Comparative techno-economic potential study to produce green hydrogen products via CSP-PV-hybrid-power-plants for MENA

Appendix D: Detailed site-specific results

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

TRACTEBEL ENGIE

Contents

Results Optimized system design: Site S1 for 2030

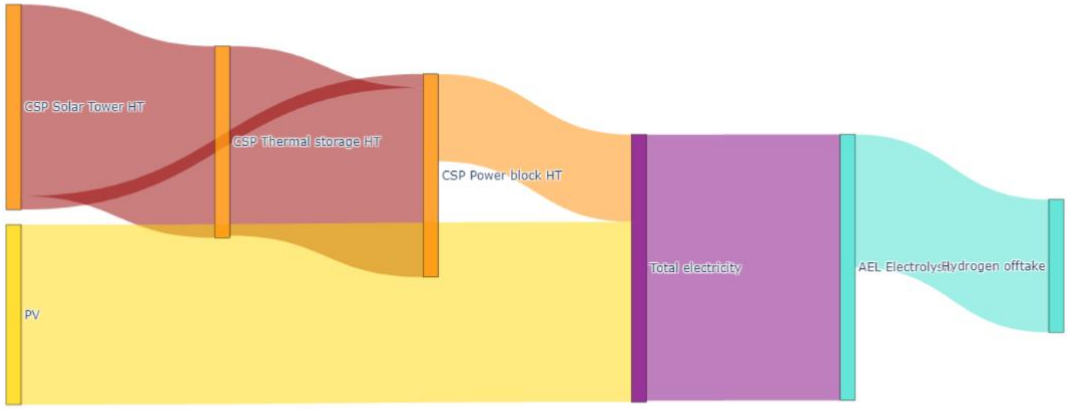
S1 2030			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	269.0	269.0	378.3	269.0	269.0	378.3
PV	capacity factor	%	39.3%	39.3%	39.3%	39.3%	39.3%	39.3%
Wind onshore	capacity	MW	-	-	-	-	-	-
Wind onshore	capacity factor	%	-	-	-	-	-	-
CSP Solar Tower HT	capacity	MW_{th}	487.0	490.0	757.6	485.9	490.0	757.6
CSP Solar Tower	capacity factor	%	24.7%	24.6%	14.2%	24.8%	24.6%	14.2%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	487.0	490.0	524.3	485.9	490.0	524.3
CSP TES HT		MWh_{th}	3,531.1	3,519.1	4,200.0	3,536.4	3,519.1	4,200.0
CSP TES HT	capacity factor	%	25.7%	25.1%	22.0%	25.4%	25.1%	22.0%
CSP TES MT	capacity	MW_{th}	-	-	332.9	-	-	332.9
CSP TES MT		MWh_{th}	-	-	3,329.2	-	-	3,329.2
CSP TES MT	capacity factor	%	-	-	6.8%	-	-	6.8%
CSP Powerblock HT	capacity	MW_{el}	97.4	97.1	77.8	97.6	97.1	77.8
CSP Power block HT	capacity factor	%	52.6%	52.8%	46.6%	52.5%	52.8%	46.6%
CSP Powerblock MT	capacity	MW_{el}	-	-	22.2	-	-	22.2
CSP Power block MT	capacity factor	%	-	-	41.4%	-	-	41.4%
Electric Heater HT	capacity	MW_{th}	-	-	-	-	-	-
Electric Heater HT	capacity factor	%	-	-	-	-	-	-
Electric Heater MT	capacity	MW_{th}	-	-	78.5	-	-	78.5
Electric Heater MT	capacity factor	%	-	-	6.7%	-	-	6.7%
Battery storage	capacity	MW	-	-	-	-	-	-
Battery storage		MWh	-	-	-	-	-	-
Battery storage	capacity factor	%	-	-	-	-	-	-
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	36.3	36.3	36.3	36.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	208.3	208.3	208.3	208.3
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	-
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	-	49.0	-	-	49.0

S1 2030			Technology open scenario			CSP PV hybrid scenario		
Commodity flows per year (MoL*) *Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
Water demineralization	Water, desalinated Import	kt	282.1	282.1	282.1	282.1	282.1	282.1
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	190.6	190.6	190.6	190.6
PV	Electricity Generation	GWh	926.3	926.3	1,302.4	926.3	926.3	1,302.4
Wind onshore	Electricity Generation	GWh	-	-	-	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	1,055.3	1,056.0	941.1	1,055.4	1,056.0	941.1
CSP Trough	Heat MT Generation	GWh	-	0.0	-	-	0.0	-
CSP TES HT	Heat HT Discharge	GWh	1,096.5	1,076.6	1,012.5	1,081.9	1,076.6	1,012.5
CSP TES MT	Heat MT Discharge	GWh	-	(0.0)	199.1	-	(0.0)	199.1
CSP Powerblock HT	Electricity Production	GWh	449.0	449.0	317.9	449.0	449.0	317.9
CSP Powerblock MT	Electricity Production	GWh	-	0.0	80.5	-	0.0	80.5
Electric Heater HT	Heat HAT Production	GWh	-	0.0	-	-	0.0	-
Electric Heater MT	Heat MT Production	GWh	-	(0.0)	46.1	-	(0.0)	46.1
Batterystorage	Electricity Discharge	GWh	-	0.0	-	-	0.0	-
Total PtX	Electricity Consumption	GWh	1,368.4	1,368.4	1,381.5	1,368.4	1,368.4	1,381.5
RES el. feed-in/Curtail	Electricity Consumption	GWh	0	0	263,73	128.9		263,71
RES th. feed-in/Curtail	Heat Consumption	GWh	131,5	138,3	905,3	128,9	138,3	905,3
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	20.5
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	-
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	-
Hydrogen compressor	Electricity Consumption	GWh	-	-	3.9	-	-	3.9
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

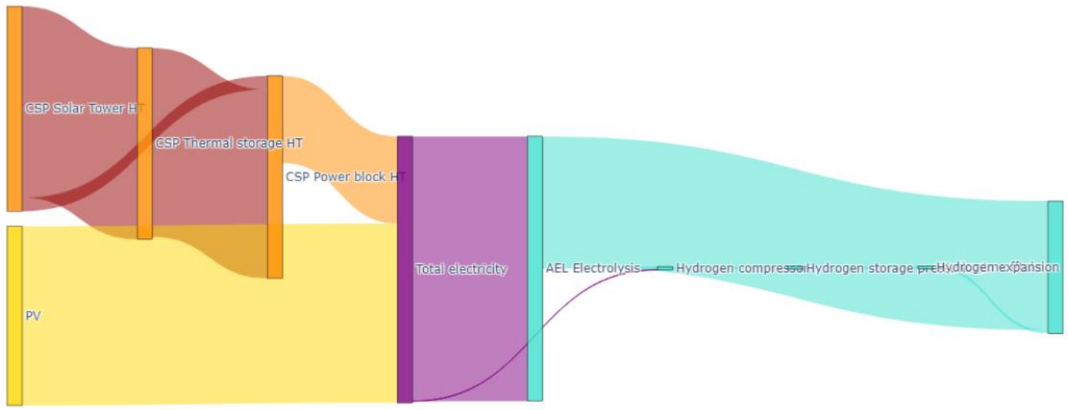
S1 2030			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	246,088.7	246,088.7	346,011.8	246,088.7	246,088.7	346,011.8
PV	OPEX	kEUR	40,315.6	40,315.6	56,685.6	40,315.6	40,315.6	56,685.6
Wind onshore	CAPEX	kEUR	-	-	-	-	-	-
Wind onshore	OPEX	kEUR	-	-	-	-	-	-
CSP Solar Tower	CAPEX	kEUR	153,882.9	154,854.7	239,405.5	153,555.5	154,854.7	239,405.5
CSP Solar Tower	OPEX	kEUR	40,234.9	40,489.0	62,596.0	40,149.3	40,489.0	62,596.0
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	136,386.1	135,916.8	108,955.8	136,596.3	135,916.8	108,955.8
CSP Power block HT	OPEX	kEUR	62,133.5	61,972.4	48,243.5	62,205.7	61,972.4	48,243.5
CSP Powerbloc kMT	CAPEX	kEUR	-	-	28,868.3	-	-	28,868.3
CSP Power block MT	OPEX	kEUR	-	-	11,994.0	-	-	11,994.0
Electric Heater HT	CAPEX	kEUR	-	-	-	-	-	-
Electric Heater HT	OPEX	kEUR	-	-	-	-	-	-
Electric Heater MT	CAPEX	kEUR	-	-	8,635.0	-	-	8,635.0
Electric Heater MT	OPEX	kEUR	-	-	603.0	-	-	603.0
CSP TES HT	CAPEX	kEUR	70,622.0	70,381.4	84,000.0	70,728.8	70,381.4	84,000.0
CSP TES HT	OPEX	kEUR	22,616.2	22,539.2	26,900.0	22,650.4	22,539.2	26,900.0
CSP TES MT	CAPEX	kEUR	-	0.0	79,901.4	-	0.0	79,901.4
CSP TES MT	OPEX	kEUR	-	-	21,323.0	-	-	21,323.0
Battery storage	CAPEX	kEUR	-	-	-	-	-	-
Battery storage	OPEX	kEUR	-	-	-	-	-	-
Water demineralization	CAPEX	kEUR	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3
Water demineralization	OPEX	kEUR	580.8	580.8	580.8	580.8	580.8	580.8
Water supply	OPEX	kEUR	301.2	301.2	301.2	301.2	301.2	301.2
AEL Electrolysis	CAPEX	kEUR	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3
AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8
SOEL Electrolysis	CAPEX	kEUR	-	0.0	-	-	0.0	-

