start year	Technical lifetime (yr)	Investment costs [M€/GW]	Fixed O&M Costs [M€/GW]
Industrial Natural gas fueled Air Heat Pump	Natural gas Ambient Heat	LTH	1.4	2020	20	550	8
Industrial Electric Air Heat Pump	Electricity Ambient Heat	LTH	4	2020	20	2020: 1200 2030: 1000 2050: 800	15
Industrial Electric Ground Heat Pump	Electricity Geothermal heat	LTH	4	2020	20	900	20

Table B.9 Techno-economic parameters of investable road transportation options for passenger, bus and freight transportation included in TIMES-Europe.

Technology	**Input**	**Output**	**Efficiency**	**Start year**	**Technical lifetime (yr)**	**Investment cost [k€/unit]**	**Fixed O&M Costs [% of Inv. cost]**
Gasoline passenger car - small	Gasoline	Passenger transport - car	2020: 0.5 2030: 0.53 2040: 0.56 2050: 0.58	2020	15	14.3	3%
Diesel passenger car - medium	Diesel	Passenger transport - car	2020: 0.52 2030: 0.55 2040: 0.58 2050: 0.61	2020	15	21.8	3%
CNG passenger car - medium	CNG	Passenger transport - car	2020: 0.46 2030: 0.48 2040: 0.50 2050: 0.53	2020	15	23.1	3%
LPG passenger car - medium	LPG	Passenger transport - car	2020: 0.46 2030: 0.48 2040: 0.50 2050: 0.53	2020	15	22.5	3%
Gasoline Plug-in Hybrid passenger car - large	Gasoline Electricity	Passenger transport - car	Gasoline: 0.4 Elec.: 1.6	2020	15	36.7	3%
Battery electric passenger car - small	Electricity	Passenger transport - car	2020: 1.7 2030: 1.8 2040: 1.9 2050: 2	2020	15	2020: 23.2 2030: 20.7 2040: 19.8 2050: 19.3	1%
New hydrogen fuel cell Passenger car - medium	Hydrogen	Passenger transport - Car	2020: 0.76 2030: 0.8 2040: 0.84 2050: 0.88	2020	20	2020: 50.8 2030: 40.3 2040: 38.4 2050: 36.8	3%
Diesel bus public transport - Low efficiency	Diesel	Passenger transport - Bus	2020: 0.078 2030: 0.079 2040: 0.081 2050: 0.083	2020	20	2020: 277 2030: 278 2040: 280 2050: 282	2%

Diesel bus public transport - High efficiency	Diesel	Passenger transport - Bus	2020: 0.083 2030: 0.085 2040: 0.088 2050: 0.091	2020	20	2020: 282 2030: 285 2040: 289 2050: 293	2%
CNG bus public transport - Low efficiency	CNG	Passenger transport - Bus	2020: 0.070 2030: 0.071 2040: 0.073 2050: 0.075	2020	20	2020: 301 2030: 302 2040: 304 2050: 306	2%
CNG bus public transport - High efficiency	CNG	Passenger transport - Bus	2020: 0.075 2030: 0.077 2040: 0.079 2050: 0.081	2020	20	2020: 306 2030: 309 2040: 313 2050: 317	2%
LPG bus public transport - Low efficiency	LPG	Passenger transport - Bus	2020: 0.097 2030: 0.099 2040: 0.101 2050: 0.103	2020	20	2020: 294 2030: 295 2040: 297 2050: 299	2%
LPG bus public transport - High efficiency	LPG	Passenger transport - Bus	2020: 0.103 2030: 0.106 2040: 0.109 2050: 0.113	2020	20	2020: 299 2030: 302 2040: 306 2050: 310	2%
Diesel hybrid bus public transport - Low efficiency	Diesel	Passenger transport - Bus	2020: 0.10 2030: 0.101 2040: 0.102 2050: 0.104	2020	20	2020: 294 2030: 295 2040: 296 2050: 298	2%
Diesel hybrid bus public transport - High efficiency	Diesel	Passenger transport - Bus	2020: 0.105 2030: 0.107 2040: 0.108 2050: 0.110	2020	20	2020: 301 2030: 302 2040: 307 2050: 311	2%
Battery electric bus public transport	Electricity	Passenger transport - Bus	2020: 0.24 2030: 0.25 2040: 0.27 2050: 0.28	2020	20	2020: 428 2030: 330 2040: 326 2050: 314	1%
Fuel cell bus public transport	Hydrogen	Passenger transport - Bus	2020: 0.102 2030: 0.109 2040: 0.117 2050: 0.117	2020	20	2020: 600 2030: 391 2040: 334 2050: 319	2%

