Transition toward a fully renewable-based energy system in Chile by 2050 across power, heat, transport and desalination sectors

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Supplementary Material

Table S1: Population projection

	Unit	2015	2020	2025	2030	2035	2040	2045	2050	Source
Population	[mil]	17.95	18.84	19.64	20.25	20.75	21.14	21.42	21.60	[1]

Table S2: Projection of the power, heat, transportation and desalination demand

Energy service demand	Unit	2015	2020	2025	2030	2035	2040	2045	2050
Power demand	[TWh]	40.5	43.0	45.7	48.6	51.8	55.5	59.4	63.7
Industrial heat demand	[TWh]	68.3	76.5	78.9	80.9	79.5	79.0	76.9	76.1
Space heating heat demand	[TWh]	40.1	45.0	56.2	62.9	75.9	86.7	94.6	103
Domestic water heating heat demand	[TWh]	12.9	13.9	14.9	15.8	16.5	17.2	17.8	18.3
Biomass cooking heat demand	[TWh]	0.67	0.19	0.04	0.01	0.00	0.00	0.00	0.00
Road LDV passenger transport demand	[mil km]	32327	36013	37650	38769	40077	42173	45543	50935
Road 2W/3W passenger transport demand	[mil km]	12853	13953	14332	14498	14727	15239	16198	17800

Road Bus passenger transport demand	[mil km]	5328	5452	5364	5184	5023	4955	5027	5220
Road MDV freight transport demand	[mil km]	18202	20227	21138	21689	22283	23278	24920	27445
Road HDV freight transport demand	[mil km]	2114	2349	2455	2519	2588	2703	2895	3188
Rail passenger transport demand	[mil p-km]	949	989	986	965	947	944	966	1014
Rail freight transport demand	[mil t-km]	8675	9115	9197	9121	9079	9222	9665	10498
Marine passenger transport demand	[mil p-km]	671	724	771	811	848	883	918	956
Marine freight transport demand	[mil t-km]	323361	363811	402188	439661	481384	531408	594418	675951
Aviation passenger transport demand	[mil p-km]	13799	16255	18769	21807	24321	28743	33605	38834
Aviation freight transport demand	[mil t-km]	733	936	1174	1453	1791	2250	2800	3436
Water desalination demand	[m^3/day]	216552	665664	1840992	4032840	6365688	7744728	8298072	8570376

Table S3: Projected specific energy demand by transport mode and vehicle type

Mode and vehicle type	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Road LDV ICE	[kWh,th/km]	0.782	0.770	0.739	0.695	0.646	0.588	0.526	0.462
Road LDV BEV	[kWh,el/km]	0.182	0.167	0.152	0.136	0.126	0.119	0.112	0.103
Road LDV FCEV	[kWh,th/km]	0.000	0.000	0.226	0.218	0.206	0.202	0.178	0.167
Road LDV PHEV	[kWh,el/km]	0.235	0.192	0.160	0.149	0.136	0.124	0.111	0.096
Road LDV PHEV	[kWh,th/km]	0.128	0.124	0.117	0.110	0.104	0.094	0.088	0.081
Road 2W/3W ICE	[kWh,th/km]	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
Road 2W/3W BEV	[kWh,el/km]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050

Road Bus ICE	[kWh,th/km]	4.090	4.068	4.023	3.989	3.938	3.837	3.778	3.715
Road Bus BEV	[kWh,el/km]	1.872	1.838	1.769	1.732	1.673	1.606	1.571	1.511
Road Bus FCEV	[kWh,th/km]	3.120	3.073	2.961	2.877	2.736	2.573	2.499	2.377
Road Bus PHEV	[kWh,el/km]	2.045	2.028	1.955	1.946	1.921	1.901	1.882	1.847
Road Bus PHEV	[kWh,th/km]	0.936	0.919	0.886	0.868	0.835	0.800	0.783	0.752
Road MDV ICE	[kWh,th/km]	2.387	2.347	2.268	2.171	2.078	1.972	1.845	1.696
Road MDV BEV	[kWh,el/km]	0.935	0.839	0.778	0.712	0.651	0.608	0.571	0.528
Road MDV FCEV	[kWh,th/km]	0.000	1.362	1.293	1.244	1.176	1.109	1.063	1.006
Road MDV PHEV	[kWh,el/km]	1.432	1.380	1.317	1.265	1.197	1.128	1.067	0.998
Road MDV PHEV	[kWh,th/km]	0.374	0.345	0.314	0.290	0.265	0.243	0.227	0.209
Road HDV ICE	[kWh,th/km]	3.509	3.429	3.224	3.034	2.855	2.654	2.497	2.289
Road HDV BEV	[kWh,el/km]	0.000	1.671	1.508	1.417	1.311	1.189	1.132	1.063
Road HDV FCEV	[kWh,th/km]	0.000	1.952	1.827	1.736	1.589	1.476	1.413	1.319
Road HDV PHEV	[kWh,el/km]	0.000	2.277	2.150	2.065	1.929	1.734	1.612	1.508
Road HDV PHEV	[kWh,th/km]	0.000	0.501	0.462	0.436	0.401	0.357	0.333	0.313
Rail pass fuel	[kWh,th/(p-km)]	0.105	0.105	0.104	0.104	0.104	0.104	0.103	0.097
Rail pass electricity	[kWh,el/(p-km)]	0.068	0.067	0.065	0.063	0.061	0.060	0.058	0.056
Rail freight fuel	[kWh,th/(t*km)]	0.065	0.064	0.064	0.064	0.063	0.063	0.062	0.054
Rail freight electricity	[kWh,el/(t-km)]	0.034	0.033	0.032	0.030	0.028	0.027	0.026	0.024
Marine pass fuel	[kWh,th/(p-km)]	0.680	0.673	0.663	0.650	0.643	0.638	0.632	0.619
Marine pass electricity	[kWh,el/(p-km)]	0.000	0.319	0.322	0.324	0.325	0.325	0.325	0.325
Marine pass LH2	[kWh,th/(p-km)]	0.000	0.000	0.000	0.565	0.535	0.498	0.482	0.472
Marine pass LNG	[kWh,th/(p-km)]	0.000	0.657	0.645	0.627	0.619	0.610	0.601	0.592
Marine freight fuel	[kWh,th/(t-km)]	0.042	0.042	0.041	0.040	0.040	0.039	0.039	0.038
Marine freight electricity	[kWh,el/(t-km)]	0.000	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Marine freight LH2	[kWh,th/(t-km)]	0.000	0.000	0.000	0.035	0.033	0.031	0.030	0.029
Marine freight LNG	[kWh,th/(t-km)]	0.000	0.041	0.040	0.039	0.038	0.038	0.037	0.037
Aviation pass fuel	[kWh,th/(p-km)]	0.545	0.536	0.524	0.508	0.486	0.485	0.471	0.458
Aviation pass electricity	[kWh,el/(p-km)]	0.000	0.000	0.000	0.000	0.166	0.159	0.153	0.147
Aviation pass LH2	[kWh,th/(p-km)]	0.000	0.000	0.000	0.000	0.318	0.305	0.293	0.282
Aviation freight fuel	[kWh,th/(t-km)]	0.142	0.139	0.136	0.132	0.127	0.122	0.118	0.113
Aviation freight electricity	[kWh,el/(t-km)]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aviation freight LH2	[kWh,th/(t-km)]	0.000	0.000	0.000	0.000	0.083	0.079	0.076	0.073

Table S4: Projected shares of passenger demand by transport mode and vehicle type

Passenger mode and vehicle type	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Road LDV ICE - liquid fuel	99.6 %	94.0 %	79.9 %	50.0 %	20.0 %	11.0 %	7.0 %	4.0 %
Road LDV BEV - electricity	0.2%	3.0%	10.0%	39.0%	68.0%	74.0%	73.0%	76.0%

Road LDV FCEV - hydrogen	0.0%	0.0%	0.1%	1.0%	2.0%	5.0%	10.0%	10.0%
Road LDV PHEV - electricity/liquid fuel	0.2%	3.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Road 2W/3W ICE - liquid fuel	70.0%	65.0%	60.0%	40.0%	25.0%	15.0%	10.0%	5.0%
Road 2W/3W BEV - electricity	30.0%	35.0%	40.0%	60.0%	75.0%	85.0%	90.0%	95.0%
Road BUS ICE - liquid fuel	89.4%	78.9%	47.9%	16.9%	5.9%	4.9%	3.9%	2.9%
Road BUS BEV - electricity	10.0 %	20.0 %	50.0 %	80.0 %	90.0 %	90.0 %	90.0 %	90.0 %
Road BUS FCEV - hydrogen	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Road BUS PHEV - electricity/liquid fuel	0.5 %	1.0 %	2.0 %	3.0 %	4.0 %	5.0 %	6.0 %	7.0 %
Rail - electricity	14.4%	14.7%	24.1%	39.7%	54.3%	68.8%	81.8%	94.7%
Rail - liquid fuel	85.6%	85.3%	75.9%	60.3%	45.7%	31.2%	18.2%	5.3%
Marine - liquid fuel	100 %	99.4 %	98.4 %	95.9 %	91.2 %	79.4 %	57.2 %	26.1 %
Marine - electricity	0.0 %	0.1 %	0.6 %	1.1 %	2.8 %	5.6 %	7.8 %	8.9 %
Marine - hydrogen	0.0 %	0.0 %	0.0 %	1.0 %	3.0 %	10.0 %	25.0 %	45.0 %
Marine - LNG	0.0 %	0.5 %	1.0 %	2.0 %	3.0 %	5.0 %	10.0 %	20.0 %
Aviation - liquid fuel	100 %	100 %	100 %	100 %	96.5 %	86.0 %	68.5 %	43.9 %
Aviation - electricity	0.0 %	0.0 %	0.0 %	0.0 %	1.2 %	4.7 %	10.5 %	18.7 %
Aviation - hydrogen	0.0 %	0.0 %	0.0 %	0.0 %	2.3 %	9.3 %	21.0 %	37.4 %

Table S5: Projected share of freight demand by transport mode and vehicle type

Freight mode and vehicle type	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Road MDV ICE - liquid fuel	99.6 %	88.9 %	78.0 %	47.0 %	16.0 %	5.0 %	4.0 %	3.0 %
Road MDV BEV - electricity	0.2 %	10.0 %	19.0 %	48.0 %	75.0 %	80.0 %	80.0 %	80.0 %
Road MDV FCEV - hydrogen	0.0 %	0.1 %	1.0 %	2.0 %	5.0 %	10.0 %	10.0 %	10.0 %
Road MDV PHEV - electricity/liquid fuel	0.2 %	1.0 %	2.0 %	3.0 %	4.0 %	5.0 %	6.0 %	7.0 %
Road HDV ICE - liquid fuel	100 %	97.5 %	88.0 %	77.0 %	46.0 %	12.0 %	4.0 %	3.0 %
Road HDV BEV - electricity	0.0 %	1.0 %	8.0 %	15.0 %	30.0 %	50.0 %	50.0 %	50.0 %
Road HDV FCEV - hydrogen	0.0 %	0.5 %	2.0 %	5.0 %	20.0 %	30.0 %	30.0 %	30.0 %
Road HDV PHEV - electricity/liquid fuel	0.0 %	1.0 %	2.0 %	3.0 %	4.0 %	8.0 %	16.0 %	17.0 %
Rail - electricity	14.4%	14.7%	24.1%	39.7%	54.3%	68.8%	81.8%	94.7%
Rail - liquid fuel	85.6%	85.3%	75.9%	60.3%	45.7%	31.2%	18.2%	5.3%
Marine - liquid fuel	100 %	99.4 %	98.4 %	95.9 %	91.2 %	79.4 %	57.8 %	26.7 %
Marine - electricity	0.0 %	0.1 %	0.6 %	1.1 %	2.8 %	5.6 %	7.2 %	8.3 %
Marine - hydrogen	0.0 %	0.0 %	0.0 %	1.0 %	3.0 %	10.0 %	25.0 %	45.0 %
Marine - LNG	0.0 %	0.5 %	1.0 %	2.0 %	3.0 %	5.0 %	10.0 %	20.0 %
Aviation - liquid fuel	100 %	100 %	100 %	100 %	97.7 %	90.7 %	79.0 %	62.6 %
Aviation - electricity	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Aviation - hydrogen	0.0 %	0.0 %	0.0 %	0.0 %	2.3 %	9.3 %	21.0 %	37.4 %

Table S6: Projected final energy demand by energy form

Energy form	Unit	2015	2020	2025	2030	2035	2040	2045	2050
Electricity demand	[TWh]	42.1	48.5	58.0	72.4	84.4	90.6	96.3	101
Heat demand	[TWh]	122	136	150	160	172	183	189	197
Fuel demand	[TWh]	119	120	106	77.3	52.3	43.9	45.5	41.0
Total	[TWh]	283	305	314	310	309	318	331	339

Table S7: Projected final energy demand by sector

Sector	Unit	2015	2020	2025	2030	2035	2040	2045	2050
Power demand	[TWh]	40.5	43.0	45.7	48.6	51.8	55.5	59.4	63.7
Heat demand	[TWh]	122	136	150	160	172	183	189	197
Transport demand	[TWh]	120	125	116	95.5	76.7	69.4	72.4	68.4
Desalination demand	[TWh]	0.37	1.15	2.75	5.53	8.20	9.63	10.1	10.2
Total	[TWh]	283	305	314	310	309	318	331	339

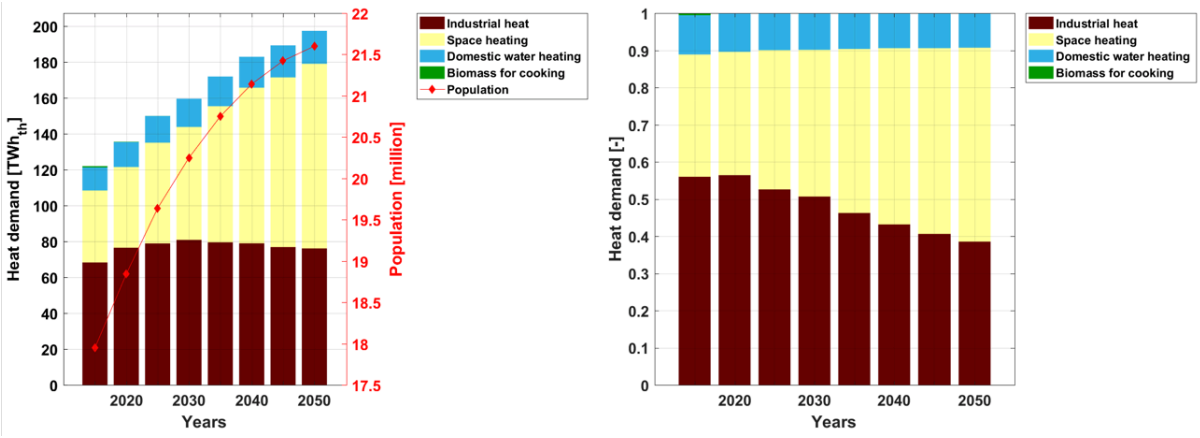

Figure S1: Heat demand by categories in absolute (left) and relative (right) shares

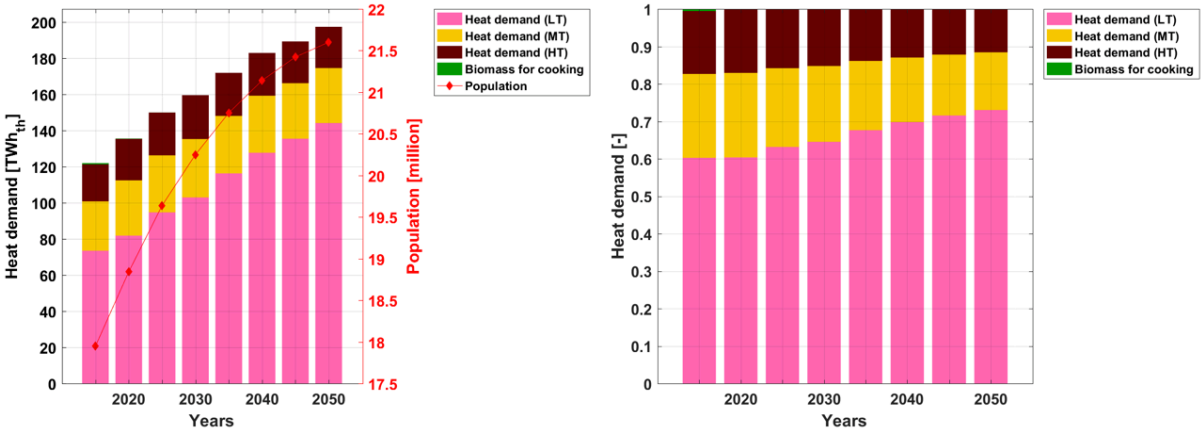

Figure S2: Heat demand by application and temperature levels in absolute (left) and relative (right) shares

