S1. Cost assumptions

Table S1: Overnight investment cost assumptions per technology and year. All costs are given in real 2015 money.

Technology	Unit	2020	2025	2030	2035	2040	2045	2050	source
Onshore Wind	€/kW	1118	1077	1035	1006	977	970	963	[1]
Offshore Wind	€/kW	1748	1660	1573	1510	1447	1431	1415	[1]
Solar PV (utility-scale)	€/kW	529	452	376	352	329	315	301	[1]
Solar PV (rooftop)	€/kW	1127	955	784	723	661	600	539	[2]
OCGT	€/kW	453	444	435	429	423	417	411	[1]
CCGT	€/kW	880	855	830	822	815	807	800	[1]
Coal power plant	€/kW$_{el}$	3845	3845	3845	3845	3845	3845	3845	[3]
Lignite	€/kW$_{el}$	3845	3845	3845	3845	3845	3845	3845	[3]
Nuclear	€/kW$_{el}$	7940	7940	7940	7940	7940	7940	7940	[3]
Reservoir hydro	€/kW$_{el}$	2208	2208	2208	2208	2208	2208	2208	[4]
Run of river	€/kW$_{el}$	3312	3312	3312	3312	3312	3312	3312	[4]
PHS	€/kW$_{el}$	2208	2208	2208	2208	2208	2208	2208	[4]
Gas CHP	€/kW	590	575	560	550	540	530	520	[1]
Biomass CHP	€/kW$_{el}$	3381	3295	3210	3135	3061	2986	2912	[1]
HVDC overhead	€/MWkm	400	400	400	400	400	400	400	[5]
HVDC inverter pair	€/MW	150000	150000	150000	150000	150000	150000	150000	[5]
Battery storage	€/kWh	232	187	142	118	94	84	75	[1]
Battery inverter	€/kW	270	215	160	130	100	80	60	[1]
Home battery storage	€/kWh	323	264	202	169	136	122	108	[1, 6]
Home battery inverter	€/kW	377	303	228	186	144	115	87	[1, 6]
Electrolysis	€/kW$_{el}$	650	550	450	375	300	275	250	[1]
Fuel cell	€/kW$_{el}$	1300	1200	1100	1025	950	875	800	[1]
H_2 storage underground	€/kWh	3.0	2.5	2.0	1.8	1.5	1.4	1.2	[1]
H_2 storage tank	USD/kWh	11	11	11	11	11	11	11	[1, 7]
direct air capture	€/(tCO$_2$/h)	7000000	7000000	6000000	5500000	5000000	4500000	4000000	[1]
Methanation	€/kW$_{CH4}$	278	278	278	252	226	226	226	[8]
Central gas boiler	€/kW$_{th}$	60	55	50	50	50	50	50	[1]
Domestic gas boiler	€/kW$_{th}$	312	304	296	289	282	275	268	[1]
Central resistive heater	€/kW$_{th}$	70	65	60	60	60	60	60	[1]
Domestic resistive heater	€/kWh$_{th}$	100	100	100	100	100	100	100	[9]
Central water tank storage	€/kWh	0.6	0.6	0.5	0.5	0.5	0.5	0.5	[1]
Domestic water tank storage	€/kWh	18	18	18	18	18	18	18	[1, 10]
Domestic air-sourced heat pump	€/kW$_{th}$	940	895	850	827	805	782	760	[1]
Central air-sourced heat pump	€/kW$_{th}$	951	951	856	856	856	856	856	[1]
Domestic ground-sourced heat pump	€/kW$_{th}$	1500	1450	1400	1350	1300	1250	1200	[1]
CO_2 capture in CHP	€/(tCO$_2$/h)	3300000	3000000	2700000	2550000	2400000	2200000	2000000	[1]
Fischer-Tropsch	€/kW$_{FT}$/a	2100	1850	1600	1350	1100	1000	900	[1]
Steam Methane Reforming	€/kW$_{CH4}$	540	540	540	540	540	540	540	[11]
Steam Methane Reforming with CC	€/kW$_{CH4}$	1032	1032	1032	1032	1032	1032	1032	[11]

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Table S2: Efficiency, lifetime and FOM cost per technology (values shown corresponds to 2020).

Technology	FOM[a] [%/a]	Lifetime [a]	Efficiency	Source
Onshore Wind	1.2	27		[1]
Offshore Wind	2.3	27		[1]
Solar PV (utility-scale)	1.6	35		[1]
Solar PV (rooftop)	1.2	30		[2]
OCGT	1.8	25	0.4	[1]
CCGT	3.3	25	0.56	[1]
Coal power plant	1.6	40	0.33	[3]
Lignite	1.6	40	0.33	[3]
Nuclear	1.4	40	0.33	[3]
Reservoir hydro	1.0	80	0.9	[4]
Run of river	2.0	80	0.9	[4]
PHS	1.0	80	0.75	[4]
Gas CHP	3.3	25		[1]
Biomass CHP	3.6	25		[1]
HVDC overhead	2.0	40		[5]
HVDC inverter pair	2.0	40		[5]
Battery storage		20		[1]
Battery inverter	0.2	10	0.95	[1]
Home battery storage		20		[1, 6]
Home battery inverter	0.2	10	0.95	[1, 6]
Electrolysis	2.0	25	0.66	[1]
Fuel cell	5.0	10	0.5	[1]
H_2 storage underground	0.0	100		[1]
H_2 storage tank		20		[1, 7]
direct air capture	5.0	20		[1]
Methanation	4.0	30	0.8	[8]
Central gas boiler	3.2	25	1.03	[1]
Domestic gas boiler	6.6	20	0.97	[1]
Central resistive heater	1.5	20	0.99	[1]
Domestic resistive heater	2.0	20	0.9	[9]
Central water tank storage	0.5	20		[1]
Domestic water tank storage	1.0	20		[1, 10]
Water tank charger/discharger			0.84	
Domestic air-sourced heat pump	3.0	18		[1]
Central air-sourced heat pump	0.2	25	3.4	[1]
Domestic ground-sourced heat pump	1.8	20		[1]
CO_2 capture in CHP	3.0	25		[1]
Fischer-Tropsch	3.0	25	0.65	[1]
Steam Methane Reforming	5.4	25	0.74	[11]
Steam Methane Reforming with CC	5.4	25	0.67	[11]

[a] Fixed Operation and Maintenance (FOM) costs are given as a percentage of the overnight cost per year.

[b] Hydroelectric facilities are not expanded in this model and are considered to be fully amortized.

[c] Coefficient of performance (COP) of heat pumps is modelled as a function of temperature, as described in the text.

Table S3: Costs and emissions coefficient of fuels.

Fuel	Cost [€/MWh$_{th}$]	Source	Emissions [tCO$_2$/MWh$_{th}$]	Source
coal	8.2	[12]	0.34	[13]
lignite	2.9	[4]	0.41	[13]
gas	20.1	[12]	0.2	[13]
oil	50.0	[14]	0.27	[13]
nuclear	2.6	[3]	0	
solid biomass	25.2	[15, 16]	0	

[a] Raw biomass fuel cost is assumed as the middle value of the range provided in the references for different European countries and types of sustainable biomass.

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