Gasoline LCV	Gasoline	Freight transport – LCV	2020: 0.41 2030: 0.44 2040: 0.48 2050: 0.50	2020	15	2020: 17.9 2030: 18.0 2040: 19.2 2050: 21.6	3%
Diesel LCV - Low efficiency	Diesel	Freight transport – LCV	2020: 0.50 2030: 0.54 2040: 0.54 2050: 0.54	2020	15	2020: 22.5 2030: 22.8 2040: 22.8 2050: 22.8	3%
Diesel LCV - High efficiency	Diesel	Freight transport – LCV	2020: 0.54 2030: 0.56 2040: 0.56 2050: 0.56	2020	15	2020: 26.9 2030: 24.8 2040: 24.8 2050: 24.8	3%
CNG LCV	CNG	Freight transport – LCV	2020: 0.42 2030: 0.49 2040: 0.51 2050: 0.52	2020	15	2020: 20.0 2030: 21.3 2040: 23.6 2050: 23.6	3%
LPG LCV - Low efficiency	LPG	Freight transport – LCV	2020: 0.54 2030: 0.58 2040: 0.63 2050: 0.63	2020	15	2020: 19.4 2030: 19.5 2040: 20.7 2050: 20.7	3%
LPG LCV - High efficiency	LPG	Freight transport – LCV	2020: 0.65 2030: 0.68 2040: 0.68 2050: 0.68	2020	15	2020: 34.3 2030: 28.5 2040: 28.5 2050: 28.5	3%
Diesel plug-in hybrid LCV	Diesel Electricity	Freight transport – LCV	Diesel: 0.50 Elec.: 1.63	2020	15	2020: 22.5 2030: 22.8 2040: 22.8 2050: 22.8	3%
Gasoline plug-in hybrid LCV	Gasoline Electricity	Freight transport – LCV	Gasoline: 0.41 Elec.: 1.63	2020	15	2020: 25.9 2030: 21.0 2040: 19.8 2050: 19.5	3%
Battery electric LCV	Electricity	Freight transport – LCV	2020: 1.63 2030: 1.72 2040: 1.81 2050: 1.90	2020	15	2020: 22.8 2030: 21.2 2040: 20.6 2050: 19.8	1%