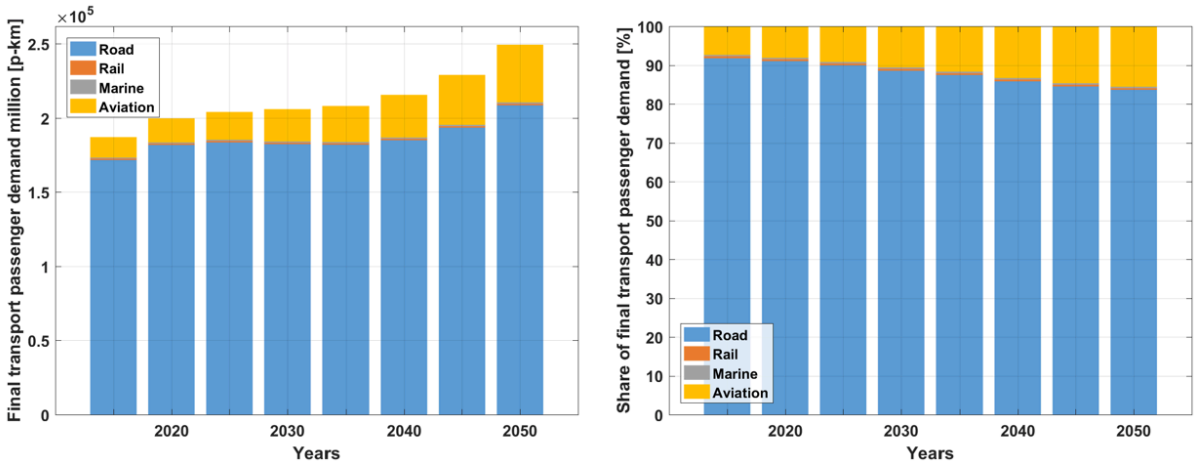

Figure S3: Final transport passenger demand in absolute (left) and relative (right) shares

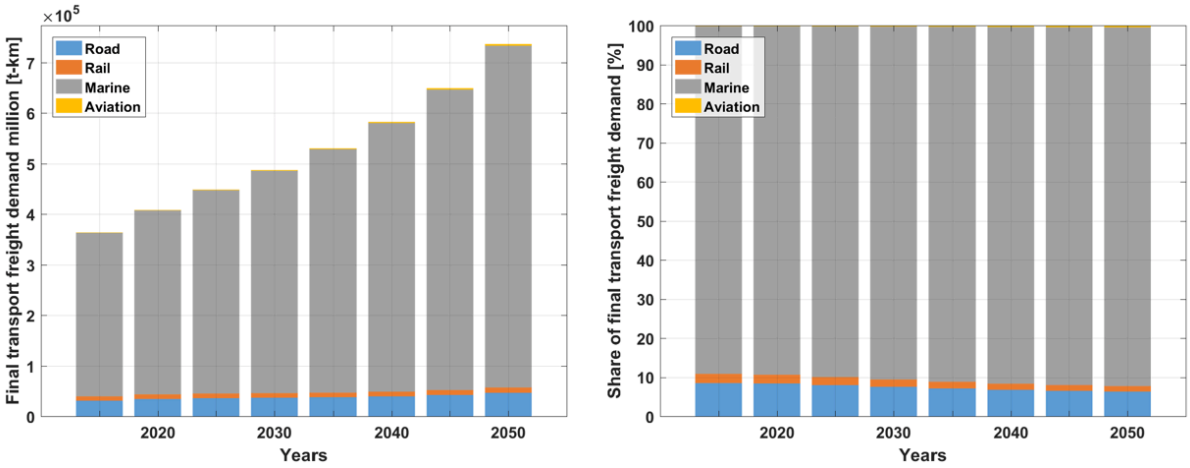

Figure S4: Final transport freight demand in absolute (left) and relative (right) shares

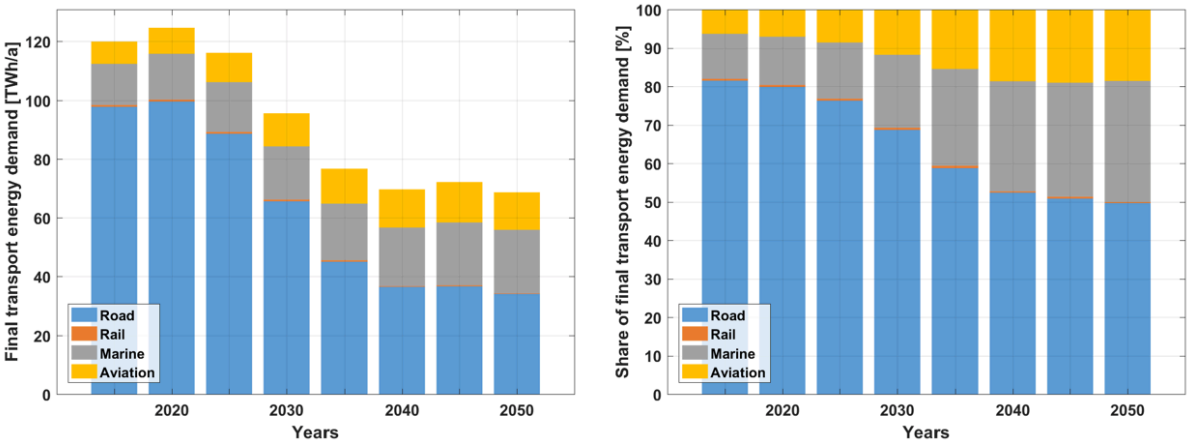

Figure S5: Final transport energy demand based on transport mode in absolute (left) and relative (right) shares

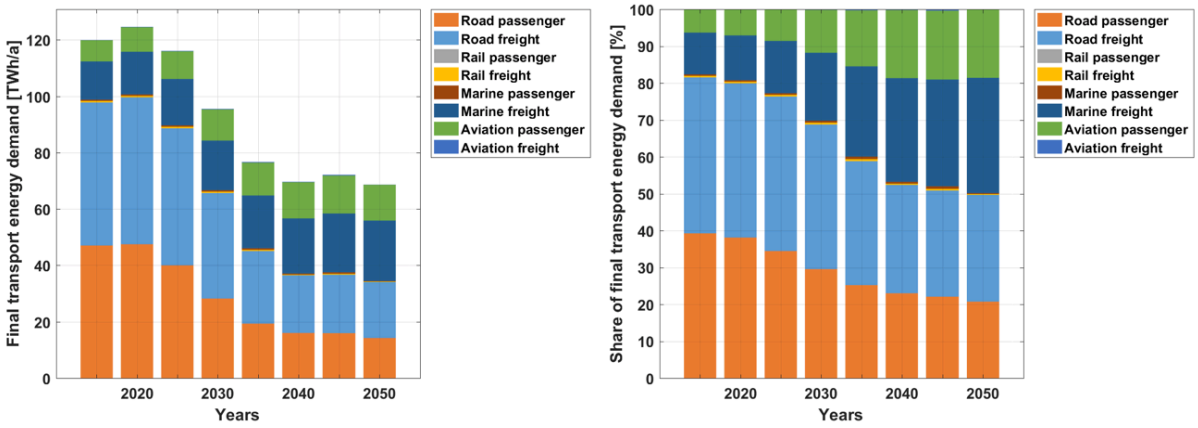

Figure S6: Final transport energy demand passenger and freight of different modes in absolute (left) and relative (right) shares

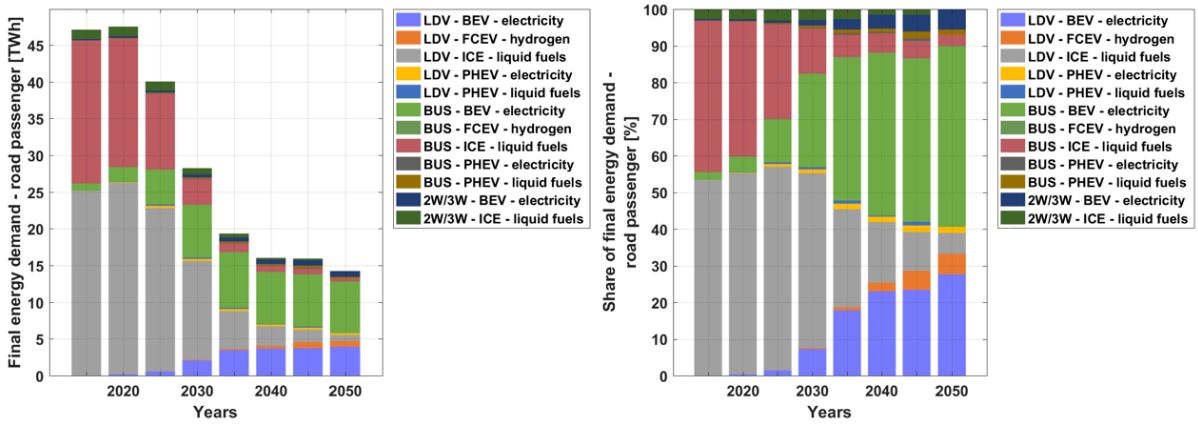

Figure S7: Final energy demand – road passenger by type of vehicle in absolute (left) and relative (right) shares

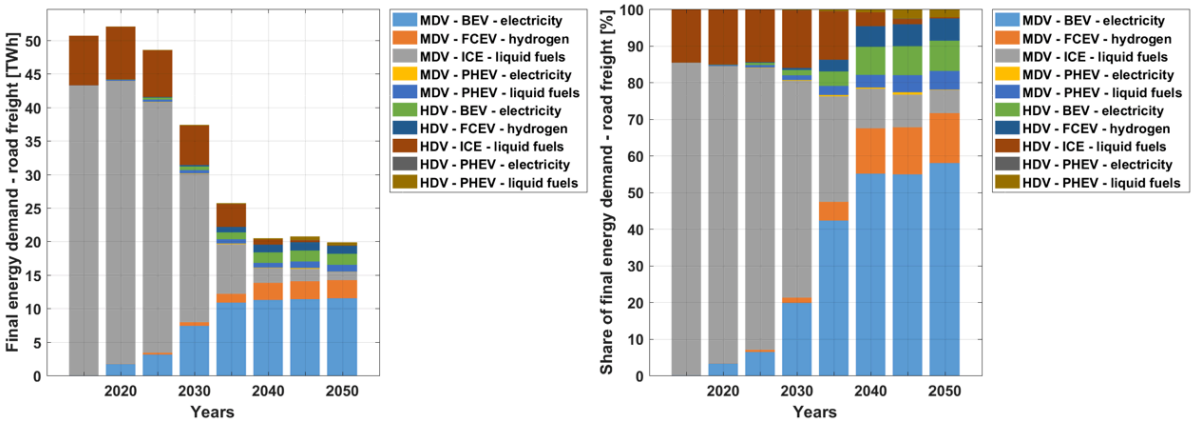

Figure S8: Final energy demand – road freight by type of vehicle in absolute (left) and relative (right) shares

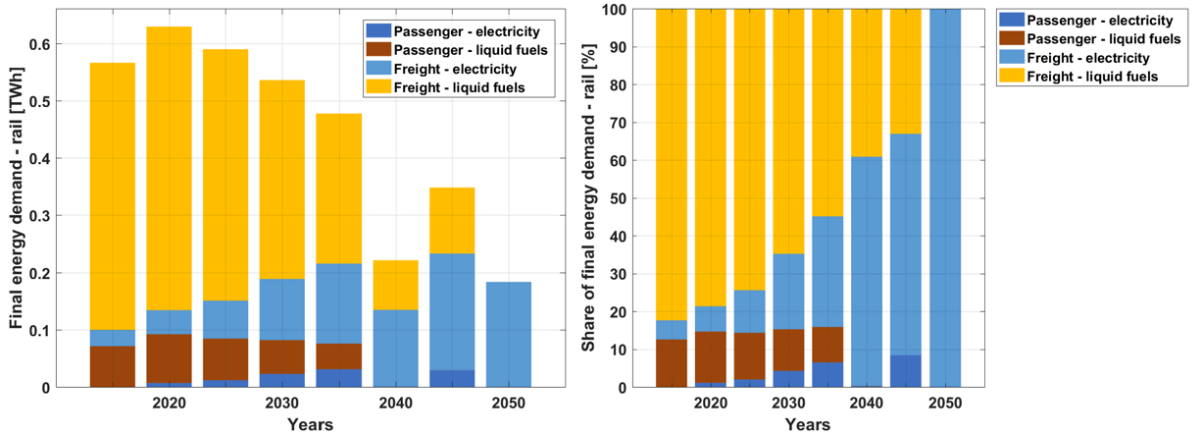

Figure S9: Final energy demand – rail in absolute (left) and relative (right) shares

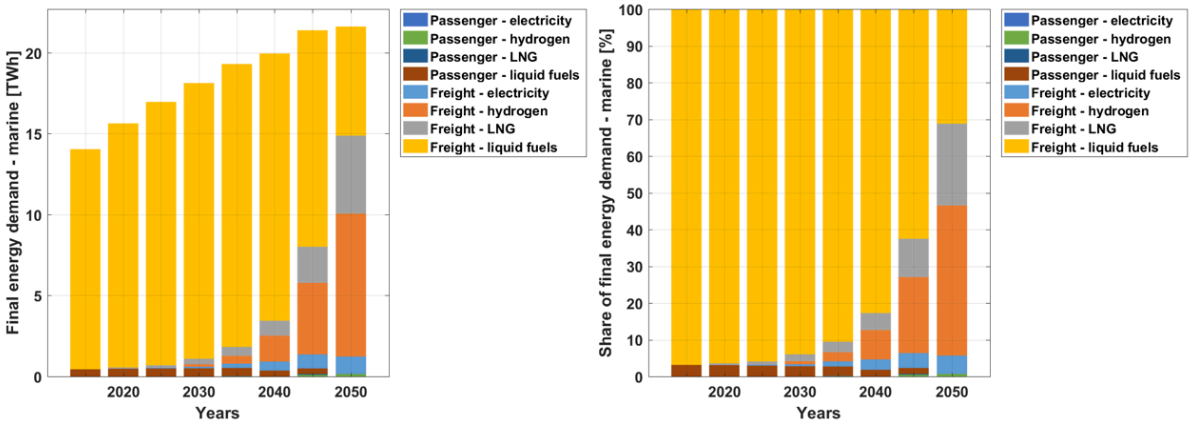

Figure S10: Final energy demand – marine in absolute (left) and in relative (right) shares

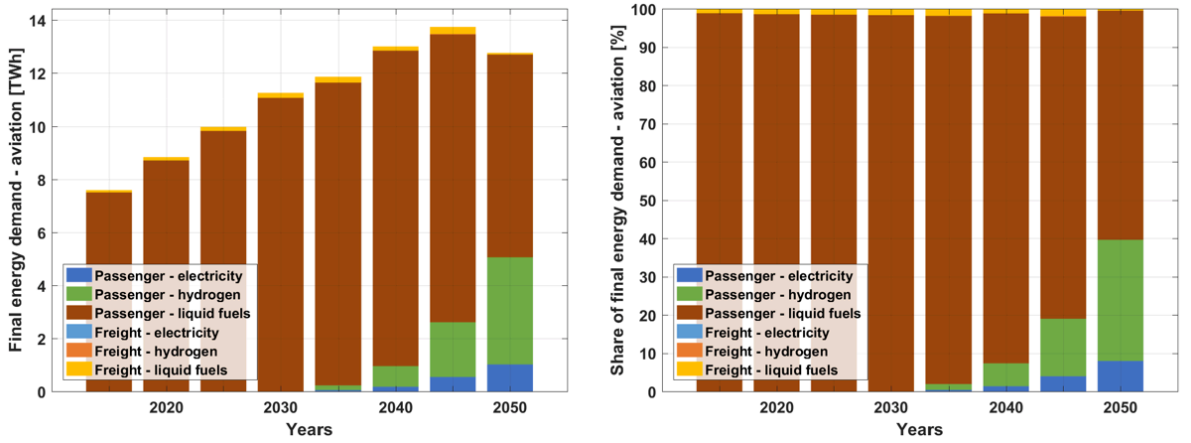

Figure S11: Final energy demand – aviation in absolute (left) and in relative (right) shares

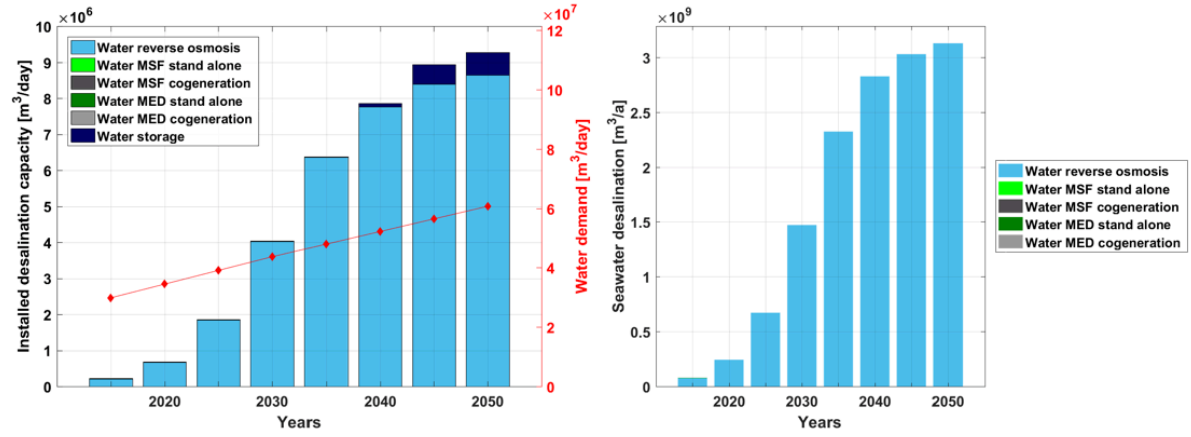

Figure S12: Installed desalination capacity (left) and seawater desalination (right)