SOEL Electrolysis	OPEX	kEUR	-	0.0	-	-	0.0	-
Hydrogen compressor LP	CAPEX	kEUR	-	-	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	-	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	-	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	-	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	-	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	-	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**950,400.3**	**1,047,755.9**	**1,347,382.4**	**950,389.8**	**1,047,755.9**	**1,347,382.4**
Total OPEX		**kEUR**	**221,766.0**	**261,299.7**	**491,785.2**	**221,786.9**	**261,299.7**	**491,785.2**

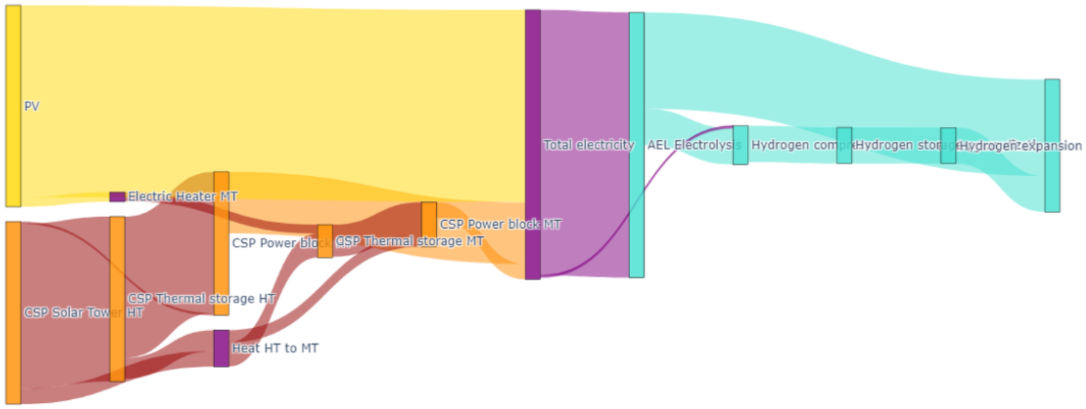
S1, H2, Technology open scenario, 2030



S1, NH3, Technology open scenario, 2030



S1, MeOH, Technology open scenario, 2030



Results Optimized system design: Site S1 for 2050

S1 2050			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	187.8	188.0	291.3	187.8	188.0	291.3
PV	capacity factor	%	39.3%	39.3%	39.3%	39.3%	39.3%	39.3%
Wind onshore	capacity	MW	-	-	-	-	-	-
Wind onshore	capacity factor	%	-	-	-	-	-	-
CSP Solar Tower HT	capacity	MW_{th}	397.5	397.3	495.3	397.5	397.3	495.3
CSP Solar Tower	capacity factor	%	24.2%	24.1%	18.5%	24.2%	24.1%	18.5%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	420.0	420.0	472.4	420.0	420.0	472.4
CSP TES HT		MWh_{th}	4,200.0	4,200.0	4,200.0	4,200.0	4,200.0	4,200.0
CSP TES HT	capacity factor	%	22.0%	23.2%	20.1%	22.0%	23.2%	20.1%
CSP TES MT	capacity	MW_{th}	23.9	23.8	70.9	23.9	23.8	70.9
CSP TES MT		MWh_{th}	239.0	238.4	685.7	239.0	238.4	685.7
CSP TES MT	capacity factor	%	18.2%	24.3%	25.3%	18.2%	24.3%	25.3%
CSP Powerblock HT	capacity	MW_{el}	56.4	56.4	65.7	56.4	56.4	65.7
CSP Power block HT	capacity factor	%	59.6%	59.6%	47.6%	59.6%	59.6%	47.6%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	-	-	-
CSP Power block MT	capacity factor	%	-	-	-	-	-	-
Electric Heater HT	capacity	MW_{th}	15.9	15.9	7.7	15.9	15.9	7.7
Electric Heater HT	capacity factor	%	4.4%	4.6%	4.6%	4.4%	4.6%	4.6%
Electric Heater MT	capacity	MW_{th}	28.7	28.7	80.1	28.7	28.7	80.1
Electric Heater MT	capacity factor	%	8.6%	9.5%	3.2%	8.6%	9.5%	3.2%
Battery storage	capacity	MW	-	-	-	-	-	-
Battery storage		MWh	-	-	-	-	-	-
Battery storage	capacity factor	%	-	-	-	-	-	-
Waterdemineralization	capacity	t_{H2O}/h	43.3	43.3	43.3	43.3	43.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	-
SOEL Electrolysis (fix)	capacity	MW_{el}	160.7	160.7	160.7	160.7	160.7	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	-	49.0	-	-	49.0

S1 2050			Technology open scenario			CSP PV hybrid scenario		

Commodity flows per year (MoL*)

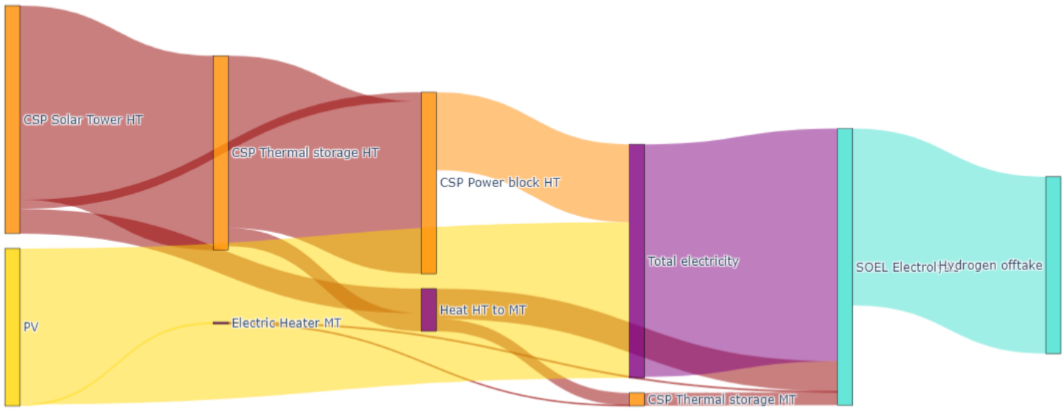
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
Water demineralization	Water, desalinated Import	kt	336.7	336.7	336.7	336.7	336.7	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	227.5	227.5	227.5	227.5	227.5	227.5
PV	Electricity Generation	GWh	646.6	647.2	1,003.1	646.6	647.2	1,003.1
Wind onshore	Electricity Generation	GWh	-	-	-	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	841.8	838.1	803.7	841.8	838.1	803.7
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	810.1	853.6	832.3	810.1	853.6	832.3
CSP TES MT	Heat MT Discharge	GWh	38.1	50.8	157.0	38.1	50.8	157.0
CSP Powerblock HT	Electricity Production	GWh	294.5	294.4	273.6	294.5	294.4	273.6
CSP Powerblock MT	Electricity Production	GWh	-	-	-	-	-	-
Electric Heater HT	Heat HAT Production	GWh	6.1	6.4	3.1	6.1	6.4	3.1
Electric Heater MT	Heat MT Production	GWh	21.7	23.9	22.8	21.7	23.9	22.8
Batterystorage	Electricity Discharge	GWh	-	-	-	-	-	-
Total PtX	Electricity Consumption	GWh	898.6	898.6	910.8	898.6	898.6	910.8
RES el.feed-in/Curtail	Electricity Consumption	GWh	135.5	136.7	729.1	135.5	136.7	729.1
AEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	898.4	898.4	898.4	898.4	898.4	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	-	3.6	-	-	3.6
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

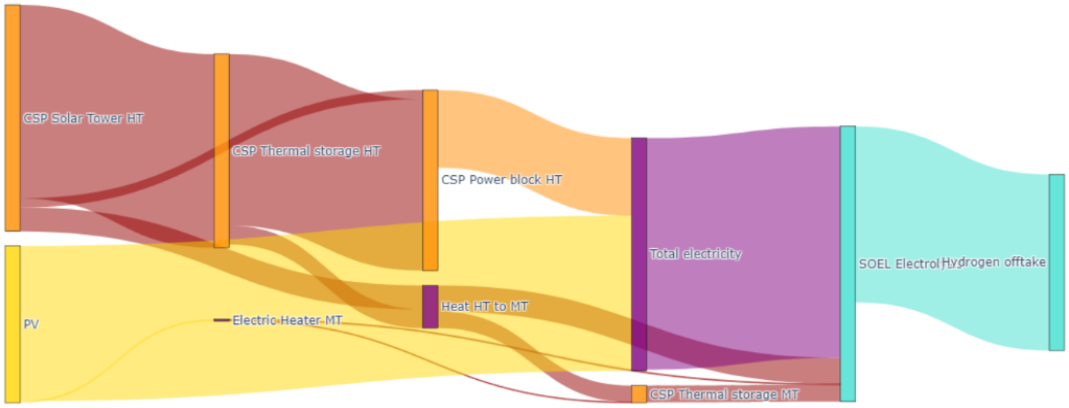
S1 2050			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	118,668.9	118,781.8	184,092.4	118,668.9	118,781.8	184,092.4
PV	OPEX	kEUR	19,441.0	19,459.5	27,915.2	19,441.0	19,459.5	27,915.2
Wind onshore	CAPEX	kEUR	-	-	-	-	-	-
Wind onshore	OPEX	kEUR	-	-	-	-	-	-
CSP Solar Tower	CAPEX	kEUR	116,911.2	116,864.5	145,683.1	116,911.2	116,864.5	145,683.1
CSP Solar Tower	OPEX	kEUR	32,840.7	32,827.6	44,356.4	32,840.7	32,827.6	44,356.4
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	73,467.9	73,494.7	85,582.9	73,467.9	73,494.7	85,582.9
CSP Power block HT	OPEX	kEUR	37,142.8	37,148.8	41,400.5	37,142.8	37,148.8	41,400.5
CSP Powerbloc k MT	CAPEX	kEUR	-	-	-	-	-	-
CSP Power block MT	OPEX	kEUR	-	-	-	-	-	-
Electric Heater HT	CAPEX	kEUR	2,193.4	2,203.7	1,058.0	2,193.4	2,203.7	1,058.0
Electric Heater HT	OPEX	kEUR	135.5	136.1	-	135.5	136.1	-
Electric Heater MT	CAPEX	kEUR	2,935.3	2,936.6	8,200.6	2,935.3	2,936.6	8,200.6
Electric Heater MT	OPEX	kEUR	220.3	220.4	492.2	220.3	220.4	492.2
CSP TES HT	CAPEX	kEUR	78,187.2	78,187.2	78,187.2	78,187.2	78,187.2	78,187.2
CSP TES HT	OPEX	kEUR	26,900.4	26,900.4	26,900.4	26,900.4	26,900.4	26,900.4
CSP TES MT	CAPEX	kEUR	5,339.5	5,326.6	15,317.6	5,339.5	5,326.6	15,317.6
CSP TES MT	OPEX	kEUR	1,530.9	1,527.2	5,015.3	1,530.9	1,527.2	5,015.3
Battery storage	CAPEX	kEUR	-	-	-	-	-	-
Battery storage	OPEX	kEUR	-	-	-	-	-	-
Water demineralizat ion	CAPEX	kEUR	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2
Water demineralizat ion	OPEX	kEUR	693.2	693.2	693.2	693.2	693.2	693.2
Water supply	OPEX	kEUR	359.5	359.5	359.5	359.5	359.5	359.5
AEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	-