Fuel cell LCV - Low efficiency	Hydrogen	Freight transport – LCV	2020: 0.69 2030: 0.72 2040: 0.76 2050: 0.79	2020	15	2020: 45.8 2030: 33.9 2040: 28.4 2050: 27.3	3%
Fuel cell LCV - High efficiency	Hydrogen	Freight transport – LCV	2020: 0.83 2030: 0.88 2040: 0.93 2050: 0.99	2020	15	2020: 50.5 2030: 36.9 2040: 29.8 2050: 28.6	3%
Diesel HDV - Low efficiency	Diesel	Freight transport – HDV	2020: 0.107 2030: 0.117 2040: 0.122 2050: 0.122	2020	15	2020: 106 2030: 105 2040: 105 2050: 105	3%
Diesel HDV - High efficiency	Diesel	Freight transport – HDV	2020: 0.122 2030: 0.127 2040: 0.132 2050: 0.132	2020	15	2020: 117 2030: 107 2040: 110 2050: 109	3%
Diesel hybrid HDV - Low efficiency	Diesel	Freight transport – HDV	2020: 0.129 2030: 0.134 2040: 0.134 2050: 0.134	2020	15	2020: 127 2030: 117 2040: 116 2050: 115	3%
Diesel hybrid HDV - High efficiency	Diesel	Freight transport – HDV	2020: 0.139 2030: 0.139 2040: 0.145 2050: 0.145	2020	15	2020: 132 2030: 122 2040: 128 2050: 127	3%
LNG HDV - Low efficiency	LNG	Freight transport – HDV	2020: 0.089 2030: 0.098 2040: 0.102 2050: 0.102	2020	15	2020: 137 2030: 136 2040: 136 2050: 136	3%
LNG HDV - High efficiency	LNG	Freight transport – HDV	2020: 0.102 2030: 0.111 2040: 0.111 2050: 0.111	2020	15	2020: 148 2030: 141 2040: 141 2050: 140	3%
LPG HDV	LPG	Freight transport – HDV	2020: 0.124 2030: 0.141 2040: 0.147 2050: 0.153	2020	15	2020: 117 2030: 116 2040: 118 2050: 120	3%

Fuel cell HDV - Low efficiency	Hydrogen	Freight transport – HDV	2020: 0.149 2030: 0.153 2040: 0.169 2050: 0.182	2020	15	2020: 354 2030: 207 2040: 163 2050: 148	3%
Fuel cell HDV - High efficiency	Hydrogen	Freight transport – HDV	2020: 0.189 2030: 0.189 2040: 0.189 2050: 0.189	2020	15	2020: 373 2030: 228 2040: 165 2050: 149	3%
Battery electric HDV - range 500km	Electricity	Freight transport – HDV	2020: 0.214 2030: 0.225 2040: 0.236 2050: 0.248	2020	15	2020: 258 2030: 174 2040: 153 2050: 142	1%

Table B.10 Techno-economic parameters of investable options for space heating, space cooling, hot water (excl. heat pumps) and cooking for deployment in the Residential sector included in TIMES-Europe.

Technology	**Input**	**Output**	**Efficiency**	**Technical lifetime (yr)**	**Investment cost [k€/Dwelling]**	**Fixed O&M Costs [% of Inv. cost]**
Residential sector combi boiler - Oil	Oil	Space heating Hot water	75%	15	Central: 8.9 North: 8.9 East: 5.6 South: 5.6	1%
Residential sector combi boiler - Gas	Natural gas	Space heating Hot water	85%	15	Central: 6.0 North: 6.0 East: 4.0 South: 4.0	1%
Residential sector combi boiler - Biomass	Biomass	Space heating Hot water	67%	20	Central: 12.6 North: 12.6 East: 10.1 South: 10.1	1%
Residential sector combi boiler - Electric	Electricity	Space heating Hot water	100%	15	Central: 3.0 North: 1.7 East: 1.4	1%

					South: 0.5	
Residential sector district heating installation	Heat	Space heating Hot water	100%	30	Central: 17.5 North: 13.0 East: 11.0 South: 17.5	1%
Residential sector water boiler - Gas	Natural gas	Hot water	85%	30	Central: 0.6 North: 0.6 East: 0.6 South: 0.6	1%
Residential sector water boiler - Electric	Electricity	Hot water	100%	30	Central: 0.6 North: 0.6 East: 0.6 South: 0.6	1%
Residential sector space cooling - Electric	Electricity	Space cooling	100%	30	Central: 0.6 North: 0.6 East: 0.6 South: 0.6	1%
Residential sector cooking - Electric	Electricity	Cooking	100%	30	Central: 1.5 North: 1.5 East: 1.5 South: 1.5	1%
Residential sector cooking - Gas	Natural gas	Cooking	85%	30	Central: 0.9 North: 0.9 East: 0.9 South: 0.9	1%
Residential sector cooking - LPG	LPG	Cooking	85%	30	Central: 0.9 North: 0.9 East: 0.9 South: 0.9	1%

Table B.11 Techno-economic parameters of investable heat pump options for space heating, space cooling and hot water for deployment in the Residential sector included in TIMES-Europe.