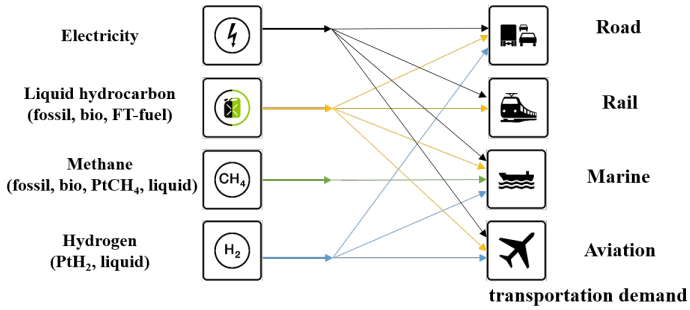

Figure S13: Schematic of the transport modes and corresponding fuels utilised [2,3]

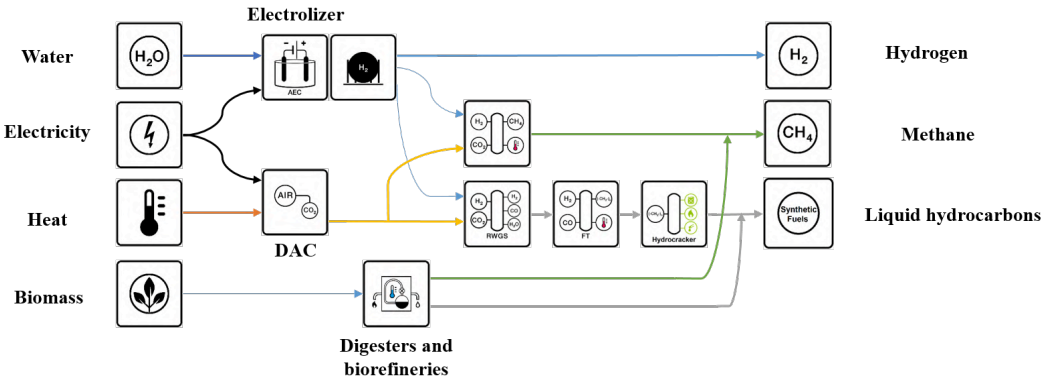

Figure S14: Schematic of the value chain elements in the production of sustainable fuels [2,3]

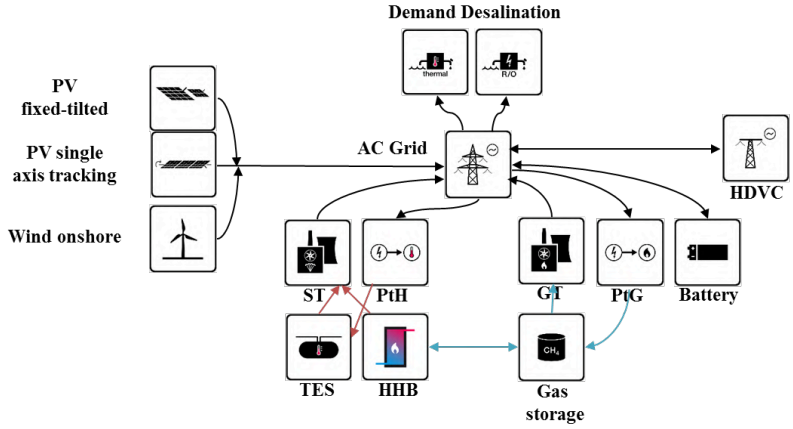

Figure S15: Schematic of the LUT Energy System Transition model for the desalination sector [2,3]

Table S8: Financial and technical assumptions of energy system technologies used

Technologies		Unit	2015	2020	2025	2030	2035	2040	2045	2050	Sources
PV rooftop – residential	Capex	€/kW$_{,el}$	1360	1169	966	826	725	650	589	537	[4]
	Opex fix	€/(kW$_{,el}$ a)	20.4	17.6	15.7	14.2	12.8	11.7	10.7	9.8	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	35	35	35	40	40	40	
PV rooftop - commercial	Capex	€/kW$_{,el}$	1360	907	737	623	542	484	437	397	[4]
	Opex fix	€/(kW$_{,el}$ a)	20.4	17.6	15.7	14.2	12.8	11.7	10.7	9.8	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	35	35	35	40	40	40	
PV rooftop - industrial	Capex	€/kW$_{,el}$	1360	682	548	459	397	353	318	289	[4]
	Opex fix	€/(kW$_{,el}$ a)	20.4	17,6	15,7	14,2	12,8	11,7	10.7	9.8	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	35	35	35	40	40	40	
PV optimally tilted	Capex	€/kW$_{,el}$	1000	580	466	390	337	300	270	246	[4]
	Opex fix	€/(kW$_{,el}$ a)	15	13.2	11.8	10.6	9.6	8.8	8.0	7.4	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	

	Lifetime	years	30	30	35	35	35	40	40	40	
PV single-axis tracking	Capex	€/kW$_{,el}$	1150	638	513	429	371	330	297	271	[4,5]
	Opex fix	€/(kW$_{,el}$ a)	17.3	15.0	13.0	12.0	11.0	10.0	9.0	8.0	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	35	35	35	40	40	40	
Wind onshore	Capex	€/kW$_{,el}$	1250	1150	1060	1000	965	940	915	900	[6]
	Opex fix	€/(kW$_{,el}$ a)	25	23	21	20	19	19	18	18	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	25	25	25	25	25	25	25	25	
Wind offshore	Capex	€/kW$_{,el}$	3220	2880	2700	2580	2460	2380	2320	2280	[7]
	Opex fix	€/(kW$_{,el}$ a)	113	92	84	77	71	67	58	52	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	25	25	25	25	25	25	25	
Hydro Reservoir/ Dam	Capex	€/kW$_{,el}$	1650	1650	1650	1650	1650	1650	1650	1650	[7]
	Opex fix	€/(kW$_{,el}$ a)	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	
	Opex var	€/(kWh$_{,el}$)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
	Lifetime	years	50	50	50	50	50	50	50	50	
Hydro Run-of-River	Capex	€/kW$_{,e}$	2560	2560	2560	2560	2560	2560	2560	2560	[7]
	Opex fix	€/(kW$_{,e}$ a)	76.8	76.8	76.8	76.8	76.8	76.8	76.8	76.8	
	Opex var	€/(kWh$_{,e}$)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
	Lifetime	years	50	50	50	50	50	50	50	50	
Geothermal power	Capex	€/kW$_{,el}$	5250	4970	4720	4470	4245	4020	3815	3610	[7,8]
	Opex fix	€/(kW$_{,el}$ a)	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	40	40	40	40	40	40	40	40	
Coal PP	Capex	€/(kW$_{,el}$)	1500	1500	1500	1500	1500	1500	1500	1500	[9,10]
	Opex fix	€/(kW$_{el}$ a)	20	20	20	20	20	20	20	20	
	Opex var	€/(kWh)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Lifetime	years	40	40	40	40	40	40	40	40	
Nuclear PP	Capex	€/(kW$_{el}$)	6210	6003	6003	5658	5658	5244	5244	5175	[9,11,12]
	Opex fix	€/(kW$_{el}$ a)	162	157	157	137	137	116	116	109	
	Opex var	€/(kWh$_{,el}$)	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	
	Lifetime	years	40	40	40	40	40	40	40	40	
CCGT	Capex	€/(kW$_{el}$)	775	775	775	775	775	775	775	775	[9]
	Opex fix	€/(kW$_{el}$ a)	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	
	Opex var	€/(kWh$_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	35	35	35	35	35	35	35	35	
OCGT	Capex	€/(kW$_{el}$)	475	475	475	475	475	475	475	475	[13]

	Opex fix	€/(kW_{el} a)	14.25	14.25	14.25	14.25	14.25	14.25	14.25	14.25	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	35	35	35	35	35	35	35	35	
Steam turbine (CSP)	Capex	€/(kW_{el})	1000	968	946	923	902	880	860	840	[3]
	Opex fix	€/(kW_{el} a)	20	19.4	18.9	18.5	18	17.6	17.2	16.8	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	25	25	25	25	30	30	30	30	
Biomass PP	Capex	€/$kW_{,el}$	2755	2620	2475	2330	2195	2060	1945	1830	[3]
	Opex fix	€/($kW_{,el}$ a)	55.4	47.2	44.6	41.9	39.5	37.1	35	32.9	
	Opex var	€/($kWh_{,el}$)	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
	Lifetime	years	25	25	25	25	25	25	25	25	
CHP NG Heating	Capex	€/$kW_{,el}$	880	880	880	880	880	880	880	880	[3]
	Opex fix	€/($kW_{,el}$ a)	74.8	74.8	74.8	74.8	74.8	74.8	74.8	74.8	
	Opex var	€/($kWh_{,el}$)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
	Lifetime	years	30	30	30	30	30	30	30	30	
CHP Oil Heating	Capex	€/$kW_{,el}$	880	880	880	880	880	880	880	880	[3]
	Opex fix	€/($kW_{,el}$ a)	74.8	74.8	74.8	74.8	74.8	74.8	74.8	74.8	
	Opex var	€/($kWh_{,el}$)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
	Lifetime	years	30	30	30	30	30	30	30	30	
CHP Coal Heating	Capex	€/$kW_{,el}$	2030	2030	2030	2030	2030	2030	2030	2030	[3]
	Opex fix	€/($kW_{,el}$ a)	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	
	Opex var	€/($kWh_{,el}$)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
	Lifetime	years	40	40	40	40	40	40	40	40	
CHP Biomass Heating	Capex	€/$kW_{,el}$	3560	3300	3145	2990	2870	2750	2645	2540	[3]
	Opex fix	€/($kW_{,el}$ a)	81.9	75.9	72.3	68.8	66	63.3	60.8	58.4	
	Opex var	€/($kWh_{,el}$)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
	Lifetime	years	25	25	25	25	25	25	25	25	
CHP Biogas	Capex	€/$kW_{,el}$	503	429	400	370	340	326	311	296	[3]
	Opex fix	€/($kW_{,el}$ a)	20.1	17.2	16.0	14.8	13.6	13.0	12.4	11.8	
	Opex var	€/($kWh_{,el}$)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Lifetime	years	30	30	30	30	30	30	30	30	
Waste incinerator	Capex	€/$kW_{,el}$	5940	5630	5440	5240	5030	4870	4690	4540	[3]
	Opex fix	€/($kW_{,el}$ a)	267.3	253.4	244.8	235.8	226.4	219.1	211.0	204.3	
	Opex var	€/($kWh_{,el}$)	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	
	Lifetime	years	30	30	30	30	30	30	30	30	
Biogas digester	Capex	€/$kW_{,th}$	771	731	706	680	653	632	609	589	[3]
	Opex fix	€/($kW_{,th}$ a)	30.8	29.2	28.2	27.2	26.1	25.3	24.3	23.6	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	

	Lifetime	years	20	20	20	20	25	25	25	25	
Biogas upgrade	Capex	€/kW,th	340	290	270	250	230	220	210	200	[14]
	Opex fix	€/(kW,th a)	27.2	23.2	21.6	20	18.4	17.6	16.8	16	
	Opex var	€/(kWh,th)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	20	20	20	25	25	25	25	
CSP (solar field, parabolic trough)	Capex	€/kW,th	438.3	344.5	303.6	274.7	251.1	230.2	211.9	196	[15,16]
	Opex fix	€/(kW,th a)	10.1	7.9	7	6.3	5.8	5.3	4.9	4.5	
	Opex var	€/(kWh,th)	0	0	0	0	0	0	0	0	
	Lifetime	years	25	25	25	25	25	25	25	25	
Residential Solar Heat Collectors - Space Heating	Capex	€/kW,th	1286	1214	1179	1143	1071	1000	929	857	[3]
	Opex fix	€/(kW,th a)	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	
	Opex var	€/(kWh,th)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	25	25	30	30	30	30	30	
Residential Solar Heat Collectors - hot water	Capex	€/kW,th	485	485	485	485	485	485	485	485	[3]
	Opex fix	€/(kW,th a)	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85	
	Opex var	€/(kWh,th)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	15	15	15	15	15	15	15	
DH Electric Heating	Capex	€/kW,th	100	100	100	75	75	75	75	75	[3]
	Opex fix	€/(kW,th a)	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	
	Opex var	€/(kWh,th)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Lifetime	years	35	35	35	35	35	35	35	35	
DH Heat Pump	Capex	€/kW,th	700	660	618	590	568	554	540	530	[3]
	Opex fix	€/(kW,th a)	2	2	2	2	2	2	2	2	
	Opex var	€/(kWh,th)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
	Lifetime	years	25	25	25	25	25	25	25	25	
DH Natural gas Heating	Capex	€/kW,th	75	75	75	100	100	100	100	100	[3]
	Opex fix	€/(kW,th a)	2.775	2.775	2.775	3.7	3.7	3.7	3.7	3.7	
	Opex var	€/(kWh,th)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	
	Lifetime	years	35	35	35	35	35	35	35	35	
DH Oil Heating	Capex	€/kW,th	75	75	75	100	100	100	100	100	[3]
	Opex fix	€/(kW,th a)	2.775	2.775	2.775	3.7	3.7	3.7	3.7	3.7	
	Opex var	€/(kWh,th)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	
	Lifetime	years	35	35	35	35	35	35	35	35	
DH Coal Heating	Capex	€/kW,th	75	75	75	100	100	100	100	100	[3]
	Opex fix	€/(kW,th a)	2.775	2.775	2.775	3.7	3.7	3.7	3.7	3.7	
	Opex var	€/(kWh,th)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	
	Lifetime	years	35	35	35	35	35	35	35	35	
DH Biomass	Capex	€/kW,th	75	75	75	100	100	100	100	100	[3]

Heating	Opex fix	€/($kW_{,th}$ a)	2.8	2.8	2.8	3.7	3.7	3.7	3.7	3.7	
	Opex var	€/($kWh_{,th}$)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	
	Lifetime	years	35	35	35	35	35	35	35	35	
DH Geothermal Heating	Capex	€/$kW_{,th}$	3936	3642	3384	3200	3180	3160	3150	3146	[3]
	Opex fix	€/($kW_{,th}$ a)	144	133	124	117	116	115	115	115	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	22	22	22	22	22	22	22	22	
Local Electric Heating	Capex	€/$kW_{,th}$	800	800	800	800	800	800	800	800	[3]
	Opex fix	€/($kW_{,th}$ a)	10	10	10	10	10	10	10	10	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	30	30	30	30	30	30	
Local Heat Pump	Capex	€/$kW_{,th}$	800	780	750	730	706	690	666	650	[3]
	Opex fix	€/($kW_{,th}$ a)	16	15.6	15	7.3	7.1	6.9	6.7	6.5	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	20	20	20	20	20	20	20	
Local Natural gas Heating	Capex	€/$kW_{,th}$	800	800	800	800	800	800	800	800	[3]
	Opex fix	€/($kW_{,th}$ a)	27	27	27	27	27	27	27	27	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	22	22	22	22	22	22	22	22	
Local Oil Heating	Capex	€/$kW_{,th}$	440	440	440	440	440	440	440	440	[3]
	Opex fix	€/($kW_{,th}$ a)	18	18	18	18	18	18	18	18	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	20	20	20	20	20	20	20	
Local Coal Heating	Capex	€/$kW_{,th}$	500	500	500	500	500	500	500	500	[3]
	Opex fix	€/($kW_{,th}$ a)	10	10	10	10	10	10	10	10	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	15	15	15	15	15	15	15	
Local Biomass Heating	Capex	€/$kW_{,th}$	675	675	675	750	750	750	750	675	[3]
	Opex fix	€/($kW_{,th}$ a)	2	2	2	3	3	3	3	3	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	20	20	20	20	20	20	20	20	
Local Biogas Heating	Capex	€/$kW_{,th}$	800	800	800	800	800	800	800	800	[3]
	Opex fix	€/($kW_{,th}$ a)	27	27	27	27	27	27	27	27	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	22	22	22	22	22	22	22	22	
Water electrolysis	Capex	€/$kW_{,H2}$	800	685	500	363	325	296	267	248	[17,18]
	Opex fix	€/($kW_{,H2}$ a)	32	27	20	12.7	11.4	10.4	9.4	8.7	
	Opex var	€/($kWh_{,H2}$)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	