AEL Electrolysis	OPEX	kEUR	-	-	-	-	-	-
SOEL Electrolysis	CAPEX	kEUR	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3
SOEL Electrolysis	OPEX	kEUR	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	-	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	-	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	-	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	-	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	-	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	-	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**563,239.8**	**660,425.3**	**791,842.2**	**563,239.8**	**660,425.3**	**791,842.2**
Total OPEX		**kEUR**	**178,573.3**	**218,099.4**	**413,416.0**	**178,573.3**	**218,099.4**	**413,416.0**

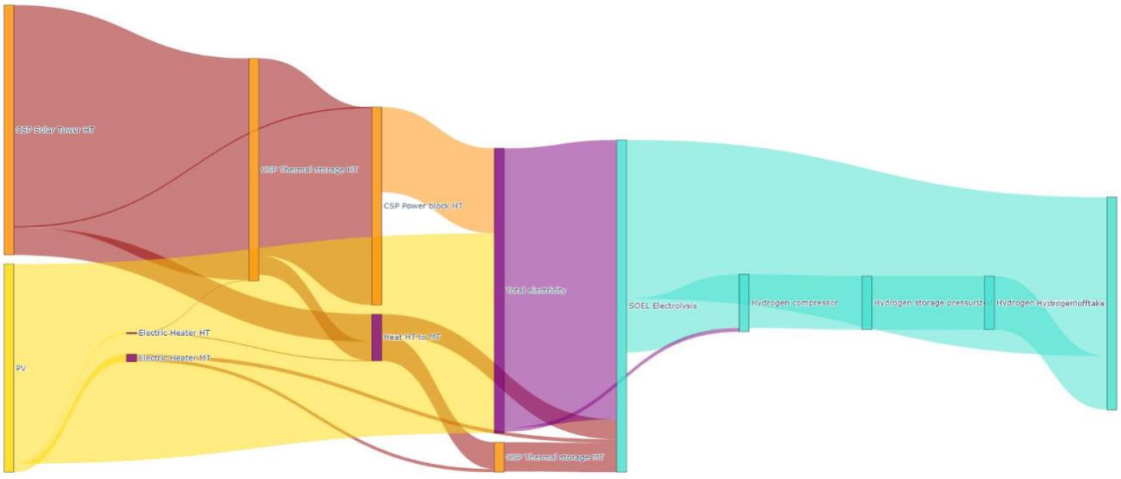
S1, NH3, Technology open scenario, 2050



S1, H2, Technology open scenario, 2050



S1, MeOH, Technology open scenario, 2050



Results Optimized system design: Site S2 for 2030

S2 2030			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	1.8	24.7	269.2	686.6	659.7	903.6
PV	capacity factor	%	33.7%	33.7%	33.7%	33.7%	33.7%	33.7%
Wind onshore	capacity	MW	334.3	318.1	394.8	-	-	-
Wind onshore	capacity factor	%	47.4%	47.4%	47.4%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	-	-	74.0	-
CSP Solar Tower	capacity factor	%					13.6%	
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	-	-	420.0	379.7	427.4	482.1
CSP TES HT		MWh_{th}	-	-	4,200.0	3,504.1	3,627.5	4,200.0
CSP TES HT	capacity factor	%			0.5%	28.4%	26.8%	20.6%
CSP TES MT	capacity	MW_{th}	-	-	-	-	-	365.5
CSP TES MT		MWh_{th}	-	-	-	-	-	3,655.0
CSP TES MT	capacity factor	%						4.0%
CSP Powerblock HT	capacity	MW_{el}	-	-	23.1	109.3	110.2	55.6
CSP Power block HT	capacity factor	%			3.7%	41.1%	41.3%	48.0%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	-	-	-
CSP Power block MT	capacity factor	%	-	-	-	-	-	-
Electric Heater HT	capacity	MW_{th}	-	-	53.6	379.7	355.2	482.1
Electric Heater HT	capacity factor	%			4.4%	27.8%	27.4%	17.5%
Electric Heater MT	capacity	MW_{th}	-	-	-	-	-	-
Electric Heater MT	capacity factor	%	-	-	-	-	-	-
Battery storage	capacity	MW	1.3	1.3	-	-	-	18.8
Battery storage		MWh	3.6	3.8	-	-	-	72.5
Battery storage	capacity factor	%	2.8%	3.7%				12.3%
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	36.3	36.3	36.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	208.3	208.3	208.3	-
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60	60	60	60	60	60
Hydrogen compressor LP		t_{H2}/h	-	0.09	1.56	-	0.34	1.56
Hydrogen compressor HP		t_{H2}/h	-	0.09	1.56	-	0.34	1.56
Hydrogen storage pressurized		t_{H2}	-	13.1	49.0	-	5.5	49.0

S2 2030	Technology open scenario	CSP PV hybrid scenario

Commodity flows per year (MoL*)

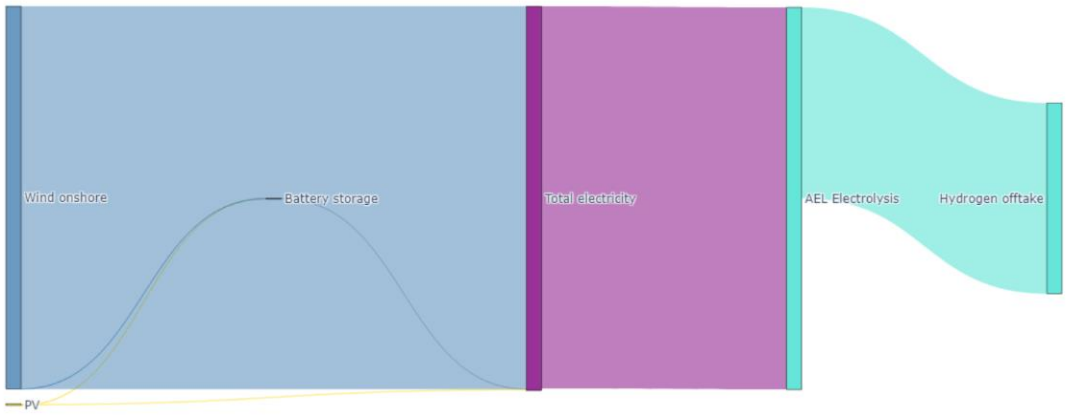
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		Unit	H_2	NH_3	MeOH	H_2	NH_3	MeOH
Water demineralization	Water, desalinated Import	kt	282.1	282.1	282.1	282.1	282.1	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	190.6	190.6	190.6	227.5
PV	Electricity Generation	GWh	5.3	72.9	795.0	2,027.5	1,948.0	2,668.3
Wind onshore	Electricity Generation	GWh	1,388.4	1,321.3	1,639.9	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	-	-	-	-	88.1	-
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	-	-	19.9	945.1	1,004.1	868.6
CSP TES MT	Heat MT Discharge	GWh	-	-	-	-	0.0	127.7
CSP Powerblock HT	Electricity Production	GWh	-	-	7.5	393.7	399.2	233.4
CSP Powerblock MT	Electricity Production	GWh	-	-	-	-	-	-
Electric Heater HT	Heat HAT Production	GWh	-	-	20.6	925.7	851.9	740.3
Electric Heater MT	Heat MT Production	GWh	-	-	-	-	-	-
Batterystorage	Electricity Discharge	GWh	0.3	0.4	-	-	-	20.2
Total PtX	Electricity Consumption	GWh	1,368.4	1,368.7	1,372.0	1,368.4	1,369.6	911.2
RES el.feed-in/Curtail	Electricity Consumption	GWh	16.8	17.5	1,000.6	51.4	61.9	1,160.4
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	0.1	1.1	-	0.4	3.7
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