Technology	**Input**	**Output**	**COP**	**Technical lifetime (yr)**	**Investment cost [k€/Dwelling]**	**Fixed O&M Costs [% of Inv. cost]**
Residential sector air to air heat pump	Electricity Ambient heat	Space heating Cooling	2.5	18	Central: 1.8 North: 1.8 East: 1.8 South: 1.8	1%
Residential sector air to water heat pump	Electricity Ambient heat	Space heating Cooling Hot water	3.5	28	Central: 6.0 North: 6.0 East: 6.0 South: 6.0	1%
Residential sector ground heat pump	Electricity Geothermal heat	Space heating Cooling Hot water	4.5	30	Central: 9.0 North: 9.0 East: 9.0 South: 9.0	1%

Table B.12 Techno-economic parameters of investable options for space heating, space cooling, hot water (excl. heat pumps) and cooking for deployment in the Commercial / Service sector included in TIMES-Europe.

Technology	**Input**	**Output**	**Efficiency**	**Technical lifetime (yr)**	**Investment costs [M€/GW]**	**Fixed O&M Costs [% of Inv. cost]**
Commercial sector combi boiler - Biomass	Biomass	Space heating Hot water	71%	15	900	1%
Commercial sector combi boiler - Heat	Heat	Space heating Hot water	99%	15	433	1%
Commercial sector combi boiler - Electricity	Electricity	Space Heating Hot water	100%	15	307	1%
Commercial sector combi boiler - Gas	Natural gas	Space Heating Hot water	70%	15	200	1%

Commercial sector combi boiler - Oil	Oil	Space Heating Hot water	72%	15	296	1%
Commercial sector combi boiler - Geothermal	Geothermal heat	Space Heating Hot water	73%	15	455	1%
Commercial sector combi boiler - LPG	LPG	Space Heating Hot water	60%	15	220	1%
Commercial sector combi boiler - Coal	Coal	Space Heating Hot water	57%	15	210	1%
Commercial sector water boiler – Biomass	Biomass	Hot water	50%	20	185	1%
Commercial sector water boiler – Electricity	Electricity	Hot water	100%	20	75	1%
Commercial sector water boiler – Gas	Natural gas	Hot water	60%	20	116	1%
Commercial sector water boiler – Oil	Oil	Hot water	57%	20	85	1%
Commercial sector water boiler – LPG	LPG	Hot water	61%	20	61	1%
Commercial sector water boiler – Coal	Coal	Hot water	40%	20	42	1%
Commercial sector water boiler – Solar	Solar	Hot water	100%	20	1727	1%
Commercial sector cooling - Electric	Electricity	Cooling	250%	20	333	1%
Commercial sector cooking – Biomass	Biomass	Cooking	59%	10	0.34	1%
Commercial sector cooking – Electric	Electricity	Cooking	100%	10	0.90	1%
Commercial sector cooking – Gas	Natural gas	Cooking	51%	10	0.34	1%
Commercial sector cooking - LPG	LPG	Cooking	47%	10	0.23	1%

Table B.13 Techno-economic parameters of investable heat pump options for space heating, space cooling and hot water for deployment in the Commercial / Service sector included in TIMES-Europe.

Technology	**Input**	**Output**	**COP**	**Technical lifetime (yr)**	**Investment costs [M€/GW]**	**Fixed O&M Costs [% of Inv. cost]**
Commercial sector air to air heat pump	Electricity Ambient heat	Space heating Hot water	2.5	18	300	1%
Commercial sector air to water heat pump	Electricity Ambient heat	Space heating Space cooling Hot water	3.5	28	1000	1%
Commercial sector ground heat pump	Electricity Geothermal heat	Space heating Space cooling Hot water	4.5	30	900	1%