	Lifetime	years	30	30	30	30	30	30	30	30	
Methanation	Capex	€/$kW_{,CH4}$	547	502	368	278	247	226	204	190	[17,18]
	Opex fix	€/($kW_{,CH4}$ a)	25.16	23.09	16.93	12.79	11.36	10.4	9.38	8.74	
	Opex var	€/($kWh_{,CH4}$)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
	Lifetime	years	30	30	30	30	30	30	30	30	
CO_2 direct air capture	Capex	€/t_{CO2} a	1000	730	493	335	274.4	234	210.6	195	[19]
	Opex fix	€/t_{CO2} a	40	29.2	19.7	13.4	11	9.4	8.4	7.8	
	Opex var	€/t_{CO2}	0	0	0	0	0	0	0	0	
	Lifetime	years	20	20	30	30	30	30	30	30	
Fischer-Tropsch Unit	Capex	€/kW,FT_{Liq}	947	947	947	947	947	852.3	852.3	852.3	[3]
	Opex fix	€/kW,FT_{Liq}	28.41	28.41	28.41	28.41	28.41	25.57	25.57	25.57	
	Opex var	€/kWh,FT_{Liq}	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	30	30	30	30	30	30	
Battery storage	Capex	€/(kWh_{el})	400	270	182	134	108	92	78	70	[20]
	Opex fix	€/(kWh_{el} a)	24	9	5	3.75	3	2.5	2.125	1.875	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery interface	Capex	€/(kW_{el})	200	135	91	67	54	46	39	35	[20]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV prosumer - residential storage	Capex	€/(kWh_{el})	603	407	280	209	170	146	124	111	[3]
	Opex fix	€/(kWh_{el} a)	36.2	13.6	7.7	5.8	4.7	4	3.4	3	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV prosumer - residential interface	Capex	€/(kW_{el})	302	204	140	104	85	73	62	56	[3]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV prosumer - commercial storage	Capex	€/(kWh_{el})	513	346	235	174	141	120	102	91	[3]
	Opex fix	€/(kWh_{el} a)	30.8	11.5	6.5	4.9	3.9	3.3	2.8	2.5	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV prosumer - commercial interface	Capex	€/(kW_{el})	256	173	117	87	70	60	51	46	[3]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV	Capex	€/(kWh_{el})	435	294	198	146	118	100	85	76	[3]

prosumer - industrial storage	Opex fix	€/(kWh_{el} a)	26.1	9.8	5.4	4.1	3.3	2.7	2.3	2	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
Battery PV prosumer - industrial interface	Capex	€/(kW_{el})	218	147	99	73	59	50	42	38	[3]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	20	20	20	20	20	20	20	
PHES	Capex	€/(kWh_{el})	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	[7]
	Opex fix	€/(kWh_{el} a)	1.335	1.335	1.335	1.335	1.335	1.335	1.335	1.335	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	50	50	50	50	50	50	50	50	
PHES interface	Capex	€/(kW_{el})	650	650	650	650	650	650	650	650	[7]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	50	50	50	50	50	50	50	50	
A-CAES	Capex	€/(kWh_{el})	35	35	32.6	31.1	30.3	29.8	27.7	26.3	[7]
	Opex fix	€/(kWh_{el} a)	0.53	0.53	0.50	0.47	0.46	0.45	0.42	0.40	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	40	55	55	55	55	55	55	55	
A-CAES interface	Capex	€/(kW_{el})	600	600	558	530	518	510	474	450	[7]
	Opex fix	€/(kW_{el} a)	0	0	0	0	0	0	0	0	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	40	55	55	55	55	55	55	55	
Gas Storage	Capex	€/(kWh_{el})	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	[21]
	Opex fix	€/(kWh_{el} a)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Opex var	€/($kWh_{,el}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	50	50	50	50	50	50	50	50	
Gas Storage interface	Capex	€/(kW_{th})	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8	[21]
	Opex fix	€/(kW_{th} a)	31	31	31	31	31	31	31	31	
	Opex var	€/($kWh_{,th}$)	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	
	Lifetime	years	41.4	41.4	41.4	41.4	41.4	41.4	41.4	41.4	
Hot Heat Storage	Capex	€/($kWh_{,th}$)	50.8	41.8	32.7	26.8	23.3	21	19.3	17.5	[3]
	Opex fix	€/($kWh_{,th}$ a)	0.76	0.63	0.49	0.4	0.35	0.32	0.29	0.26	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	25	25	25	25	30	30	30	30	
District Heat Storage	Capex	€/(kWh_{th})	50	40	30	30	25	20	20	20	[3]
	Opex fix	€/(kWh_{th} a)	0.8	0.6	0.5	0.5	0.4	0.3	0.3	0.3	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	

	Lifetime	years	25	25	25	25	30	30	30	30	
Hydrogen Storage	Capex	€/(kWh_{th})	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	[22]
	Opex fix	€/(kWh_{th} a)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	15	15	15	15	15	15	15	
Hydrogen Storage interface	Capex	€/(kW_{th})	255.9	255.9	255.9	255.9	255.9	255.9	255.9	255.9	[22]
	Opex fix	€/(kW_{th} a)	10.23	10.23	10.23	10.23	10.23	10.23	10.23	10.23	
	Opex var	€/($kWh_{,th}$)	0	0	0	0	0	0	0	0	
	Lifetime	years	15	15	15	15	15	15	15	15	
CO_2 Storage	Capex	€/ton	142	142	142	142	142	142	142	142	[19]
	Opex fix	€/(ton a)	9.94	9.94	9.94	9.94	9.94	9.94	9.94	9.94	
	Opex var	€/ton	0	0	0	0	0	0	0	0	
	Lifetime	years	30	30	30	30	30	30	30	30	
Reverse Osmosis Seawater Desalination	Capex	€/(m^3/day)	1150	960	835	725	630	550	480	415	[23]
	Opex fix	€/(m^3/day a)	46	38.4	33.4	29	25.2	22	19.2	16.6	
	Consumption	kWh_{th}/m^3	0	0	0	0	0	0	0	0	
	Lifetime	years	25	25	30	30	30	30	30	30	
	Consumption	kWh_{el}/m^3	4.1	3.6	3.35	3.15	3	2.85	2.7	2.6	
Multi Stage Flash Standalone	Capex	€/(m^3/day)	2000	2000	2000	2000	2000	2000	2000	2000	[23]
	Opex fix	€/(m^3/day a)	100	100	100	100	100	100	100	100	
	Consumption	kWh_{th}/m^3	85	85	85	85	85	85	85	85	
	Lifetime	years	25	25	25	25	25	25	25	25	
	Consumption	kWh_{el}/m^3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Multi Stage Flash Cogeneration	Capex	€/(m^3/day)	3069	3069	3069	3069	3069	3069	3069	3069	[3]
	Opex fix	€/(m^3/day a)	121.4	121.4	121.4	121.4	121.4	121.4	121.4	121.4	
	Consumption	kWh_{th}/m^3	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	
	Lifetime	years	25	25	25	25	25	25	25	25	
	Consumption	kWh_{el}/m^3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Multi Effect Distillation Standalone	Capex	€/(m^3/day)	1438	1200	1044	906.3	787.5	687.5	600	518.8	[23]
	Opex fix	€/(m^3/day a)	47.44	39.60	34.44	29.91	25.99	22.69	19.80	17.12	
	Consumption	kWh_{th}/m^3	68	51	44	38	32	28	28	28	
	Lifetime	years	25	25	25	25	25	25	25	25	
	Consumption	kWh_{el}/m^3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
Multi Effect Distillation Cogeneration	Capex	€/(m^3/day)	2150	2150	2150	2150	2150	2150	2150	2150	[3]
	Opex fix	€/(m^3/day a)	61.69	61.69	61.69	61.69	61.69	61.69	61.69	68.81	
	Consumption	kWh_{th}/m^3	168	168	168	168	168	168	168	168	
	Lifetime	years	25	25	25	25	25	25	25	25	
	Consumption	kWh_{el}/m^3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	

Water Storage	Capex	€/m³	64.59	64.59	64.59	64.59	64.59	64.59	64.59	64.59	[23]
	Opex fix	€/(m³ a)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	
	Opex var	€/m³	0	0	0	0	0	0	0	0	
	Lifetime	years	50	50	50	50	50	50	50	50	

Table S9: Energy to power ratio and self-discharge rates of storage technologies. In the case of Energy/Power ratios, the values are by 2050, as a result of the optimization

Technology	Efficiency [%]	Energy/Power Ratio [h]	Self-Discharge [%/h]	Sources
Battery	90	6.0	0	[21]
PHES	85	1.1	0	[7]
A-CAES	70	20	0.1	[7]
TES	90	8	0.2	[21]
Gas storage	100	99	0	[21]

Table S10: Financial assumptions for the fossil-nuclear fuel prices and GHG emission cost

Component	Unit	2015	2020	2025	2030	2035	2040	2045	2050	Sources
Coal	€/MWh_{th}	7.7	7.7	8.4	9.2	10.2	11.1	11.1	11.1	[24]
Fuel oil	€/MWh_{th}	52.5	35.2	39.8	44.4	43.9	43.5	43.5	43.5	[13]
Fossil gas	€/MWh_{th}	21.8	22.2	30.0	32.7	36.1	40.2	40.2	40.2	[24]
Uranium	€/MWh_{th}	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	[11]
GHG emissions	€/tCO_{2eq}	9	28	52	61	68	75	100	150	[24]
GHG emissions by fuel type										
Coal			tCO_{2eq}/MWh_{th}					0.34		[25]
Oil			tCO_{2eq}/MWh_{th}					0.25		[25]
Fossil gas			tCO_{2eq}/MWh_{th}					0.21		[26]

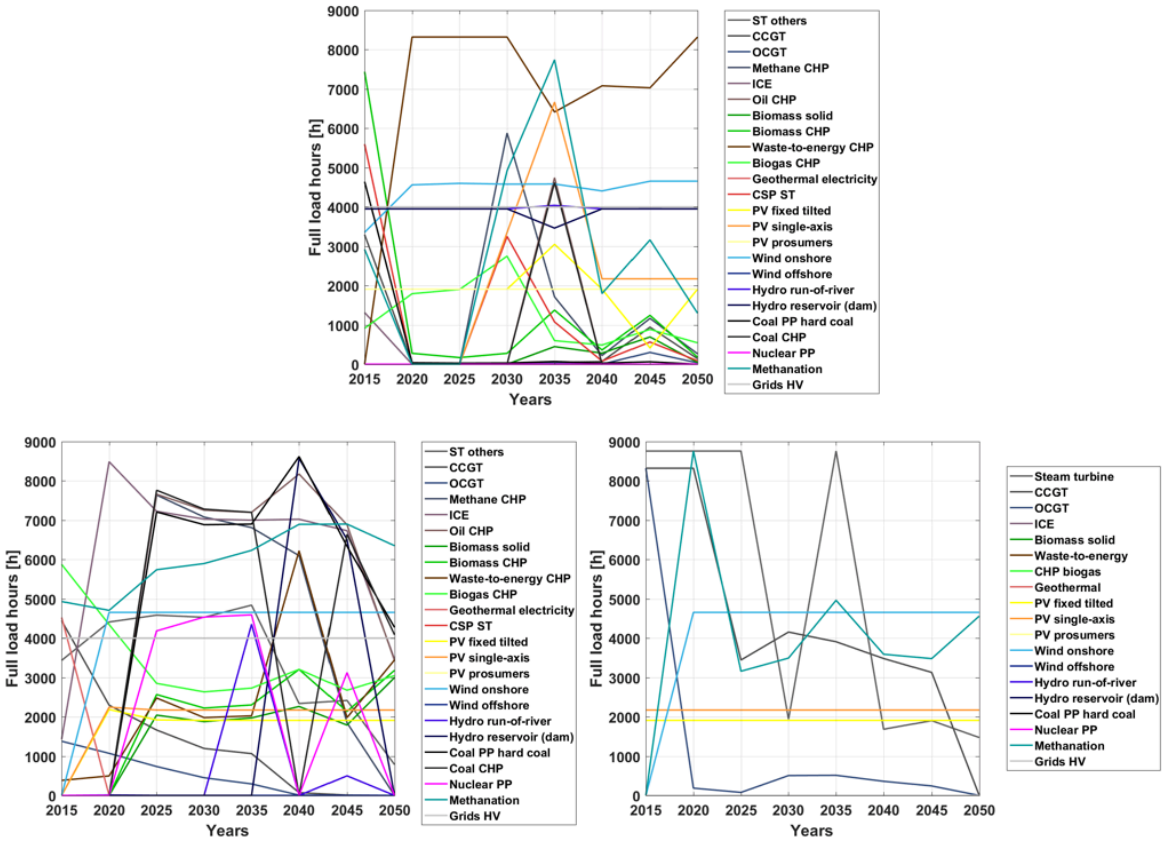

Figure S15: Full load hours – power and heat sectors (top), transport sector (bottom left), and desalination sector (bottom right)

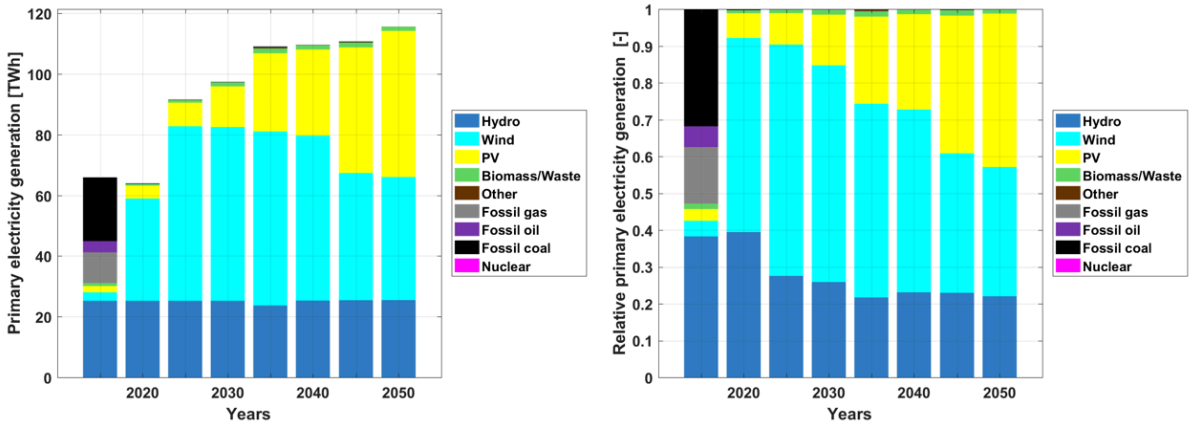

Figure S16: Primary electricity generation – power and heat sectors in absolute (top) and relative (right) shares

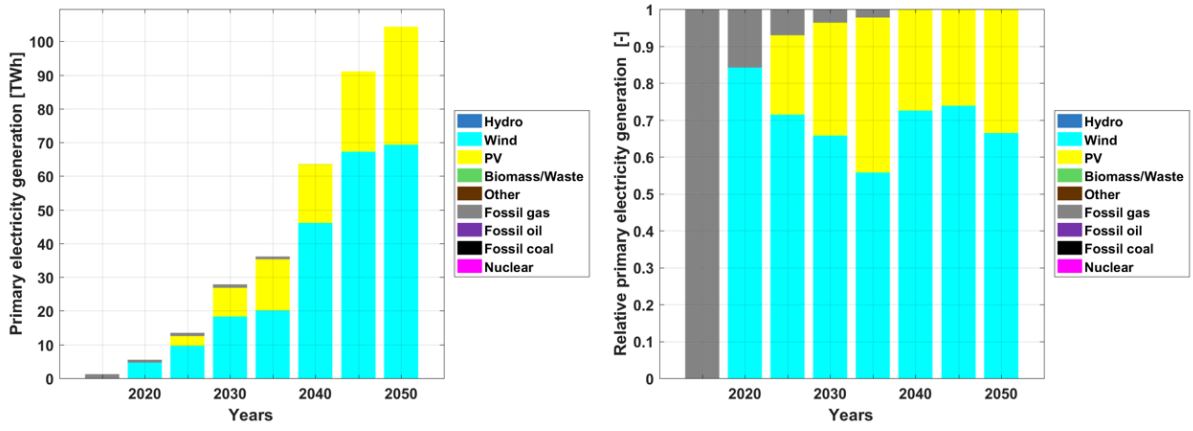

Figure S17: Primary electricity generation - transport sector in absolute (left) and relative (right) shares

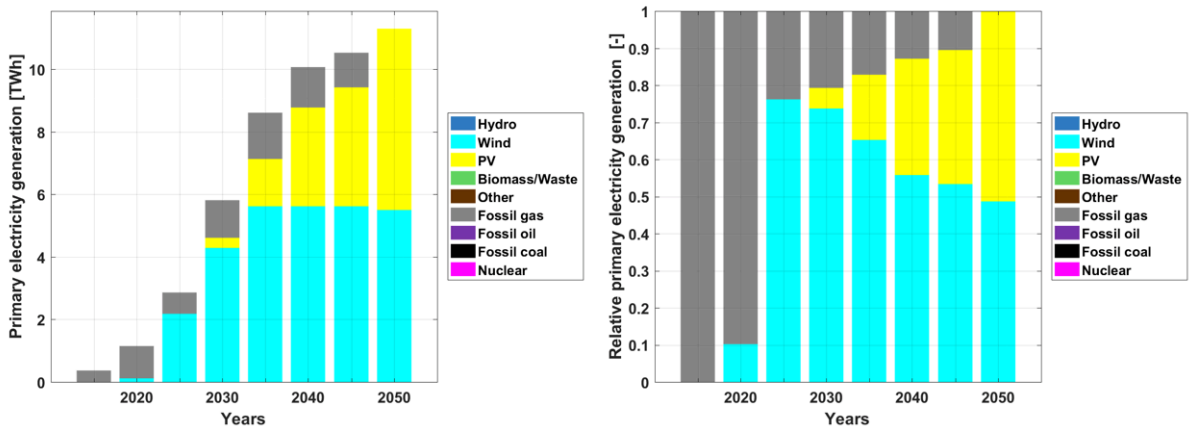

Figure S18: Primary electricity generation - desalination sector in absolute (left) and relative (right) shares