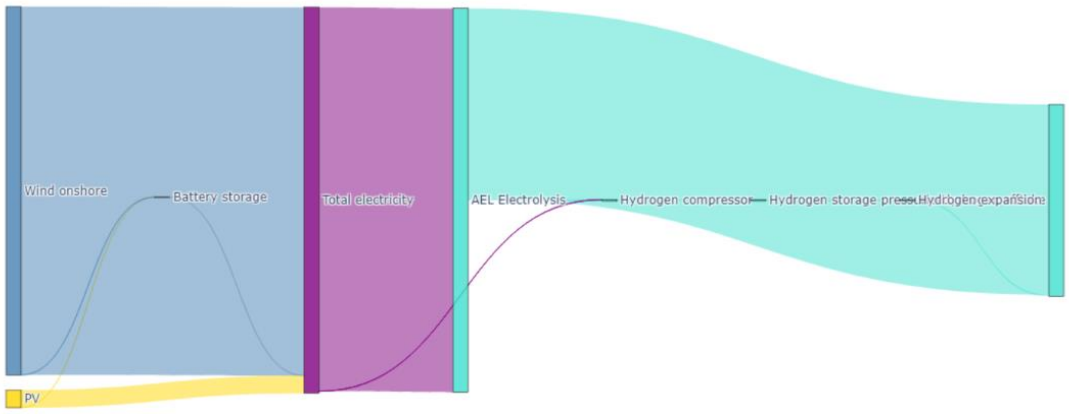
S2 2030			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	1,639.6	22,578.9	246,231.3	627,996.1	603,375.3	826,483.1
PV	OPEX	kEUR	268.6	3,699.0	40,339.0	102,881.9	98,848.4	135,399.1
Wind onshore	CAPEX	kEUR	370,510.8	352,600.8	437,627.1	-	-	-
Wind onshore	OPEX	kEUR	46,717.5	44,459.3	55,180.2	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	-	-	23,370.0	-
CSP Solar Tower	OPEX	kEUR	-	-	-	-	6,110.4	-
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	-	-	32,359.9	153,088.3	154,308.6	77,781.7
CSP Power block HT	OPEX	kEUR	(0.0)	(0.0)	11,359.0	65,976.9	66,580.9	34,660.8
CSP Powerblock MT	CAPEX	kEUR	-	-	-	-	-	-
CSP Power block MT	OPEX	kEUR	-	-	-	-	-	-
Electric Heater HT	CAPEX	kEUR	-	-	7,962.9	56,386.7	52,751.6	71,586.2
Electric Heater HT	OPEX	kEUR	-	-	458.0	3,242.6	3,033.6	4,116.7
Electric Heater MT	CAPEX	kEUR	-	-	-	-	-	-
Electric Heater MT	OPEX	kEUR	-	-	-	-	-	-
CSP TES HT	CAPEX	kEUR	-	-	84,000.0	70,081.6	72,550.9	84,000.0
CSP TES HT	OPEX	kEUR	-	-	26,900.0	22,443.2	23,233.9	26,900.4
CSP TES MT	CAPEX	kEUR	-	-	-	-	0.0	87,719.4
CSP TES MT	OPEX	kEUR	-	-	-	-	-	23,409.6
Battery storage	CAPEX	kEUR	1,653.5	1,736.7	-	-	-	32,239.9
Battery storage	OPEX	kEUR	174.6	183.3	-	-	-	3,458.9
Water demineralization	CAPEX	kEUR	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3	6,061.2
Water demineralization	OPEX	kEUR	580.8	580.8	580.8	580.8	580.8	693.2
Water supply	OPEX	kEUR	301.2	301.2	301.2	301.2	301.2	359.5

AEL Electrolysis	CAPEX	kEUR	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3	-
AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8	-
SOEL Electrolysis	CAPEX	kEUR	-	-	-	-	(0.0)	747,657.1
SOEL Electrolysis	OPEX	kEUR	-	-	-	-	(0.0)	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	305.7	5,274.1	-	1,138.2	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	169.0	2,914.9	-	629.1	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	353.6	6,101.1	-	1,316.7	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	96.6	1,665.7	-	359.5	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	9,291.5	34,704.8	-	3,867.1	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	3,080.6	11,506.3	-	1,282.1	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**717,224.5**	**827,381.6**	**1,259,785.9**	**1,250,973.3**	**1,353,192.7**	**2,041,712.7**
Total OPEX		**kEUR**	**103,626.5**	**147,671.2**	**397,676.4**	**251,010.3**	**296,061.4**	**495,281.5**

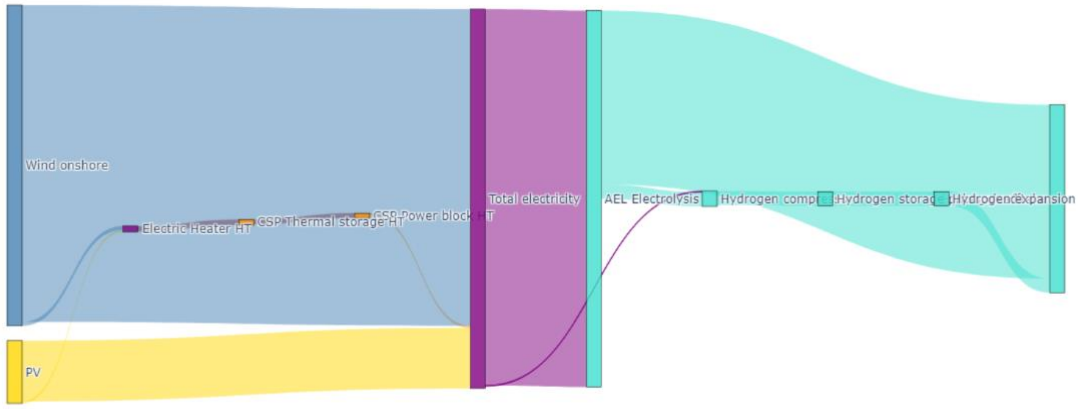
S2, H2, Technology open scenario, 2030



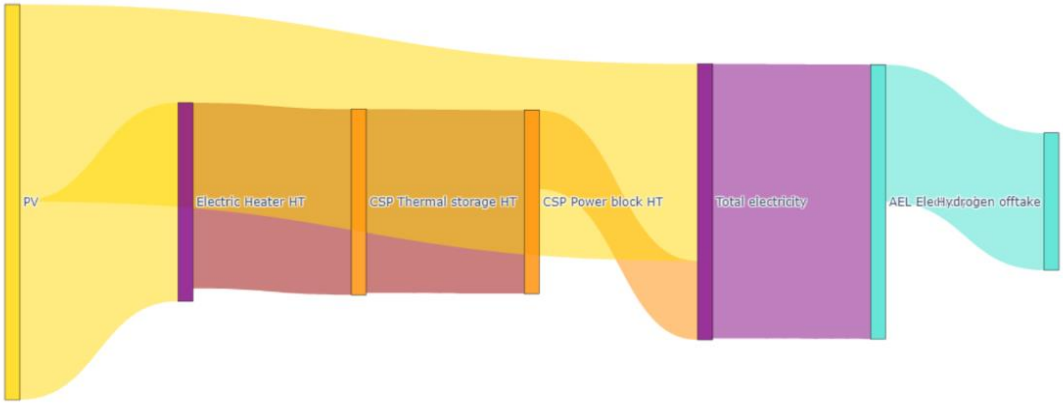
S2, NH3, Technology open scenario, 2030



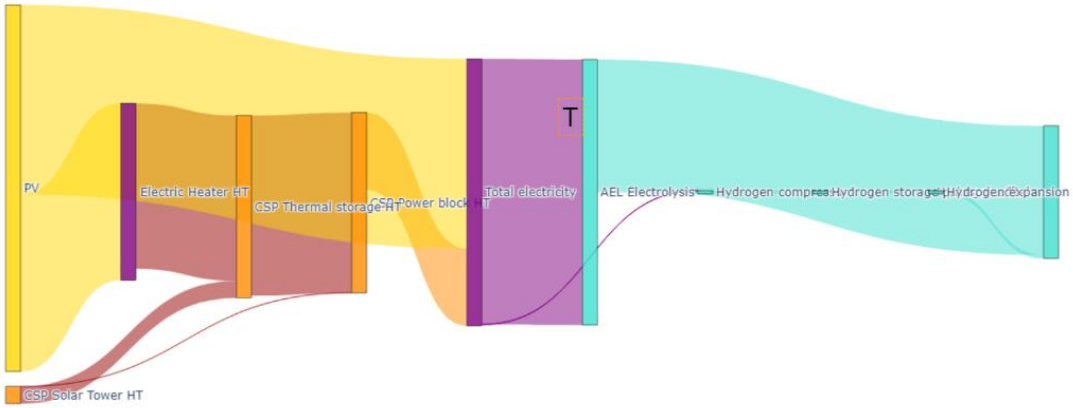
S2, MeOH, Technology open scenario, 2030



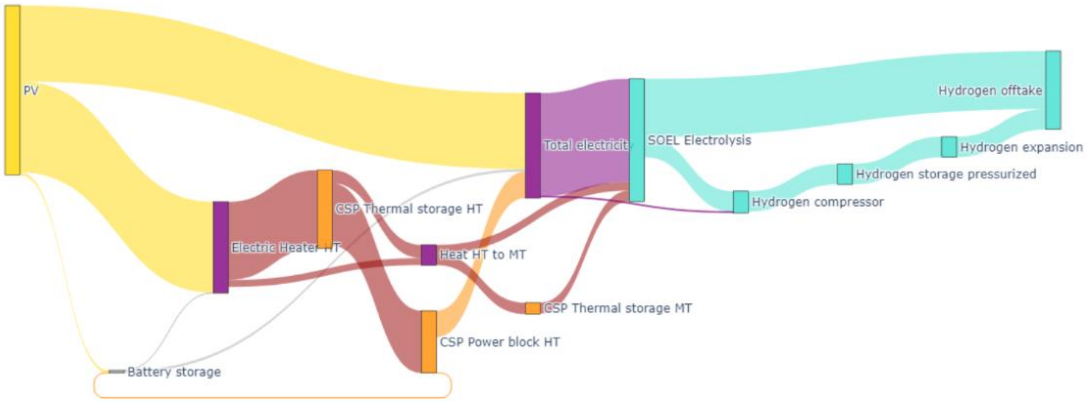
S2, H2, CSP PV hybrid system, 2030



S2, NH3, CSP PV hybrid system, 2030



S2, MeOH, CSP PV hybrid system, 2030



Results Optimized system design: Site S2 for 2050

S2 2050			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	1.8	45.3	249.1	609.2	608.1	956.6
PV	capacity factor	%	33.7%	33.7%	33.7%	33.7%	33.7%	33.7%
Wind onshore	capacity	MW	334.4	305.0	185.9	-	-	-
Wind onshore	capacity factor	%	47.4%	47.4%	47.4%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	-	-	-	-
CSP Solar Tower	capacity factor	%	-	-	-	-	-	-
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	-	-	420.0	420.0	420.0	420.0
CSP TES HT		MWh_{th}	-	-	4,200.0	4,200.0	4,200.0	4,200.0
CSP TES HT	capacity factor	%			1.7%	16.7%	18.5%	14.4%
CSP TES MT	capacity	MW_{th}	-	-	65.3	100.4	99.0	172.8
CSP TES MT		MWh_{th}	-	-	221.8	664.0	655.4	1,157.7
CSP TES MT	capacity factor	%			12.4%	13.3%	10.1%	3.9%
CSP Powerblock HT	capacity	MW_{el}	-	-	39.2	47.4	47.2	50.5
CSP Power block HT	capacity factor	%			5.3%	56.7%	56.7%	46.6%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	-	-	-
CSP Power block MT	capacity factor	%	-	-	-	-	-	-
Electric Heater HT	capacity	MW_{th}	-	-	13.3	275.2	275.0	318.8
Electric Heater HT	capacity factor	%			53.6%	24.9%	25.1%	20.6%
Electric Heater MT	capacity	MW_{th}	-	-	85.1	110.1	108.7	205.2
Electric Heater MT	capacity factor	%			21.8%	13.4%	12.9%	5.0%
Battery storage	capacity	MW	1.3	1.4	17.8	16.9	17.6	111.6
Battery storage		MWh	3.6	4.0	64.0	88.3	92.8	177.1
Battery storage	capacity factor	%	2.3%	3.1%	11.0%	16.2%	16.0%	9.0%
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	43.3	43.3	43.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	-	-	-	-
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	160.7	160.7	160.7	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	0.08	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	0.08	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	9.9	49.0	-	-	49.0

S2 2050	Technology open scenario	CSP PV hybrid scenario

Commodity flows per year (MoL*)

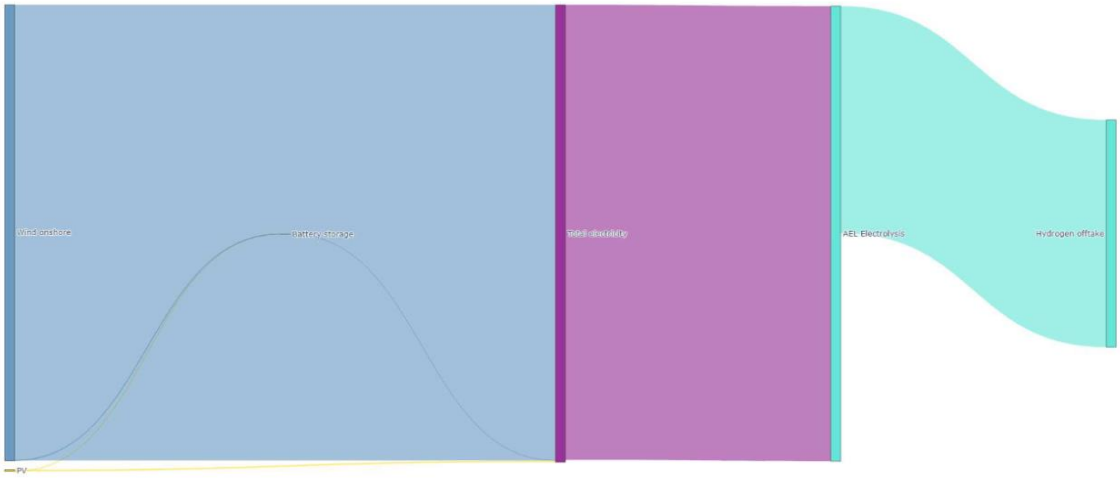
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		Unit	H_2	NH_3	MeOH	H_2	NH_3	MeOH
Water demineralization	Water, desalinated Import	kt	282.1	282.1	336.7	336.7	336.7	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	227.5	227.5	227.5	227.5
PV	Electricity Generation	GWh	5.3	133.9	735.6	1,799.1	1,795.7	2,824.9
Wind onshore	Electricity Generation	GWh	1,388.9	1,266.9	772.2	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	-	-	-	-	-	-
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	-	-	61.9	612.9	681.2	531.4
CSP TES MT	Heat MT Discharge	GWh	-	-	71.2	117.0	87.8	58.5
CSP Powerblock HT	Electricity Production	GWh	-	-	18.4	235.5	234.5	205.9
CSP Powerblock MT	Electricity Production	GWh	-	-	-	-	-	-
Electric Heater HT	Heat HAT Production	GWh	-	-	62.6	600.7	604.4	574.4
Electric Heater MT	Heat MT Production	GWh	-	-	162.7	129.1	123.0	89.2
Batterystorage	Electricity Discharge	GWh	0.3	0.4	17.1	24.0	24.8	88.4
Total PtX	Electricity Consumption	GWh	1,368.4	1,368.7	904.1	898.6	898.6	911.4
RES el.feed-in/Curtail	Electricity Consumption	GWh	17.3	24.6	373.6	329.4	329.0	1,354.0
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	-	-	-	(0.0)
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	-	-	-	(0.0)
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	898.4	898.4	898.4	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	20.5	20.5	20.5	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	0.1	1.6	-	-	3.8
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

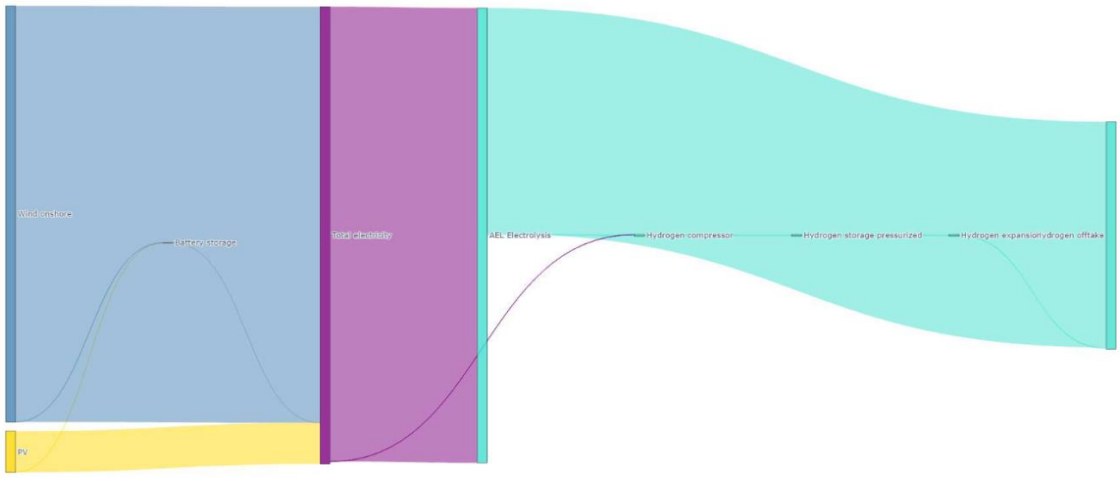
S2 2050			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	1,132.1	28,640.2	157,391.8	384,951.6	384,219.6	604,433.5
PV	OPEX	kEUR	185.5	4,692.0	25,784.8	63,064.9	62,945.0	99,021.7
Wind onshore	CAPEX	kEUR	284,444.1	259,459.2	158,148.4	-	-	-
Wind onshore	OPEX	kEUR	46,736.3	42,631.1	25,985.0	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	-	-	-	-
CSP Solar Tower	OPEX	kEUR	-	-	-	-	-	-
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	-	-	51,128.4	61,744.2	61,470.9	65,793.3
CSP Power block HT	OPEX	kEUR	(0.0)	(0.0)	19,475.0	30,805.2	30,670.2	31,286.4
CSP Powerblock MT	CAPEX	kEUR	-	-	-	-	-	-
CSP Power block MT	OPEX	kEUR	-	-	-	-	-	-
Electric Heater HT	CAPEX	kEUR	-	-	1,842.4	38,037.4	38,013.3	44,061.4
Electric Heater HT	OPEX	kEUR	-	-	114.0	2,350.1	2,348.6	2,722.2
Electric Heater MT	CAPEX	kEUR	-	-	8,716.0	11,272.2	11,129.4	21,007.0
Electric Heater MT	OPEX	kEUR	-	-	654.0	846.2	835.4	1,576.9
CSP TES HT	CAPEX	kEUR	-	-	78,187.2	78,187.2	78,187.2	78,187.2
CSP TES HT	OPEX	kEUR	-	-	26,900.0	26,900.4	26,900.4	26,900.4
CSP TES MT	CAPEX	kEUR	-	-	4,954.4	14,832.4	14,642.1	25,862.2
CSP TES MT	OPEX	kEUR	-	-	1,420.0	4,252.6	4,198.0	7,414.9
Battery storage	CAPEX	kEUR	1,239.1	1,352.5	21,444.5	28,876.2	30,318.4	65,286.0
Battery storage	OPEX	kEUR	174.5	190.5	3,059.0	4,181.9	4,391.6	8,800.6
Water demineralization	CAPEX	kEUR	5,078.3	5,078.3	6,061.2	6,061.2	6,061.2	6,061.2
Water demineralization	OPEX	kEUR	580.8	580.8	693.2	693.2	693.2	693.2
Water supply	OPEX	kEUR	301.2	301.2	359.5	359.5	359.5	359.5
AEL Electrolysis	CAPEX	kEUR	245,568.8	245,568.8	-	-	-	-

AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	-	-	-	-
SOEL Electrolysis	CAPEX	kEUR	-	-	159,475.3	159,475.3	159,475.3	159,475.3
SOEL Electrolysis	OPEX	kEUR	-	-	59,308.9	59,308.9	59,308.9	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	267.6	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	147.9	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	309.5	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	84.5	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	7,039.4	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	2,333.9	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**537,462.4**	**644,809.3**	**755,533.7**	**783,437.6**	**880,611.1**	**1,178,351.0**
Total OPEX		**kEUR**	**103,562.0**	**146,063.3**	**370,727.8**	**192,762.8**	**232,168.6**	**445,059.1**

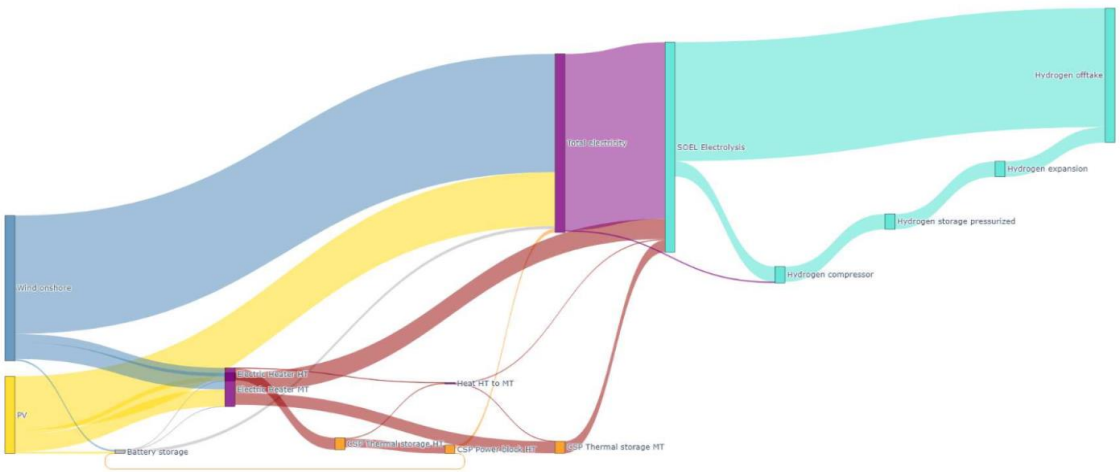
S2, H2, Technology open scenario, 2050



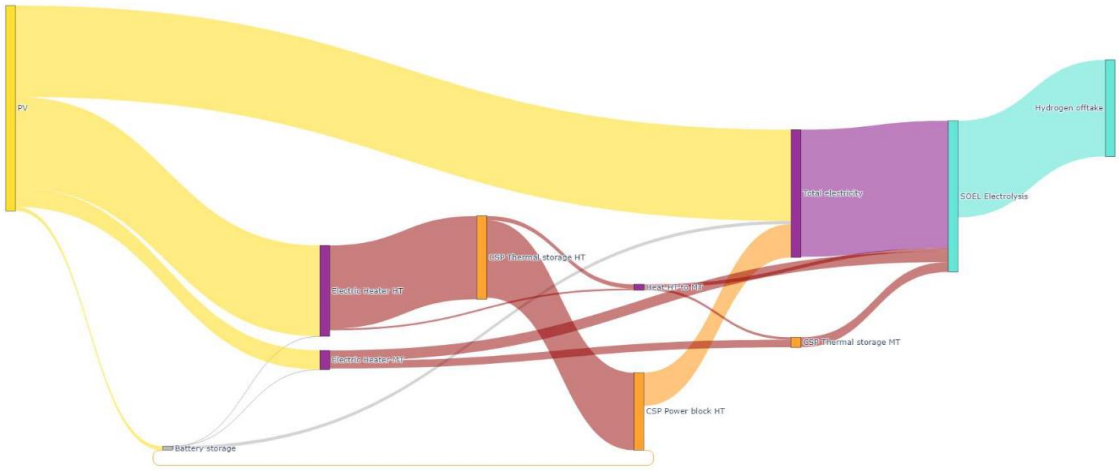
S2, NH3, Technology open scenario, 2050



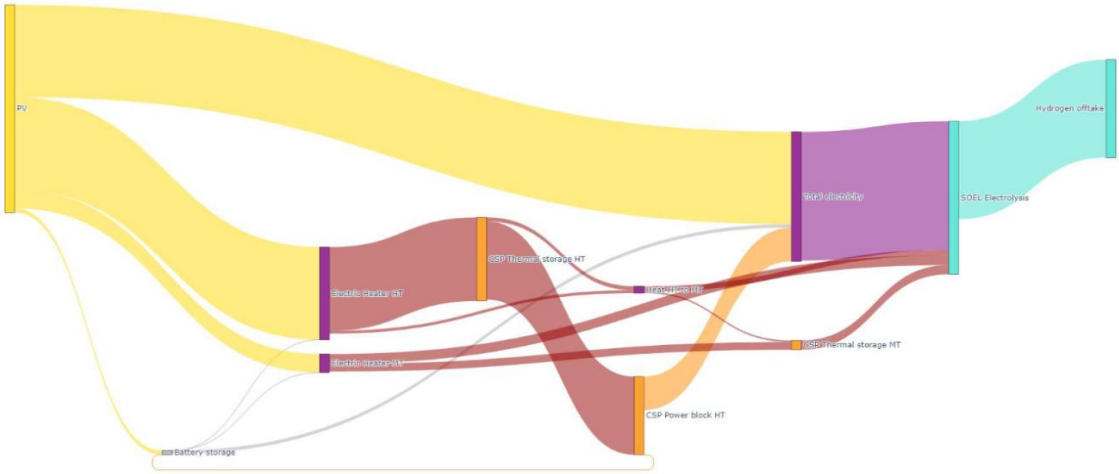
S2, MeOH, Technology open scenario, 2050



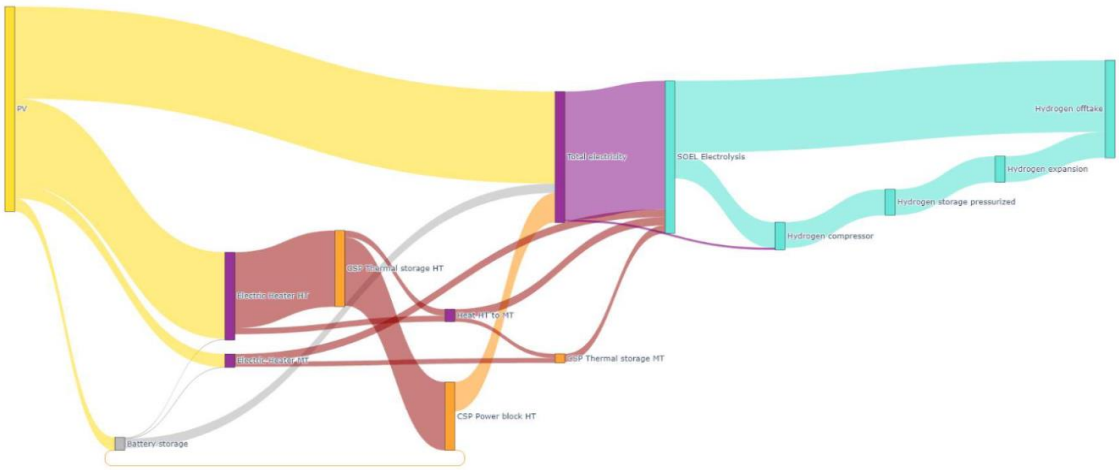
S2, H2, CSP PV hybrid system, 2050



S2, NH3, CSP PV hybrid system, 2050



S2, MeOH, CSP PV hybrid system, 2050



Results Optimized system design: Site S3 for 2030

S3 2030			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	191.3	188.0	294.0	315.6	316.2	497.4
PV	capacity factor	%	36.8%	36.8%	36.8%	36.8%	36.8%	36.8%
Wind onshore	capacity	MW	302.3	304.2	379.9	-	-	-
Wind onshore	capacity factor	%	33.8%	33.8%	33.8%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	467.6	573.7	569.7	533.8
CSP Solar Tower	capacity factor	%			3.2%	20.2%	20.6%	12.9%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	-	-	456.5	616.0	611.7	606.8
CSP TES HT		MWh_{th}	-	-	3,968.1	4,154.6	4,188.5	4,200.0
CSP TES HT	capacity factor	%			4.3%	23.2%	22.5%	15.1%
CSP TES MT	capacity	MW_{th}	-	-	-	-	-	304.9
CSP TES MT		MWh_{th}	-	-	-	-	-	3,049.3
CSP TES MT	capacity factor	%						6.4%
CSP Powerblock HT	capacity	MW_{el}	-	-	54.7	118.4	119.1	71.5
CSP Power block HT	capacity factor	%			9.5%	45.1%	44.8%	43.9%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	-	-	-
CSP Power block MT	capacity factor	%	-	-	-	-	-	-
Electric Heater HT	capacity	MW_{th}	-	-	-	42.3	42.9	201.7
Electric Heater HT	capacity factor	%				23.0%	19.4%	13.4%
Electric Heater MT	capacity	MW_{th}	-	-	-	-	-	-
Electric Heater MT	capacity factor	%	-	-	-	-	-	-
Battery storage	capacity	MW	0.5	0.5	-	-	-	-
Battery storage		MWh	0.7	0.7	-	-	-	-
Battery storage	capacity factor	%	5.5%	5.7%				
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	36.3	36.3	36.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	208.3	208.3	208.3	-
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	0.47	1.56	-	0.38	1.56
Hydrogen compressor HP		t_{H2}/h	-	0.47	1.56	-	0.38	1.56
Hydrogen storage pressurized		t_{H2}	-	7.5	49.0	-	7.0	49.0