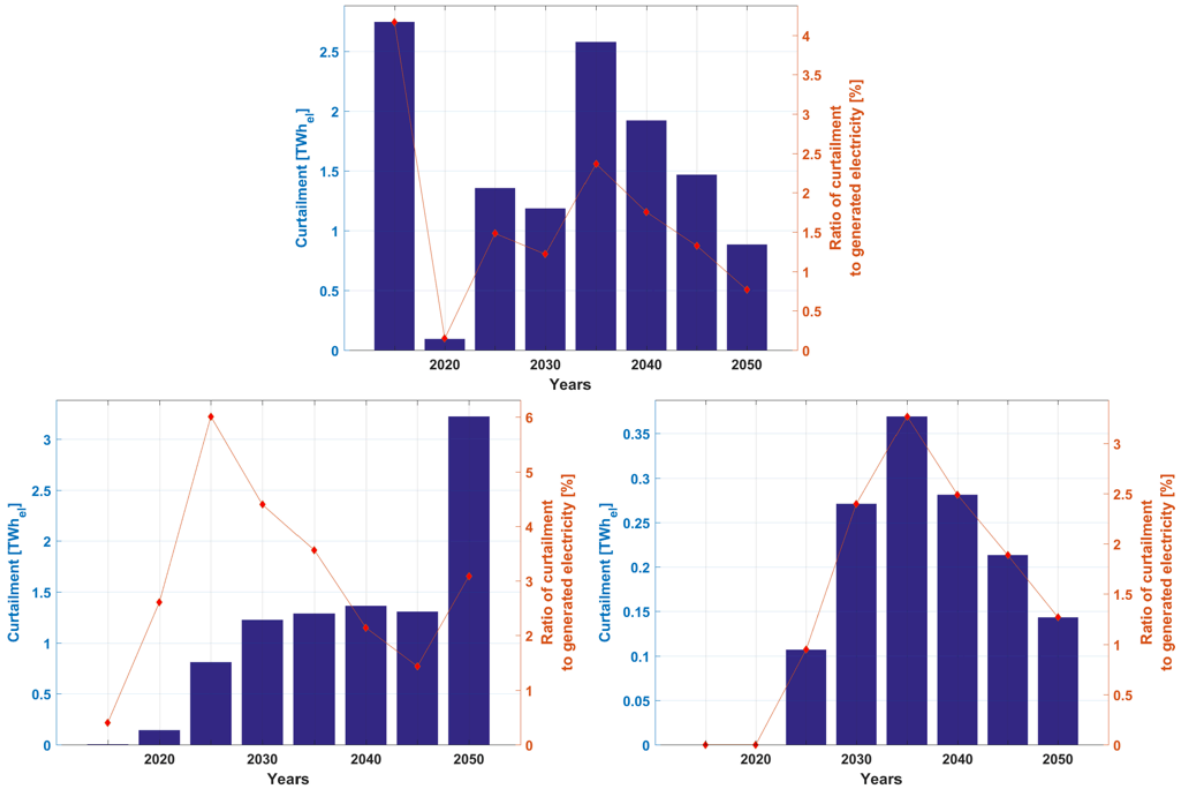

Figure S19: Curtailment – power and heat sectors (top), transport sector (bottom left), and desalination sector (bottom right)

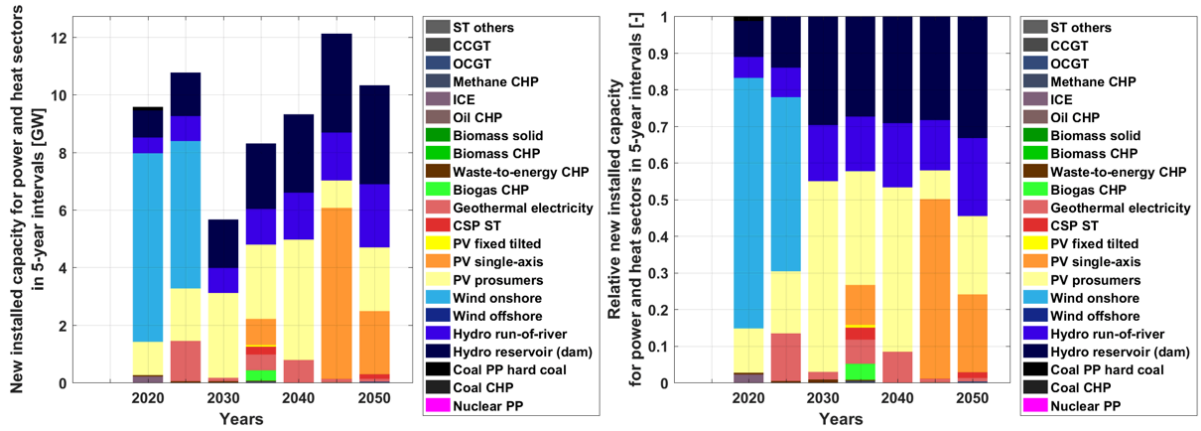

Figure S20: Technology-wise installed capacities for power and heat sectors in 5-year intervals in GW (left) and relative shares (right)

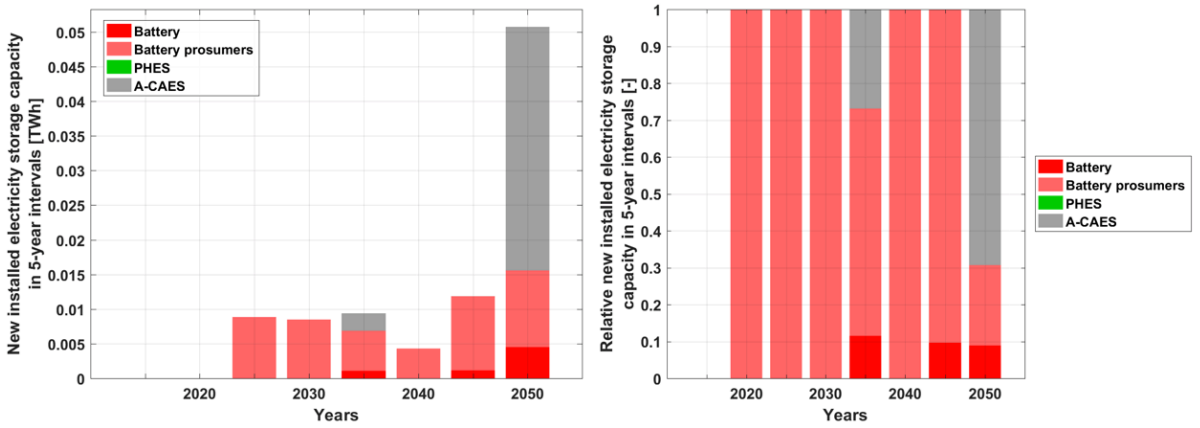

Figure S21: Technology-wise installed electricity storage capacity for power and heat sectors in 5-year intervals in TWh (left) and relative shares (right)

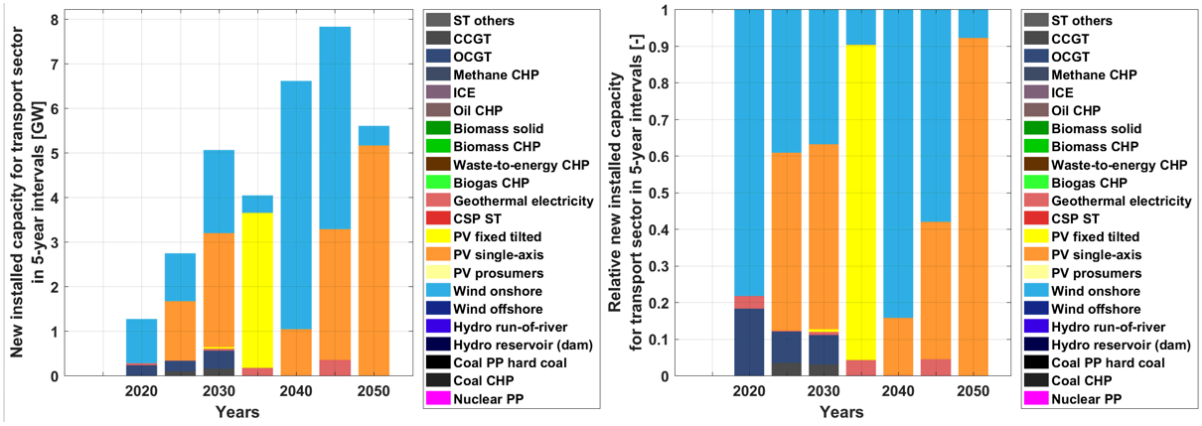

Figure S22: Technology-wise installed capacities for transport sector in 5-year intervals in GW (left) and relative shares (right)

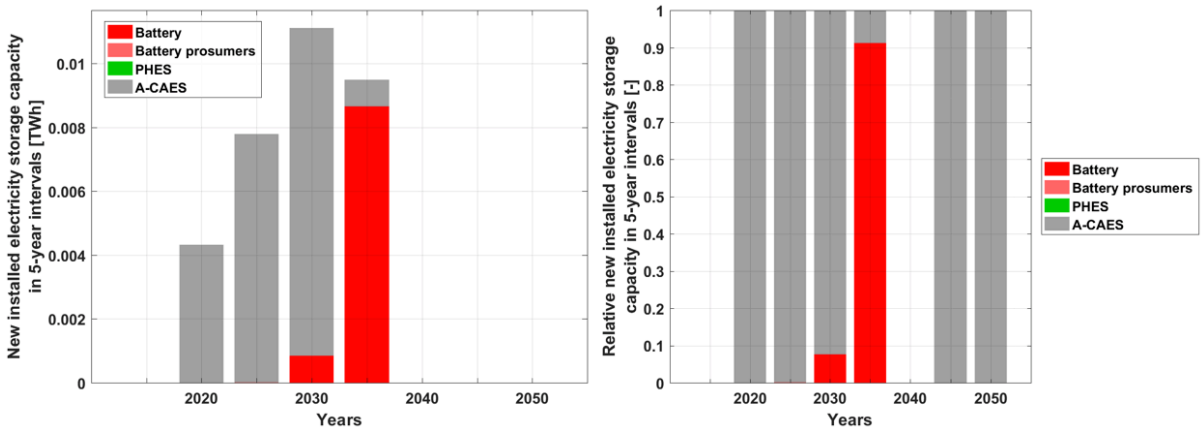

Figure S23: Technology-wise installed electricity storage capacity for transport sector in 5-year intervals in TWh (left) and relative shares (right)

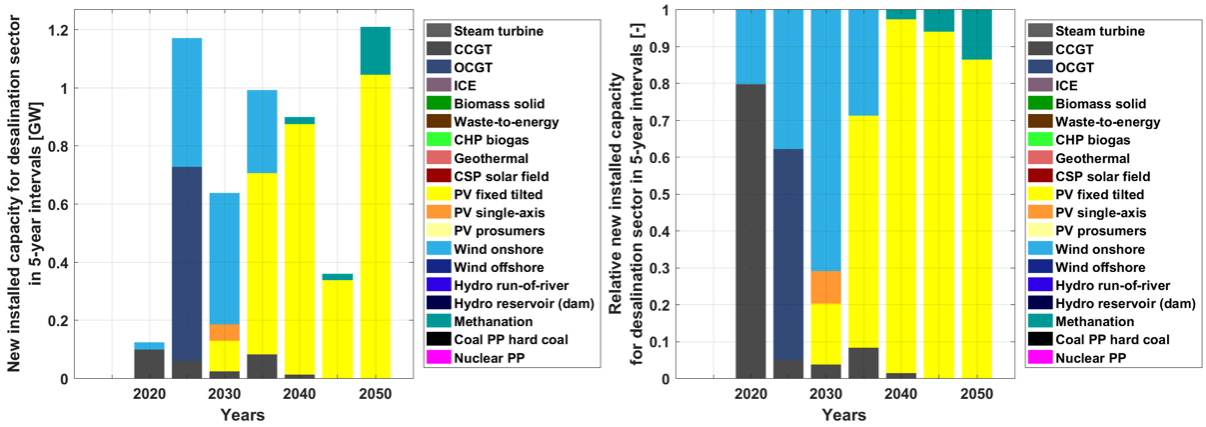

Figure S24: Technology-wise installed capacities for desalination sector in 5-year intervals in GW (left) and relative shares (right)

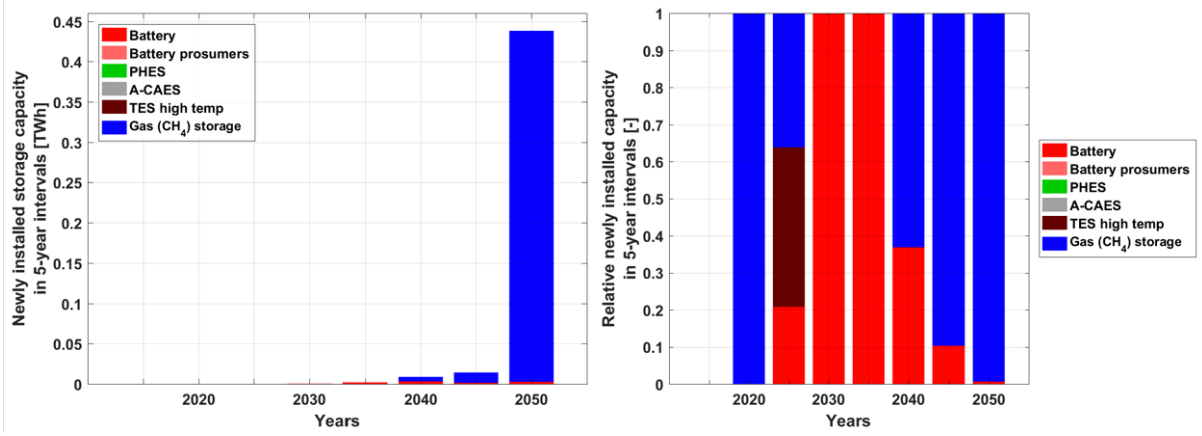

Figure S25: Technology-wise installed storage capacity for desalination sector in 5-year intervals in TWh (left) and relative shares (right)

Table S11: Installed capacity – power and heat sectors

Technology	Unit	2015	2020	2025	2030	2035	2040	2045	2050
PV prosumers RES	GW	0.00	0.21	0.73	1.53	2.15	2.69	2.88	3.08
PV prosumers COM	GW	0.00	0.14	0.48	1.00	1.39	1.78	1.96	2.17
PV prosumers IND	GW	0.00	0.81	1.78	3.39	4.97	8.21	8.80	9.44

PV fixed tilted	GW	1.09	1.09	1.09	1.09	1.15	1.15	1.15	0.25
PV single-axis	GW	0.00	0.00	0.00	0.00	0.91	0.91	6.85	9.04
CSP ST	GW	0.00	0.00	0.00	0.00	0.27	0.27	0.28	0.44
Wind onshore	GW	0.84	7.39	12.51	12.51	12.51	12.33	9.00	8.71
Wind offshore	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro run-of-river	GW	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
Hydro reservoir (dam)	GW	3.79	3.79	3.79	3.79	3.79	3.81	3.81	3.85
Geothermal electricity	GW	0.00	0.00	1.40	1.52	2.07	2.85	2.97	3.06
CCGT	GW	3.07	3.07	3.07	3.07	1.48	0.51	0.03	0.02
OCGT	GW	1.95	1.93	1.93	1.93	1.13	0.50	0.06	0.09
CSP SF	GW	0.00	1.96	2.02	2.02	2.06	2.06	5.20	5.20
ST others	GW	5.02	5.00	5.00	5.00	2.61	1.01	0.09	0.11
Biomass solid	GW	0.34	0.32	0.32	0.31	0.22	0.04	0.05	0.05
Biogas dig	GW	0.08	0.12	0.17	0.21	0.22	0.21	0.21	0.21
Biogas Upgrade	GW	0.00	0.07	0.11	0.14	0.15	0.14	0.11	0.14
Coal PP hard coal	GW	4.52	4.39	4.05	3.88	3.61	3.32	2.47	2.47
ICE	GW	2.83	2.41	1.97	0.03	0.00	0.00	0.00	0.00
Nuclear PP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methane CHP	GW	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04
Oil CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass CHP	GW	0.13	0.12	0.12	0.11	0.11	0.05	0.05	0.05
Waste-to-energy CHP	GW	0.00	0.04	0.09	0.14	0.16	0.16	0.16	0.14
Biogas CHP	GW	0.04	0.04	0.04	0.04	0.41	0.39	0.37	0.38
Electric heating DH	GW	2.72	2.72	4.53	5.28	6.90	6.95	9.38	8.84
Heat pump DH	GW	0.00	1.96	1.96	1.96	1.97	1.97	0.76	0.76
Methane DH	GW	2.22	2.20	2.06	2.00	1.45	1.13	0.52	0.18
Oil DH	GW	2.96	2.79	2.61	1.11	0.02	0.95	0.33	0.00
Coal DH	GW	0.53	0.59	0.56	0.21	0.00	0.05	0.00	0.03
Biomass DH	GW	3.65	3.44	3.95	4.53	3.64	4.42	3.68	4.92
Solar thermal heat	GW	0.00	0.57	0.98	0.98	0.98	1.05	2.28	2.28
Geothermal heat DH	GW	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electric heating IH	GW	10.05	10.05	8.04	6.03	4.02	2.01	0.00	0.30
Heat pump IH	GW	0.01	2.32	8.05	11.19	14.27	16.81	19.85	31.79
Methane IH	GW	8.83	4.53	1.72	0.09	0.00	0.00	0.00	0.53
Oil IH	GW	3.96	2.94	2.76	0.41	3.73	6.89	8.48	9.00
Biomass IH	GW	7.61	4.61	5.66	8.65	9.55	10.23	10.76	9.81
Biogas IH	GW	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.06