S3 2030			Technology open scenario			CSP PV hybrid scenario		

Commodity flows per year (MoL*)

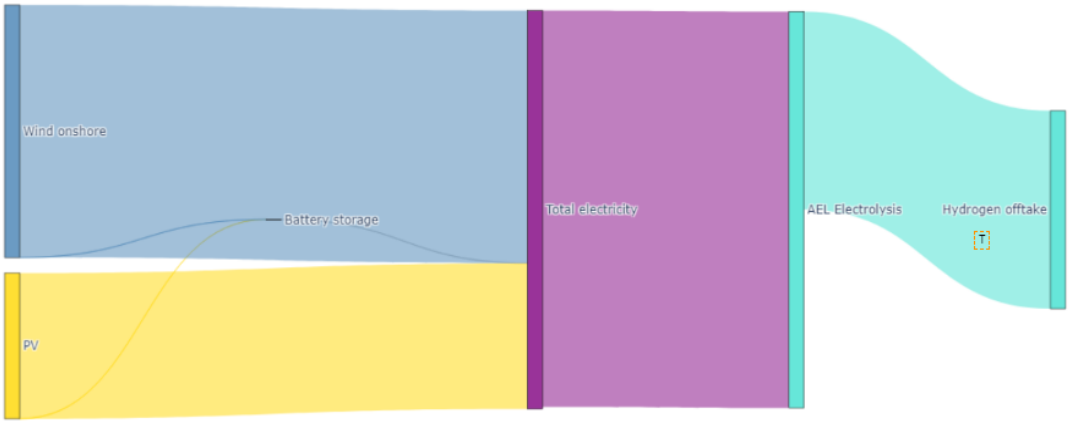
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		Unit	H_2	NH_3	MeOH	H_2	NH_3	MeOH
Water demineralization	Water, desalinated Import	kt	282.1	282.1	282.1	282.1	282.1	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	190.6	190.6	190.6	227.5
PV	Electricity Generation	GWh	615.9	605.3	946.8	1,016.2	1,018.2	1,601.9
Wind onshore	Electricity Generation	GWh	894.9	900.6	1,124.7	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	-	-	131.5	1,014.8	1,028.0	603.0
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	-	-	173.9	1,252.7	1,208.1	802.2
CSP TES MT	Heat MT Discharge	GWh	-	-	-	-	-	171.3
CSP Powerblock HT	Electricity Production	GWh	-	-	45.6	467.9	467.8	274.6
CSP Powerblock MT	Electricity Production	GWh	-	-	-	-	-	-
Electric Heater HT	Heat HAT Production	GWh	-	-	-	85.4	72.8	236.6
Electric Heater MT	Heat MT Production	GWh	-	-	-	-	-	-
Batterystorage	Electricity Discharge	GWh	0.2	0.2	-	-	-	-
Total PtX	Electricity Consumption	GWh	1,368.4	1,369.1	1,376.0	1,368.4	1,369.3	910.5
RES el.feed-in/Curtail	Electricity Consumption	GWh	135.1	129.3	1,516.1	152.4	145.6	1,076.0
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	0.2	2.3	-	0.3	3.5
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

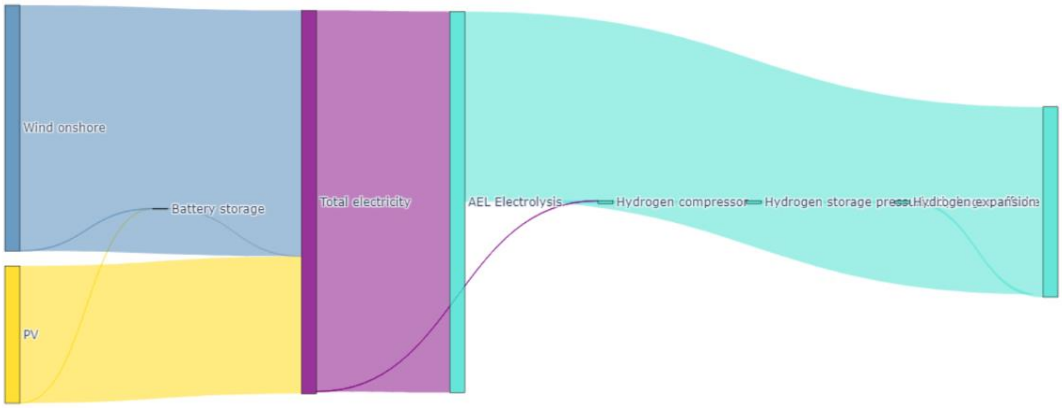
S3 2030			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	174,958.2	171,935.8	268,929.1	288,641.9	289,202.4	455,012.1
PV	OPEX	kEUR	28,662.6	28,167.5	44,057.5	47,286.9	47,378.8	74,542.7
Wind onshore	CAPEX	kEUR	335,081.5	337,201.1	421,099.8	-	-	-
Wind onshore	OPEX	kEUR	42,250.3	42,517.5	53,096.3	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	147,766.0	181,283.0	180,016.2	168,673.1
CSP Solar Tower	OPEX	kEUR	-	-	38,635.6	47,399.1	47,067.8	44,102.0
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerbloc k HT	CAPEX	kEUR	-	-	76,643.8	165,773.4	166,703.8	100,089.7
CSP Power block HT	OPEX	kEUR	(0.0)	(0.0)	27,855.0	72,863.8	73,177.6	43,724.3
CSP Powerbloc kMT	CAPEX	kEUR	-	-	-	-	-	455.6
CSP Power block MT	OPEX	kEUR	-	-	-	-	-	113.9
Electric Heater HT	CAPEX	kEUR	-	-	-	6,282.8	6,365.5	29,954.6
Electric Heater HT	OPEX	kEUR	-	-	-	361.3	366.1	1,722.6
Electric Heater MT	CAPEX	kEUR	-	-	-	-	-	-
Electric Heater MT	OPEX	kEUR	-	-	-	-	-	-
CSP TES HT	CAPEX	kEUR	-	-	79,362.0	83,091.4	83,769.4	84,000.0
CSP TES HT	OPEX	kEUR	-	-	25,415.0	26,609.5	26,826.6	26,900.4
CSP TES MT	CAPEX	kEUR	-	-	-	-	(0.0)	73,183.5
CSP TES MT	OPEX	kEUR	-	-	-	-	-	19,530.4
Battery storage	CAPEX	kEUR	357.5	348.0	-	-	-	-
Battery storage	OPEX	kEUR	35.7	34.8	-	-	-	-
Water demineraliz ation	CAPEX	kEUR	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3	6,061.2

Water demineralization	OPEX	kEUR	580.8	580.8	580.8	580.8	580.8	693.2
Water supply	OPEX	kEUR	301.2	301.2	301.2	301.2	301.2	359.5
AEL Electrolysis	CAPEX	kEUR	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3	-
AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8	-
SOEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	747,657.1
SOEL Electrolysis	OPEX	kEUR	-	-	-	-	-	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	1,583.0	5,274.1	-	1,291.8	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	874.9	2,914.9	-	714.0	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	1,831.2	6,101.1	-	1,494.4	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	499.9	1,665.7	-	408.0	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	5,325.5	34,704.8	-	4,984.2	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	1,765.7	11,506.3	-	1,652.5	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**853,817.7**	**958,739.0**	**1,445,405.3**	**1,068,493.0**	**1,174,342.1**	**1,773,271.0**
Total OPEX		**kEUR**	**127,414.4**	**169,843.8**	**452,499.4**	**250,986.3**	**293,574.9**	**477,972.3**