Battery prosumers RES	GWh	0.00	0.00	1.88	4.01	5.59	6.91	7.37	7.98
Battery prosumers COM	GWh	0.00	0.00	1.23	2.63	3.67	4.54	4.82	5.43
Battery prosumers IND	GWh	0.00	0.00	4.44	8.21	10.70	12.46	13.38	14.39
Battery	GWh	0.00	0.00	0.00	0.00	1.08	1.08	2.22	6.73
PHES	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TES HT	GWh	0.00	0.00	3.54	8.70	22.14	22.14	42.32	38.78
TES DH	GWh	0.00	4.54	7.86	7.86	8.40	8.41	18.59	18.21
A-CAES	GWh	0.00	0.00	0.00	0.00	2.52	2.53	2.53	37.69
Gas (CH4) storage	GWh	0.00	5.92	9.10	11.63	30.45	30.46	31.83	50.47

Table S12: Installed capacity – transport sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
PV prosumers	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PV fixed tilted	GW	0.00	0.00	0.00	0.04	3.52	3.52	3.52	3.52
PV single-axis	GW	0.00	0.00	1.33	3.89	3.89	4.93	7.87	13.03
CSP ST	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind onshore	GW	0.00	0.99	2.07	3.94	4.33	9.90	14.45	14.89
Wind offshore	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro run-of-river	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro reservoir (dam)	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Geothermal electricity	GW	0.00	0.04	0.05	0.09	0.26	0.27	0.62	0.62
CCGT	GW	0.27	0.27	0.37	0.52	0.52	0.52	0.52	0.25
OCGT	GW	0.00	0.23	0.47	0.87	0.87	0.87	0.87	0.87
ST others	GW	0.27	0.50	0.83	1.39	1.39	1.39	1.39	1.12
Biomass solid	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal PP hard coal	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ICE	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear PP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methane CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste-to-energy CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biogas CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water electrolysis	GW_el	0.00	0.02	0.15	0.91	1.26	5.95	10.33	13.44
Water electrolysis	GW_H2	0.00	0.01	0.13	0.77	1.06	5.00	8.68	11.29
CO_2 DAC	MtCO2/a	0.00	0.00	0.00	0.00	0.04	0.05	0.08	0.08
Methanation	GW_CH4	0.00	0.00	0.03	0.09	0.13	0.14	0.44	0.88

Fischer–Tropsch	GW_liq	0.00	0.00	0.00	0.25	0.17	2.04	3.09	3.08
Steam reforming	GW_H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Battery prosumers	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Battery	GWh	0.00	0.00	0.01	0.85	9.51	9.51	9.51	8.66
PHES	GWh	0	0	0	0	0	0	0	0
A-CAES	GWh	0.00	4.32	12.11	22.38	23.21	23.21	23.21	23.21
TES HT	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TES DH	GWh	0.00	0.00	0.00	0.01	0.06	0.06	0.06	0.05
Gas (CH4) storage	GWh	0.00	0.02	0.83	4.91	7.87	8.22	59.04	59.53

Table S13: Installed capacity – desalination sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
PV prosumers	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PV fixed tilted	GW	0.00	0.00	0.00	0.11	0.73	1.59	1.93	2.97
PV single-axis	GW	0.00	0.00	0.00	0.06	0.06	0.06	0.06	0.06
CSP solar field	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind onshore	GW	0.00	0.03	0.47	0.92	1.21	1.21	1.21	1.18
Wind offshore	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro run-of-river	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro reservoir (dam)	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Geothermal	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCGT	GW	0.03	0.12	0.18	0.21	0.29	0.30	0.30	0.30
OCGT	GW	0.02	0.02	0.69	0.69	0.69	0.69	0.69	0.69
Steam turbine	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass solid	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal PP hard coal	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ICE	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear PP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste-to-energy	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biogas CHP	GW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Battery prosumers	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Battery	GWh	0.00	0.00	0.00	0.35	2.34	5.55	7.02	9.76
PHES	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-CAES	GWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TES storage	GWh	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Gas (CH4) storage	GWh	0.00	0.00	0.00	0.00	0.00	5.51	18.30	453.72

Table S14: Electricity generation – power and heat sectors

Technology	Unit	2015	2020	2025	2030	2035	2040	2045	2050
PV prosumers RES	GWh	0	401	1396	2930	4108	5144	5489	5886
PV prosumers COM	GWh	0	270	908	1912	2654	3402	3746	4146
PV prosumers IND	GWh	0	1541	3390	6481	9482	15680	16809	18022
PV fixed tilted	GWh	2087	2087	2087	2087	3518	2202	477	481
PV single-axis	GWh	0	0	0	0	6042	1970	14877	19634
CSP ST	GWh	0	0	0	0	292	22	156	39
Wind onshore	GWh	2804	33695	57532	57274	57329	54344	41923	40542
Wind offshore	GWh	0	0	0	0	0	0	0	0
Hydro run-of-river	GWh	10237	10237	10237	10238	10467	10237	10238	10238
Hydro reservoir (dam)	GWh	14979	14979	14979	14980	13205	15073	15181	15230
Geothermal electricity	GWh	0	0	0	0	0	0	0	0
CCGT	GWh	10118	65	56	66	117	42	43	3
OCGT	GWh	1	0	0	0	56	1	29	4
ST others	GWh	10119	65	56	66	174	43	72	7
Biomass solid	GWh	0	0	0	0	98	13	32	2
Coal PP hard coal	GWh	20971	165	108	122	248	93	152	0
ICE	GWh	3718	0	0	0	0	0	0	0
Nuclear PP	GWh	0	0	0	0	0	0	0	0
Methane CHP	GWh	0	0	0	0	113	10	69	12
Oil CHP	GWh	0	0	0	0	0	0	0	0
Coal CHP	GWh	0	0	0	0	0	0	0	0
Biomass CHP	GWh	936	33	20	31	156	18	63	9
Waste-to-energy CHP	GWh	0	374	748	1134	1028	1134	1134	1134
Biogas CHP	GWh	39	77	82	118	245	189	332	204

Table S15: Electricity storage output – power and heat sectors

Technology	Unit	2015	2020	2025	2030	2035	2040	2045	2050
Battery	TWh	0.00	0.00	2.53	4.85	7.64	8.25	9.50	13.43
PHES	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-CAES	TWh	0.00	0.00	0.00	0.00	0.49	0.18	0.27	2.11
TES	TWh	0.00	0.00	0.00	0.00	0.29	0.02	0.16	0.04
Gas (CH4) storage	TWh	0.00	0.00	0.00	0.00	0.13	0.01	0.05	0.00

Table S16: Heat generation – heat sector

Technology	Unit	2015	2020	2025	2030	2035	2040	2045	2050
Methane CHP	GWh	0	0	0	0	47	6	38	9
Oil CHP	GWh	0	0	0	0	0	0	0	0

Coal CHP	GWh	0	0	0	0	0	0	0	0
CSP SF	GWh	0	1831	1735	1633	1564	1460	9076	8813
Biomass CHP	GWh	2066	74	45	69	250	38	123	20
Waste-to-energy CHP	GWh	0	1022	2044	3097	2646	3095	3017	3005
Biogas CHP	GWh	49	97	102	148	196	235	382	254
Electric heating DH	GWh	22597	11118	28191	29730	30446	29988	29939	28972
Heat pump DH	GWh	0	15426	14449	13924	13939	13950	4411	4454
Methane DH	GWh	8488	18319	1455	1566	2822	1411	1235	1197
Oil DH	GWh	350	365	74	15	147	3	134	0
Coal DH	GWh	4374	4941	4623	1780	28	23	2	0
Biomass DH	GWh	30344	19425	22157	24889	23576	24898	24625	24956
Solar thermal heat	GWh	0	0	0	0	521	678	2499	2894
Geothermal heat DH	GWh	0	0	0	0	0	0	0	0
Electric heating IH	GWh	0	516	497	535	112	15	0	16
Heat pump IH	GWh	72	19103	50056	60129	71642	82372	89497	98091
Methane IH	GWh	36622	20400	2140	32	0	0	0	58
Oil IH	GWh	3	2402	1535	137	698	916	686	0
Biomass IH	GWh	16319	16319	16680	17719	18166	18234	18569	18956
Biogas IH	GWh	0	0	0	0	1706	2443	3700	4350

Table S17: Heat storage output – heat sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
TES HT	TWh	0.00	0.00	0.63	1.54	7.32	5.12	10.80	9.26
TES DH	TWh	0.00	1.22	1.82	1.74	3.24	1.81	6.38	6.03
Gas (CH4) storage	TWh	0.00	0.00	0.00	0.00	1.47	0.23	0.50	0.25

Table S18: Electricity generation – transport sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
PV prosumers	GWh	0	0	0	0	0	0	0	0
PV fixed tilted	GWh	0	0	0	74	6715	6715	6716	6716
PV single-axis	GWh	0	0	2897	8451	8458	10711	17091	28311
CSP ST	GWh	0	0	0	0	0	0	0	0
Wind onshore	GWh	0	4628	9631	18322	20145	46096	67262	69307
Wind offshore	GWh	0	0	0	0	0	0	0	0
Hydro run-of-river	GWh	0	0	0	0	0	0	0	0
Hydro reservoir (dam)	GWh	0	0	0	0	0	0	0	0
Geothermal electricity	GWh	0	0	0	0	0	0	0	0
CCGT	GWh	1204	622	624	659	604	49	18	6

OCGT	GWh	0	249	351	416	279	9	2	1
ST others	GWh	1204	870	976	1075	883	58	20	8
Biomass solid	GWh	0	0	0	0	0	0	0	0
Coal PP hard coal	GWh	0	0	0	0	0	0	0	0
ICE	GWh	0	0	0	0	0	0	0	0
Nuclear PP	GWh	0	0	0	0	0	0	0	0
Methane CHP	GWh	0	0	0	0	0	0	0	0
Oil CHP	GWh	0	0	0	0	0	0	0	0
Coal CHP	GWh	0	0	0	0	0	0	0	0
Biomass CHP	GWh	0	0	0	0	0	0	0	0
Waste-to-energy CHP	GWh	0	0	0	0	0	0	0	0
Biogas CHP	GWh	0	0	0	0	0	0	0	0

Table S19: Electricity storage output – transport sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Battery	TWh	0.00	0.00	0.01	0.61	4.55	3.97	3.68	3.71
PHES	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-CAES	TWh	0.00	0.82	2.21	4.47	4.47	3.00	2.73	2.80
TES	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas (CH4) storage	TWh	0.00	0.00	0.02	0.06	0.07	0.01	0.01	0.01

Table S20: Sustainable fuel production (output) – transport sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Electrolyser	GWh	0	58	616	3796	5551	28956	50312	60227
Methanation	GWh	0	0	163	460	709	882	2365	4764
FT	GWh	0	0	3	1388	1039	13583	22684	22947
FT Kerosene	GWh	0	0	1	558	413	2717	4537	7546
FT diesel	GWh	0	0	1	553	418	8150	13610	10812
FT naphtha	GWh	0	0	1	278	208	2716	4537	4589
LNG	GWh	0	68	152	339	565	851	2309	4688
LH2	GWh	0	0	0	152	670	2332	6603	12965

Table S21: Final transport energy demand by mode, segment, and vehicle type

	Unit	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Road LDV ICE fuel	TWh,th	25.16	26.05	22.23	13.46	5.17	2.65	1.69	0.80
Road LDV BEV elec	TWh,el	0.00	0.18	0.57	2.05	3.44	3.69	3.73	3.93
Road LDV FCEV H2	TWh,th	0.00	0.00	0.01	0.08	0.17	0.38	0.83	0.80
Road LDV PHEV fuel	TWh,th	0.00	0.06	0.18	0.17	0.16	0.05	0.16	0.00

Road LDV PHEV elec	TWh,el	0.00	0.09	0.30	0.30	0.29	0.24	0.28	0.24
Road 2W/3W ICE fuel	TWh,th	1.27	1.29	1.22	0.83	0.53	0.24	0.24	0.00
Road 2W/3W BEV elec	TWh,el	0.18	0.24	0.28	0.43	0.55	0.61	0.73	0.79
Road 2W/3W FCEV H2	TWh,th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road 2W/3W PHEV fuel	TWh,th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road 2W/3W PHEV elec	TWh,el	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Road Bus ICE fuel	TWh,th	19.47	17.50	10.33	3.49	1.17	0.85	0.75	0.43
Road Bus BEV elec	TWh,el	0.98	2.00	4.74	7.18	7.56	7.12	7.11	7.03
Road Bus FCEV H2	TWh,th	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00
Road Bus PHEV fuel	TWh,th	0.01	0.05	0.10	0.15	0.19	0.15	0.29	0.20
Road Bus PHEV elec	TWh,el	0.00	0.02	0.04	0.07	0.08	0.05	0.12	0.00
Road MDV ICE fuel	TWh,th	43.26	42.21	37.39	22.13	7.41	2.21	1.85	1.26
Road MDV BEV elec	TWh,el	0.01	1.69	3.12	7.41	10.88	11.28	11.39	11.52
Road MDV FCEV H2	TWh,th	0.00	0.03	0.28	0.54	1.31	2.53	2.66	2.70
Road MDV PHEV fuel	TWh,th	0.02	0.16	0.33	0.49	0.64	0.70	0.97	1.01
Road MDV PHEV elec	TWh,el	0.00	0.02	0.05	0.07	0.09	0.07	0.14	0.02
Road HDV ICE fuel	TWh,th	7.41	7.85	6.96	5.88	3.40	0.78	0.30	0.07
Road HDV BEV elec	TWh,el	0.00	0.04	0.29	0.53	1.02	1.57	1.64	1.64
Road HDV FCEV H2	TWh,th	0.00	0.02	0.09	0.22	0.82	1.15	1.24	1.21
Road HDV PHEV fuel	TWh,th	0.00	0.03	0.07	0.11	0.14	0.18	0.53	0.44
Road HDV PHEV elec	TWh,el	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.00
Rail pass fuel	TWh,th	0.07	0.09	0.07	0.06	0.04	0.00	0.00	0.00
Rail pass elec	TWh,el	0.00	0.01	0.01	0.02	0.03	0.00	0.03	0.00
Rail freight fuel	TWh,th	0.47	0.50	0.44	0.35	0.26	0.09	0.12	0.00
Rail freight elec	TWh,el	0.03	0.04	0.07	0.11	0.14	0.13	0.20	0.18
Marine pass fuel	TWh,th	0.44	0.48	0.50	0.50	0.50	0.36	0.34	0.00
Marine pass elec	TWh,el	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marine pass LH2	TWh,th	0.00	0.00	0.00	0.00	0.01	0.00	0.10	0.15
Marine pass LNG	TWh,th	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.00
Marine freight fuel	TWh,th	13.60	15.08	16.27	17.03	17.48	16.51	13.37	6.74
Marine freight elec	TWh,el	0.00	0.00	0.04	0.10	0.27	0.56	0.87	1.08
Marine freight LH2	TWh,th	0.00	0.00	0.00	0.15	0.48	1.60	4.42	8.83
Marine freight LNG	TWh,th	0.00	0.07	0.16	0.34	0.55	0.93	2.23	4.82
Aviation pass fuel	TWh,th	7.50	8.71	9.82	11.07	11.42	11.90	10.85	7.65
Aviation pass elec	TWh,el	0.00	0.00	0.00	0.00	0.05	0.17	0.54	1.02
Aviation pass LH2	TWh,th	0.00	0.00	0.00	0.00	0.18	0.78	2.07	4.04
Aviation freight fuel	TWh,th	0.09	0.13	0.15	0.19	0.22	0.16	0.26	0.06
Aviation freight elec	TWh,el	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Aviation freight LH2	TWh,th	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00

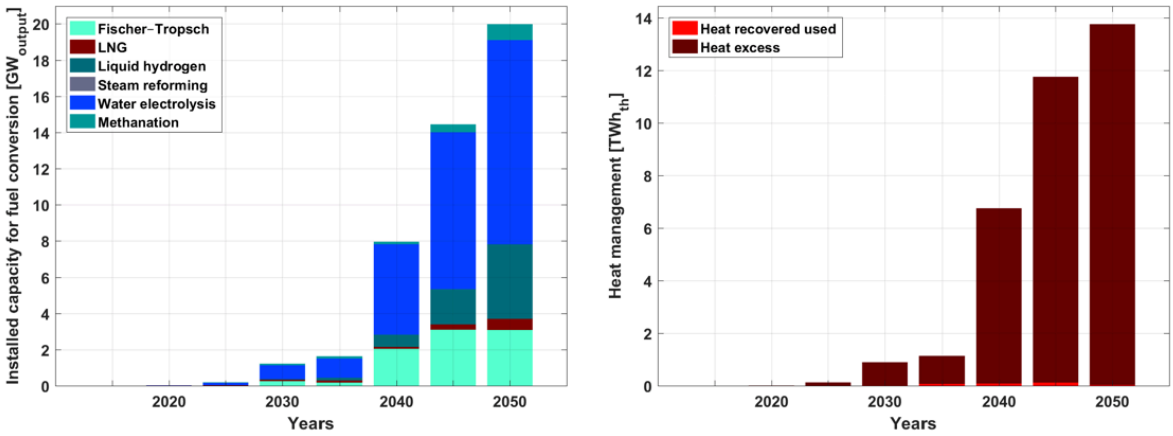

Figure S26: Transport sector - Installed capacity for fuel conversion (left) and heat management (right)

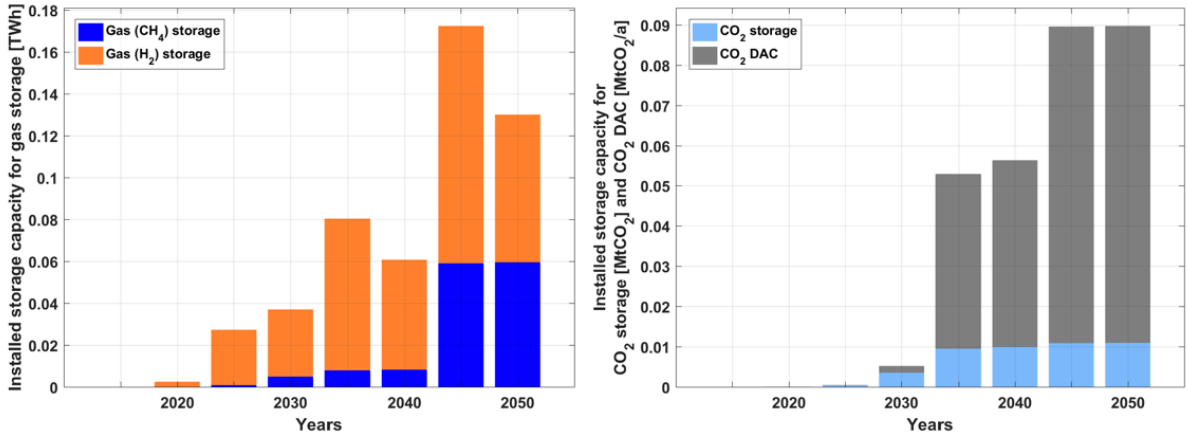

Figure S27: Transport sector - Installed capacity for gas storage (left) and CO_2 direct air capture and CO_2 storage (right)

Table S22: Electricity generation – desalination sector

Technology	Unit	2015	2020	2025	2030	2035	2040	2045	2050
PV prosumers	GWh	0	0	0	0	0	0	0	0
PV fixed tilted	GWh	0	0	0	201	1391	3036	3680	5673
PV single-axis	GWh	0	0	0	122	122	122	122	122
CSP solar field	GWh	0	0	0	0	0	0	0	0
Wind onshore	GWh	0	117	2179	4285	5615	5615	5615	5499
Wind offshore	GWh	0	0	0	0	0	0	0	0
Hydro run-of-river	GWh	0	0	0	0	0	0	0	0
Hydro reservoir (dam)	GWh	0	0	0	0	0	0	0	0
Geothermal	GWh	0	0	0	0	0	0	0	0
CCGT	GWh	209	1028	628	856	1126	1078	1003	434
OCGT	GWh	157	4	53	347	352	255	177	28
Steam turbine	GWh	0	0	0	0	0	0	0	0
Biomass solid	GWh	0	0	0	0	0	0	0	0
Coal PP hard coal	GWh	0	0	0	0	0	0	0	0

ICE	GWh	0	0	0	0	0	0	0	0
Nuclear PP	GWh	0	0	0	0	0	0	0	0
Waste-to-energy	GWh	0	0	0	0	0	0	0	0
Biogas CHP	GWh	0	0	0	0	0	0	0	0

Table S23: Electricity storage output – desalination sector

Technology	**Unit**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Battery	TWh	0.00	0.00	0.00	0.08	0.54	1.47	1.91	2.88
PHES	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-CAES	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TES storage	TWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas (CH4) storage	TWh	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.46

Table S24: Electricity costs – power and heat sectors

	Unit	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
LCOE - Generation	€/MWh	41.4	56.2	46.1	45.2	40.3	38.9	36.8	29.5
LCOC - Curtailment	€/MWh	1.8	0.1	0.7	0.6	1.0	0.8	0.5	0.2
LCOS - Storage	€/MWh	0.0	0.0	1.8	2.6	5.9	3.3	3.0	3.6
GHG emissions cost	€/MWh	3.5	0.1	0.1	0.1	0.3	0.1	0.2	0.0
Fuel costs	€/MWh	24.7	-0.2	-0.5	-0.7	-0.5	-0.7	-0.7	-0.8
Total LCOE	€/MWh	71.4	56.1	48.2	47.7	47.0	42.2	39.9	32.6

Table S25: Heat costs – power and heat sectors

	Unit	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
LCOH - Generation	€/MWh	48.9	40.3	37.2	34.4	35.7	31.6	31.0	31.6
LCOS - Storage	€/MWh	0.0	0.2	0.3	0.4	0.8	0.7	1.0	1.2
Total LCOH	€/MWh	48.9	40.5	37.5	34.8	36.5	32.3	32.0	32.8

Table S26: Sustainable fuel costs – transport sector

	Unit	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
LCOE primary	€/MWh	61.5	37.6	33.2	29	26.7	22.8	21.4	19.9
LCOE others	€/MWh	0.2	14.5	18.2	14.3	13.8	6.7	5.1	5.4
Hydrogen	€/MWh	0.0	89.7	81.3	63.7	60.3	43.3	39.2	38.0
LH2	€/MWh	0.0	0.0	0.0	74.5	67.2	49.9	45.3	44.3
SNG	€/MWh	0.0	0.0	112.0	89.4	87.3	65.2	58.7	56.1
LNG	€/MWh	0.0	31.9	103.3	97.4	94.4	69.2	62.4	59.7
Fischer–Tropsch	€/MWh	0.0	0.0	0.0	119.8	122.6	82.8	75.0	73.0

Table S27: Electricity costs – desalination sector

	Unit	2015	2020	2025	2030	2035	2040	2045	2050
LCOE - Generation	€/MWh	57.6	57.3	52.4	45.2	41.4	37.3	35.4	19.4
LCOC - Curtailment	€/MWh	0.0	0.0	2.0	2.2	1.9	1.1	0.7	0.3
LCOS - Storage	€/MWh	0.0	0.0	0.0	1.2	4.7	9.3	11.1	21.8
Total LCOE	€/MWh	57.6	57.3	54.4	48.6	47.9	47.7	47.2	41.5
LCOW	€/m^3	1.1	0.9	0.8	0.7	0.7	0.7	0.7	0.6

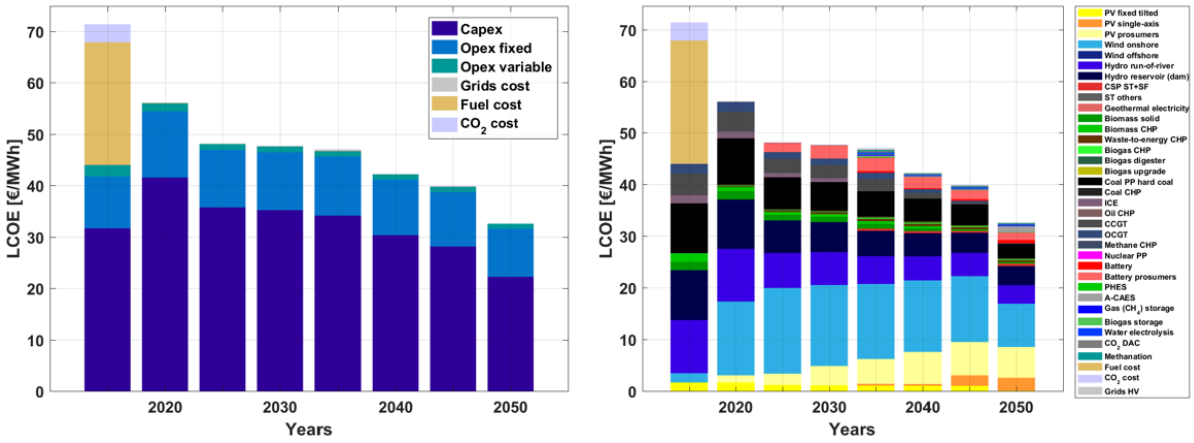

Figure S28: Power sector – Levelised cost of electricity by main cost categories (left) and technology (right)

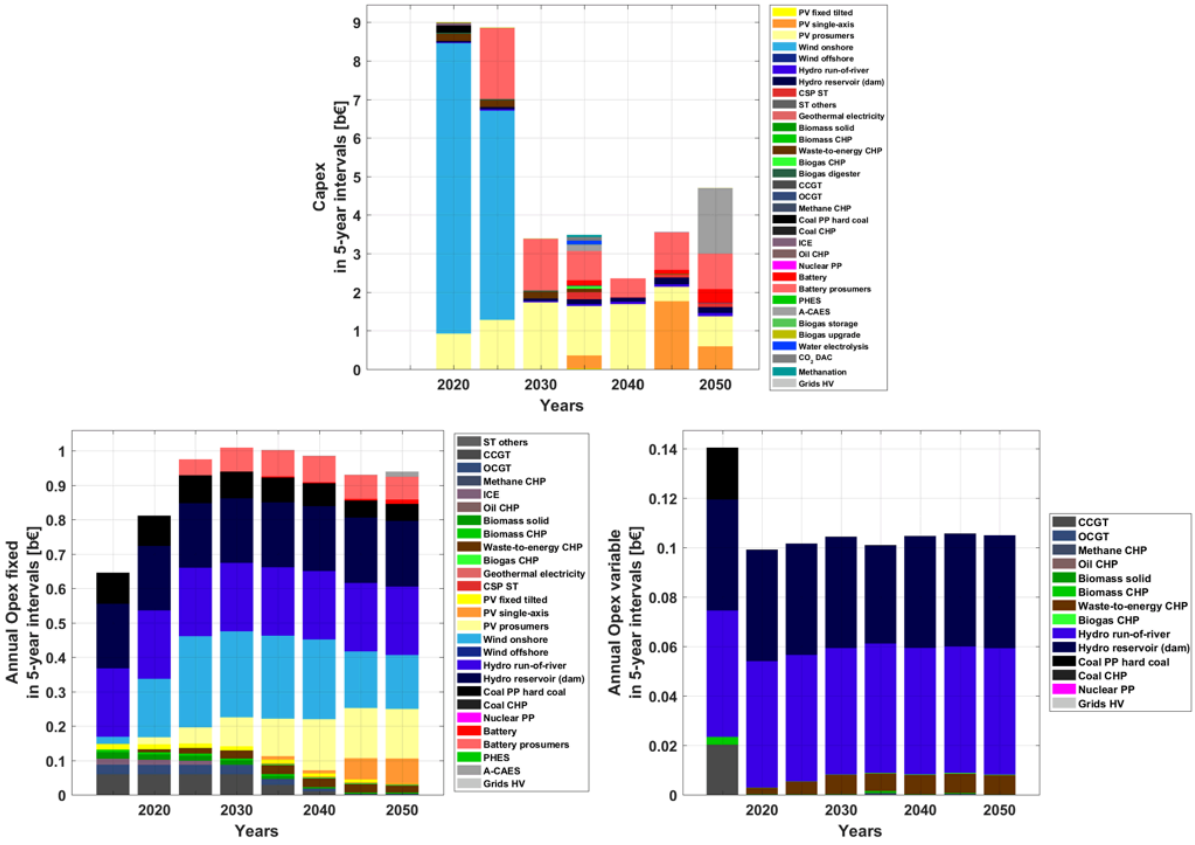

Figure S29: Power sector – Capex (top), Opex fixed (bottom left), and Opex variable (bottom right)

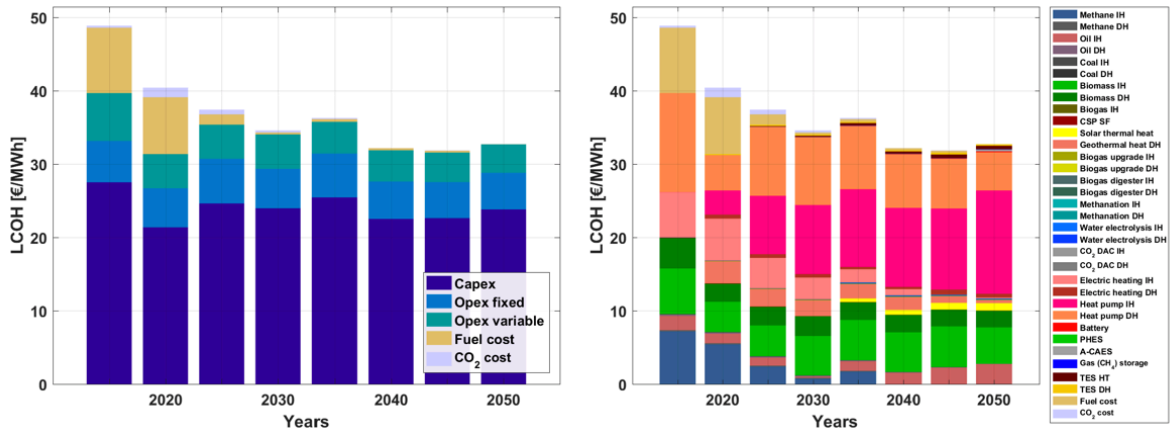

Figure S30: Heat sector – Levelised cost of heat by main cost category (left) and technology (right)

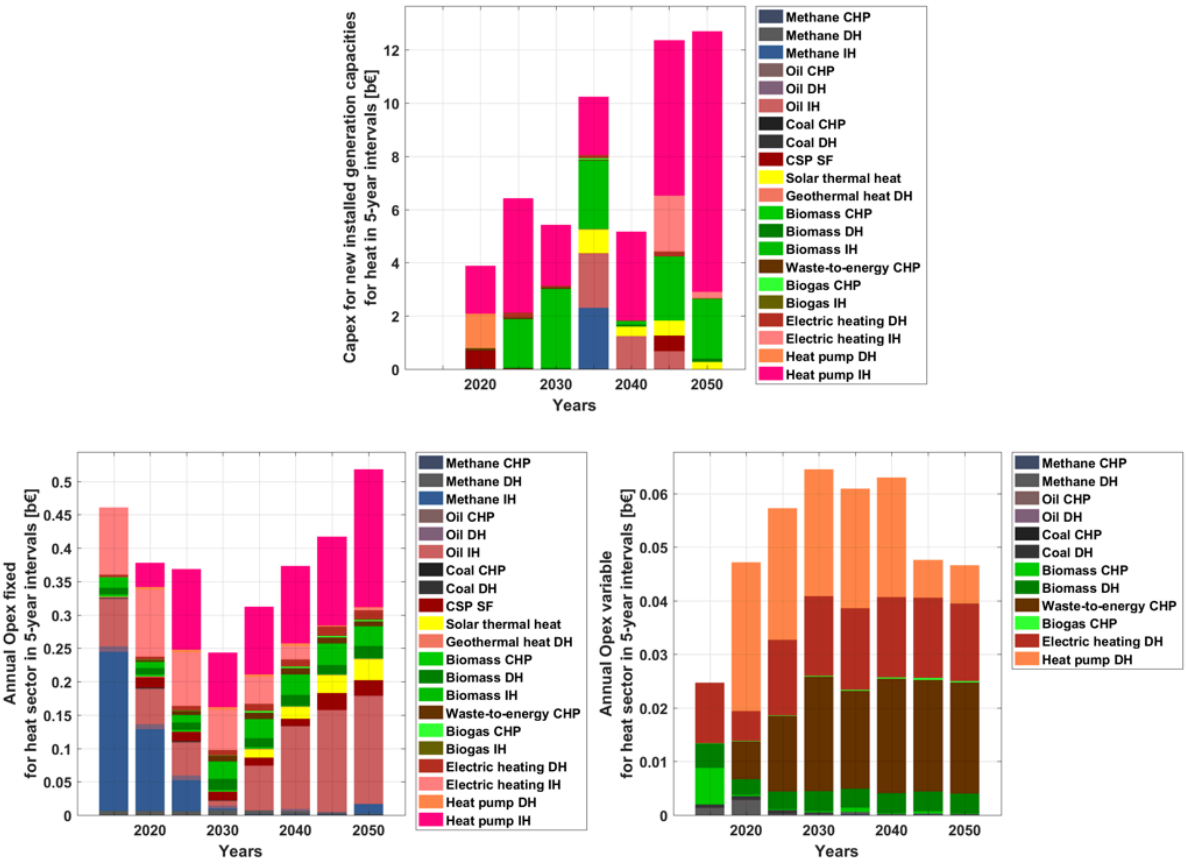

Figure S31: Heat sector – Capex (top), Opex fixed (bottom left), and Opex variable (bottom right)

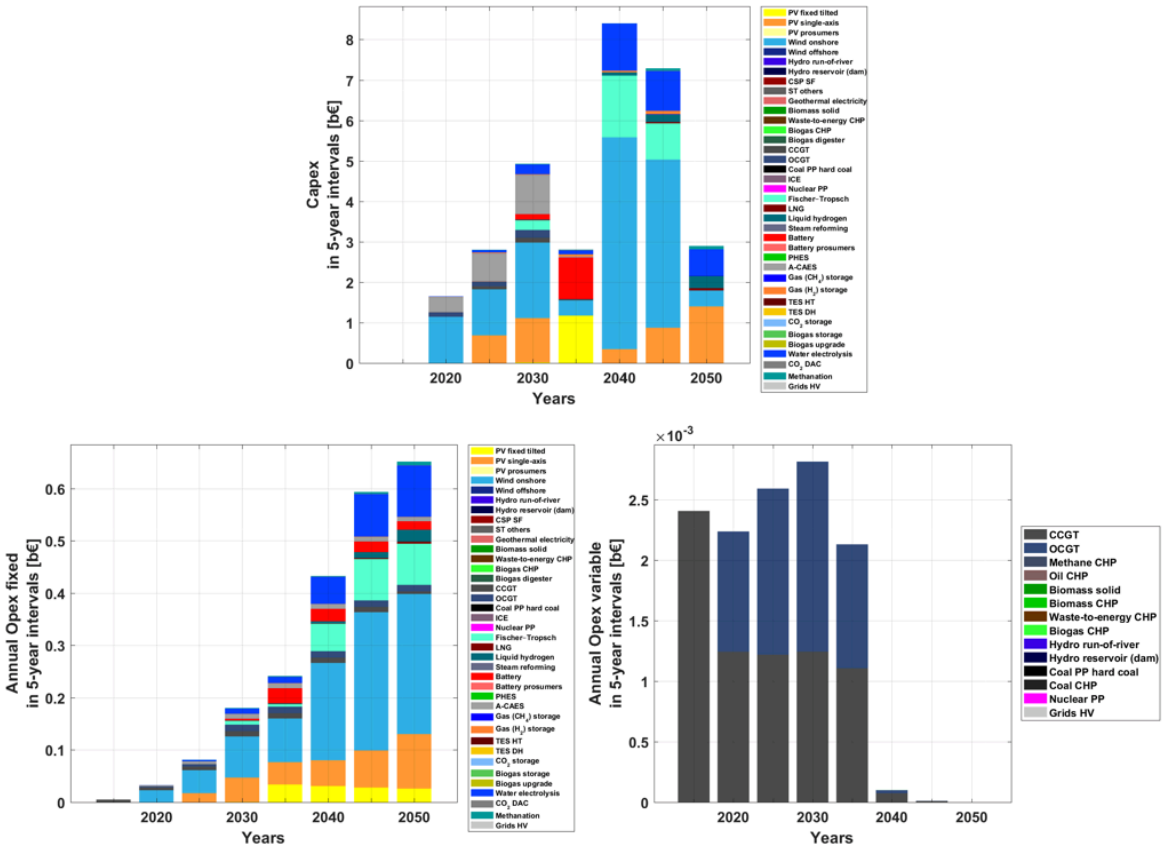

Figure S32: Transport sector – Capex (top), Opex fixed (bottom left), and Opex variable (bottom right)

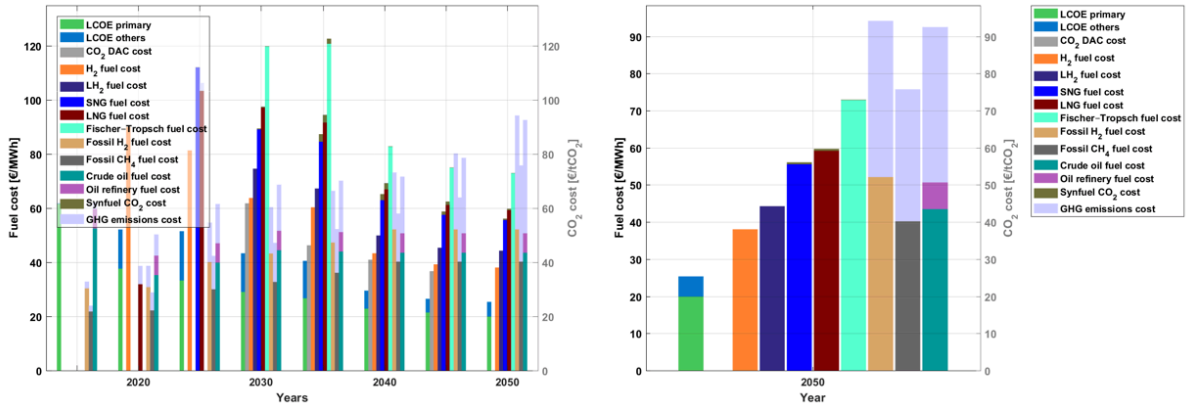

Figure S33: Fuel costs for the transport sector during the transition period (left) and fuel costs in 2050 (right)

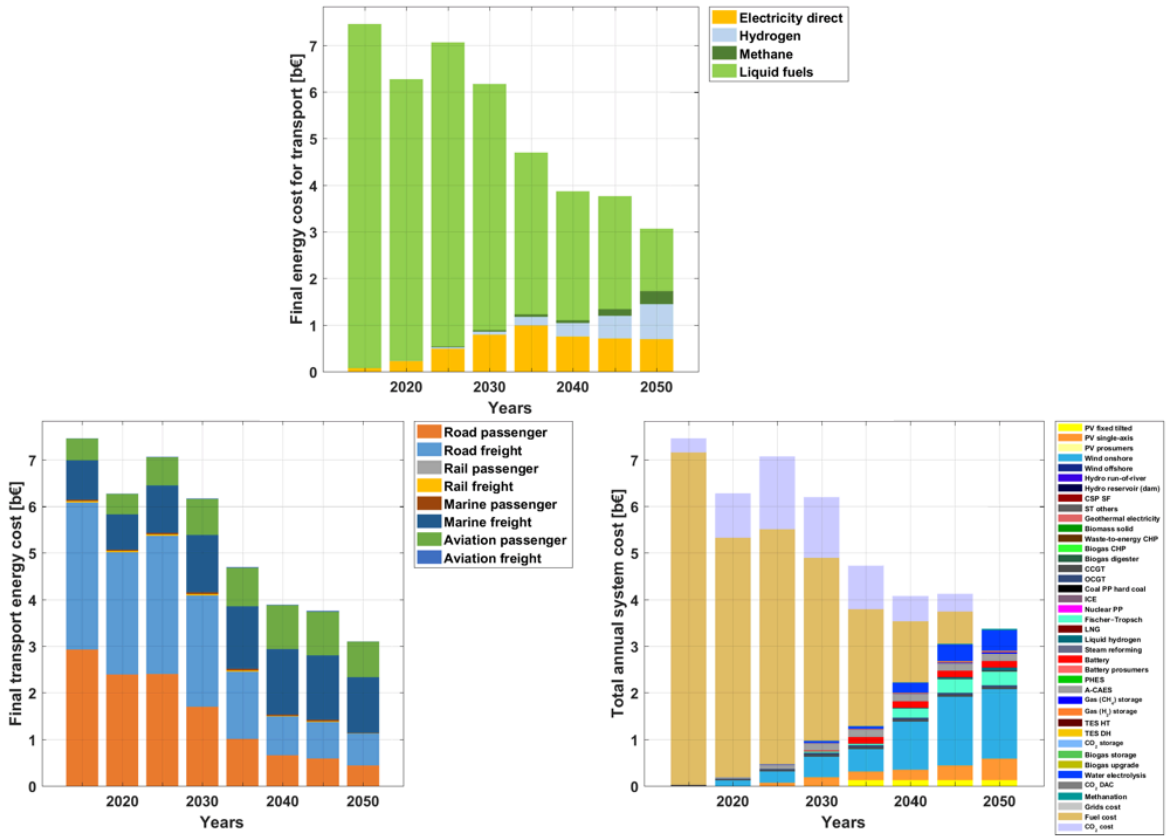

Figure S34: Final transport energy costs based on fuel form (top), mode of transport (bottom left), and technology (bottom right)

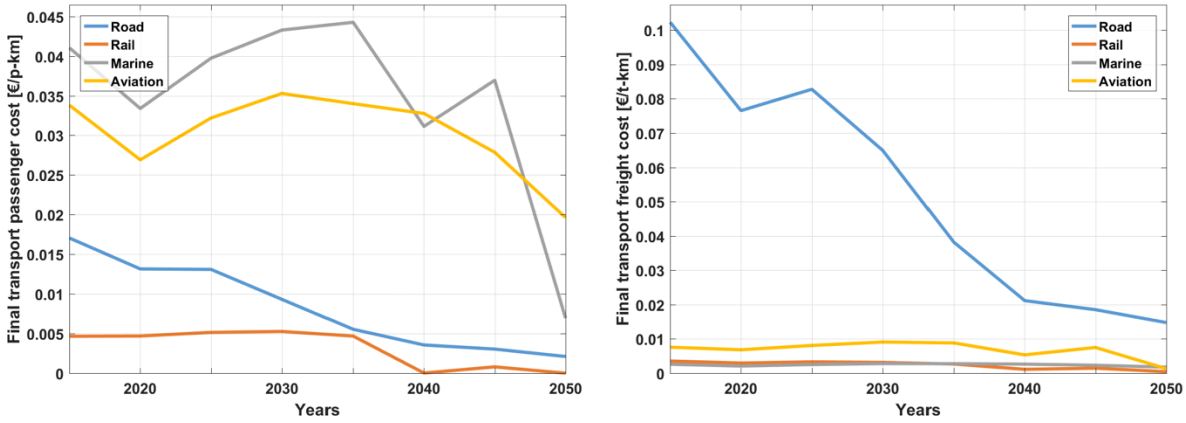

Figure S35: Final transport costs by mode – passenger (left) and freight (right)

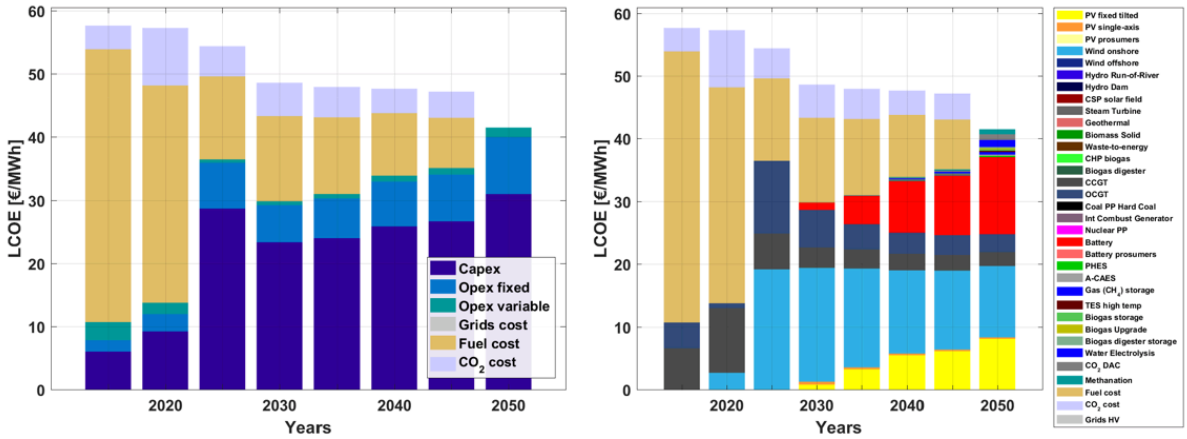

Figure S36: Desalination sector – Levelised cost of electricity by main cost categories (left) and technology (right)

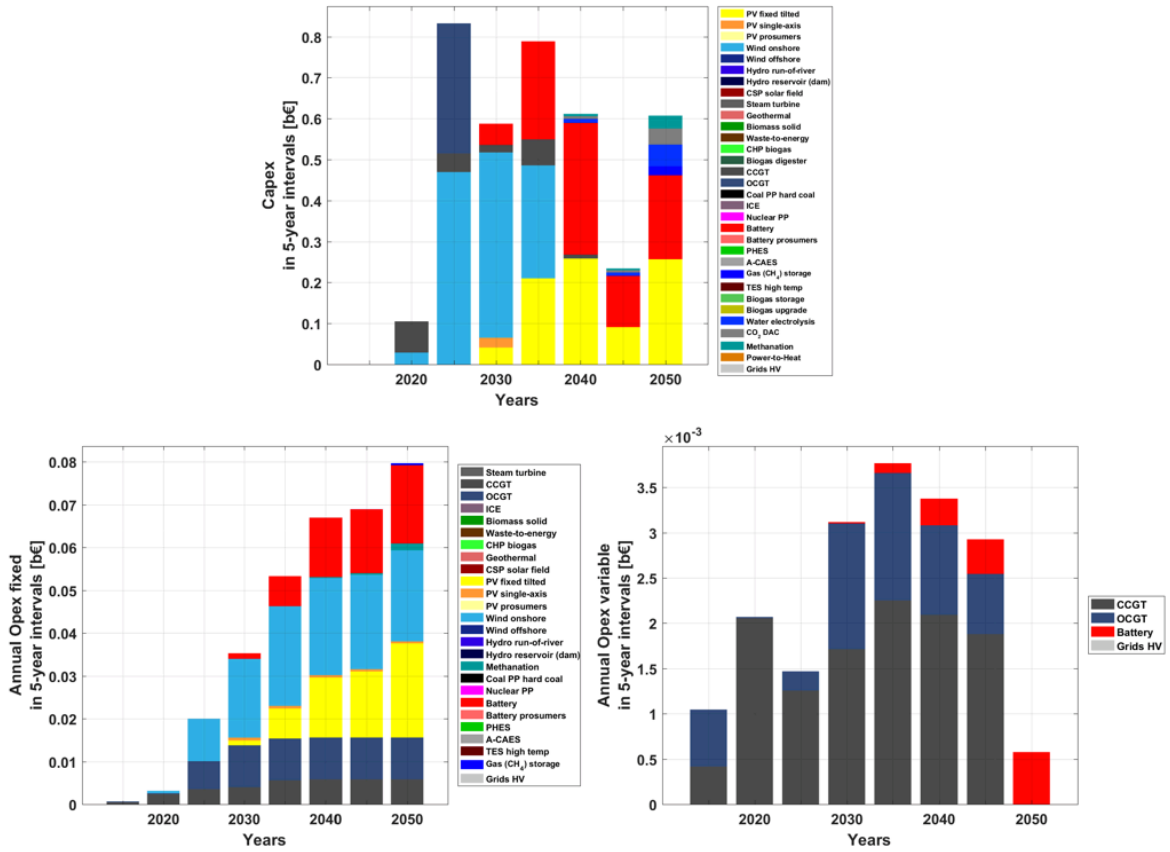

Figure S37: Desalination sector – Capex (top), Opex fixed (bottom left), and Opex variable (bottom right)

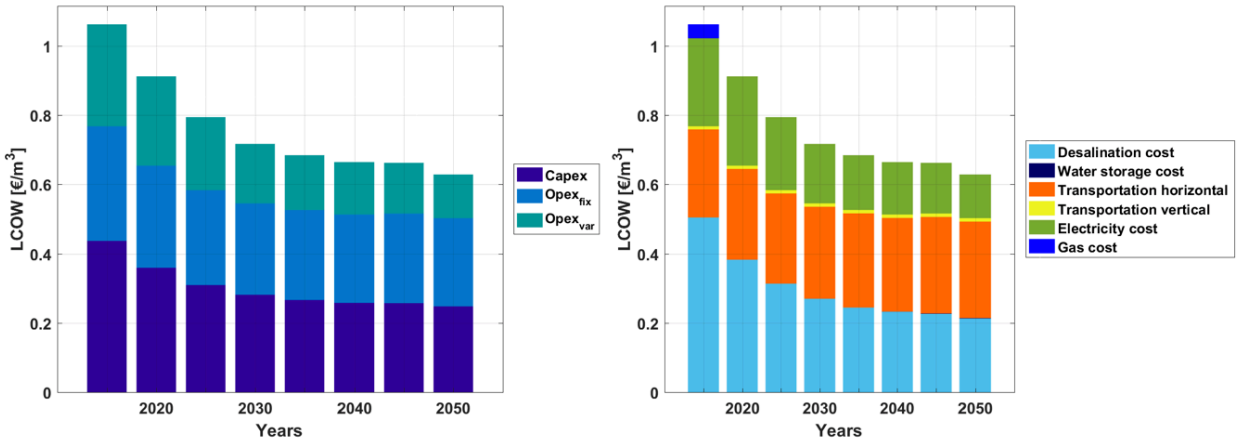

Figure S38: Desalination sector – Levelised cost of water by main cost categories (left) and process/fuel (right)

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Abbreviations

A-CAES	Adiabatic compressed air energy storage
CAPEX	Capital expenditures
CCS	Carbon capture and storage
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
CO_2	Carbon dioxide
CSP	Concentrated solar thermal power
DAC	CO_2 Direct air capture
DH	District heating
FT	Fischer-Tropsch
GHG	Greenhouse gas
GT	Gas turbine
GW	Gigawatt
HDV	Heavy duty vehicle
HHB	Hot heat burner
HT	High temperature
HVAC	High voltage alternating current
HVDC	High voltage direct current
ICE	Internal combustion engine
IH	Individual heating
LCOC	Levelised Cost of Curtailment
LCOE	Levelised Cost of Energy
LCOH	Levelised Cost of Heat

LCOS	Levelised Cost of Storage
LCOW	Levelised Cost of Water
LDV	Light duty vehicle
LNG	Liquefied natural gas
LT	Low temperature
LUT	Lappeenranta University of Technology
MDV	Medium duty vehicle
MT	Medium temperature
MW	Megawatt
MWh	Megawatt hour
OCGT	Open cycle gas turbine
OECD	Organization for Economic Co-operation and Development
OPEX	Operational expenditures
PHES	Pumped hydro energy storage
PP	Power plant
PtG	Power-to-gas
PtH	Power-to-heat
p-km	passenger kilometre
PV	Photovoltaic
SF	Solar Field
SNG	Synthetic natural gas
ST	Steam turbine
TES	Therma energy storage
TTW	Tank-to-wheel
TWh	Terawatt hour
t-km	tonne kilometre
2W	two wheelers
3W	three wheelers
€	Euro