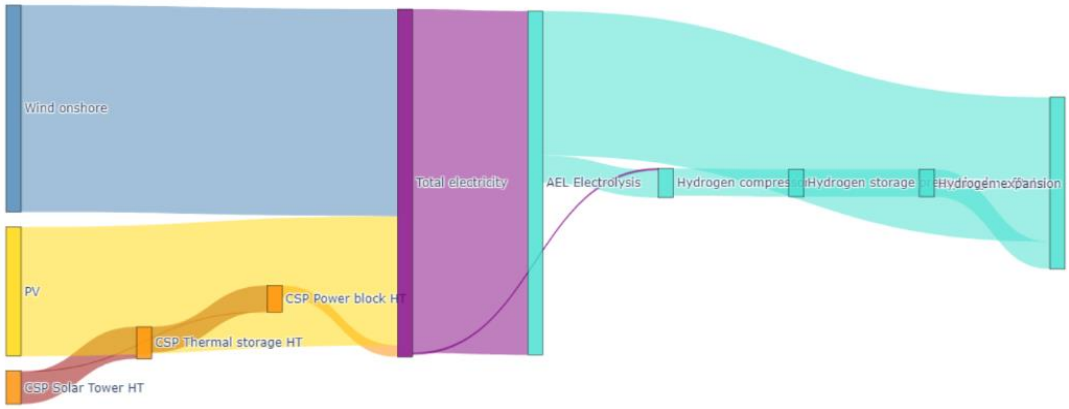
S3, H2, Technology open scenario, 2030



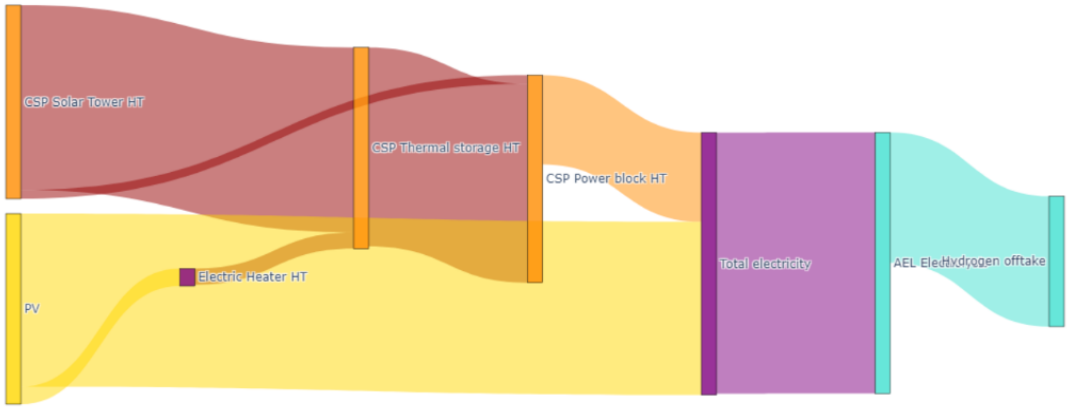
S3, NH3, Technology open scenario, 2030



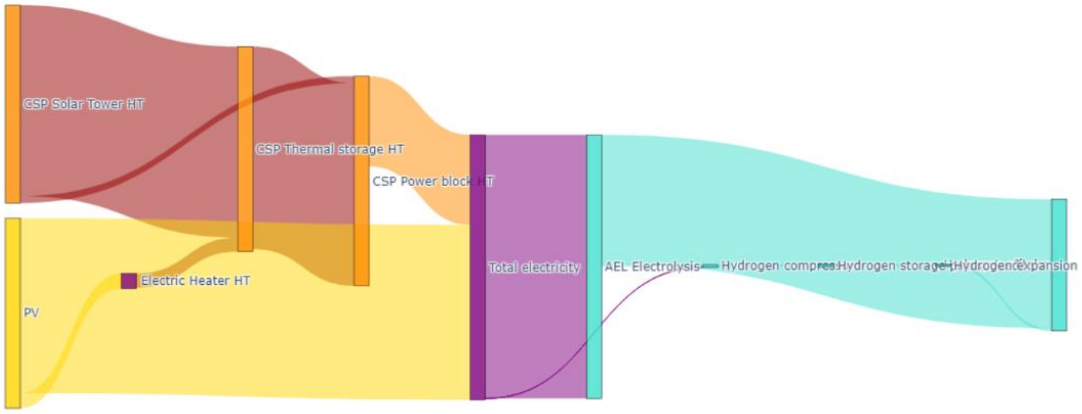
S3, MeOH, Technology open scenario, 2030



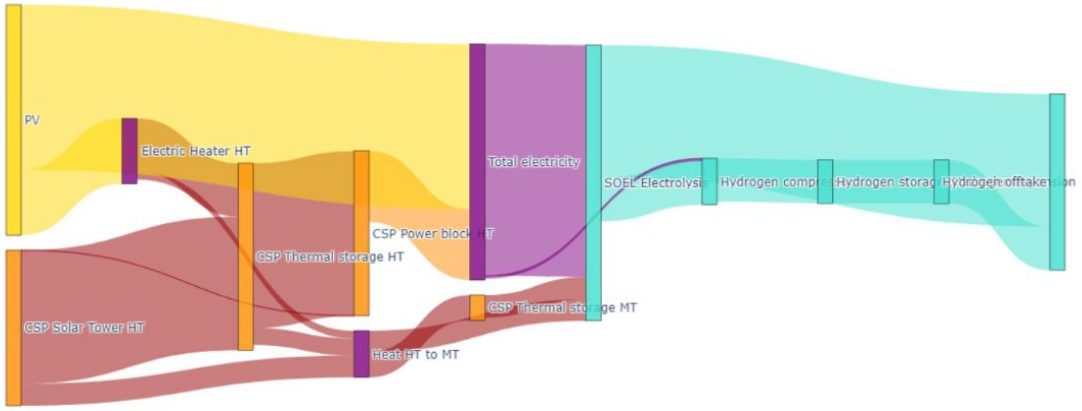
S3, H2, CSP PV hybrid system, 2030



S3, NH3, CSP PV hybrid system, 2030



S3, MeOH, CSP PV hybrid system, 2030



Results Optimized system design: Site S3 for 2050

S3 2050			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	135.9	135.9	234.9	516.8	451.3	717.5
PV	capacity factor	%	36.8%	36.8%	36.8%	36.8%	36.8%	36.8%
Wind onshore	capacity	MW	116.9	116.9	211.2	-	-	-
Wind onshore	capacity factor	%	33.8%	33.8%	33.8%			
CSP Solar Tower HT	capacity	MW_{th}	271.8	271.8	392.6	27.6	142.2	150.0
CSP Solar Tower	capacity factor	%	22.7%	22.7%	8.0%	21.5%	20.8%	13.2%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	317.0	317.1	360.5	339.1	403.2	415.5
CSP TES HT		MWh_{th}	3,170.4	3,170.6	2,733.8	3,391.0	4,032.3	3,723.8
CSP TES HT	capacity factor	%	17.8%	17.6%	9.2%	24.8%	22.2%	26.5%
CSP TES MT	capacity	MW_{th}	22.4	22.4	37.3	95.0	50.5	104.8
CSP TES MT		MWh_{th}	165.0	165.0	157.2	473.9	288.4	832.7
CSP TES MT	capacity factor	%	19.4%	21.3%	16.4%	19.3%	9.9%	30.4%
CSP Powerblock HT	capacity	MW_{el}	49.3	49.3	47.5	48.2	64.1	53.0
CSP Power block HT	capacity factor	%	41.2%	41.1%	15.0%	56.5%	52.9%	52.3%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	20.0	-	20.0
CSP Power block MT	capacity factor	%				36.4%		13.7%
Electric Heater HT	capacity	MW_{th}	27.1	27.1	2.5	228.8	208.2	272.7
Electric Heater HT	capacity factor	%	6.5%	6.5%	17.4%	32.8%	27.4%	22.1%
Electric Heater MT	capacity	MW_{th}	32.2	32.1	53.6	104.8	60.3	137.2
Electric Heater MT	capacity factor	%	13.5%	13.1%	10.2%	22.9%	22.0%	9.6%
Battery storage	capacity	MW	1.4	1.4	2.8	-	-	-
Battery storage		MWh	5.6	5.6	10.1	-	-	-
Battery storage	capacity factor	%	8.7%	8.6%	16.8%			
Waterdemineralization	capacity	t_{H2O}/h	43.3	43.3	43.3	43.3	43.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	-
SOEL Electrolysis (fix)	capacity	MW_{el}	160.7	160.7	160.7	160.7	160.7	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	-	49.0	-	-	49.0

S3 2050	Technology open scenario	CSP PV hybrid scenario

Commodity flows per year (MoL*)

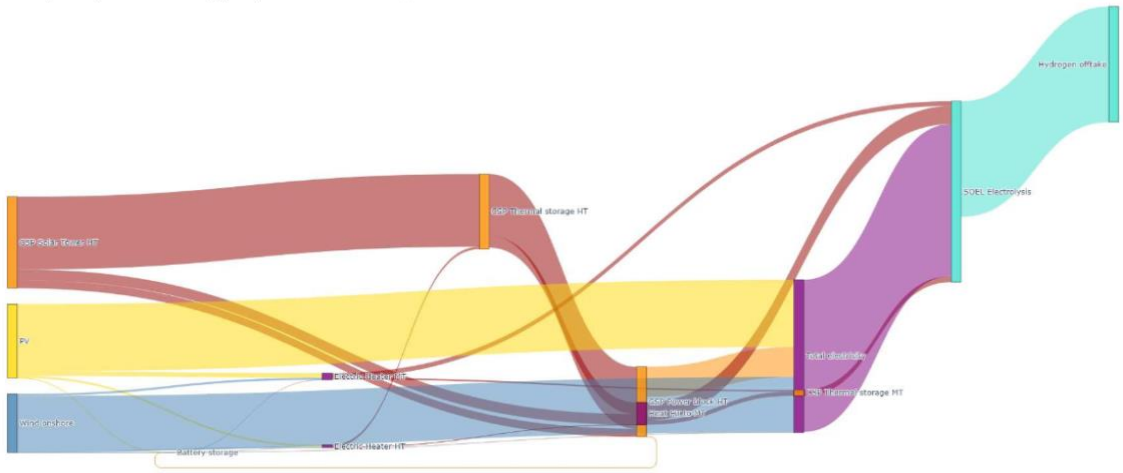
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		Unit	H_2	NH_3	MeOH	H_2	NH_3	MeOH
Water demineralization	Water, desalinated Import	kt	336.7	336.7	336.7	336.7	336.7	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	227.5	227.5	227.5	227.5	227.5	227.5
PV	Electricity Generation	GWh	437.6	437.6	756.4	1,664.3	1,453.3	2,310.6
Wind onshore	Electricity Generation	GWh	346.0	346.0	625.4	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	540.0	540.3	275.4	52.0	258.7	173.3
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	493.9	489.2	289.8	738.1	785.8	965.2
CSP TES MT	Heat MT Discharge	GWh	38.1	41.9	53.7	161.1	43.8	279.3
CSP Powerblock HT	Electricity Production	GWh	177.9	177.6	62.5	238.4	297.2	243.0
CSP Powerblock MT	Electricity Production	GWh	-	-	-	63.7	-	24.0
Electric Heater HT	Heat HAT Production	GWh	15.5	15.5	3.8	657.1	500.4	528.8
Electric Heater MT	Heat MT Production	GWh	37.9	36.9	48.1	209.8	116.4	115.3
Batterystorage	Electricity Discharge	GWh	1.1	1.1	4.1	-	-	-
Total PtX	Electricity Consumption	GWh	898.6	898.6	905.6	898.6	898.6	910.6
RES el.feed-in/Curtail	Electricity Consumption	GWh	6.7	7.2	982.5	138.3	210.8	1,090.8
AEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	898.4	898.4	898.4	898.4	898.4	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	-	2.1	-	-	3.6
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

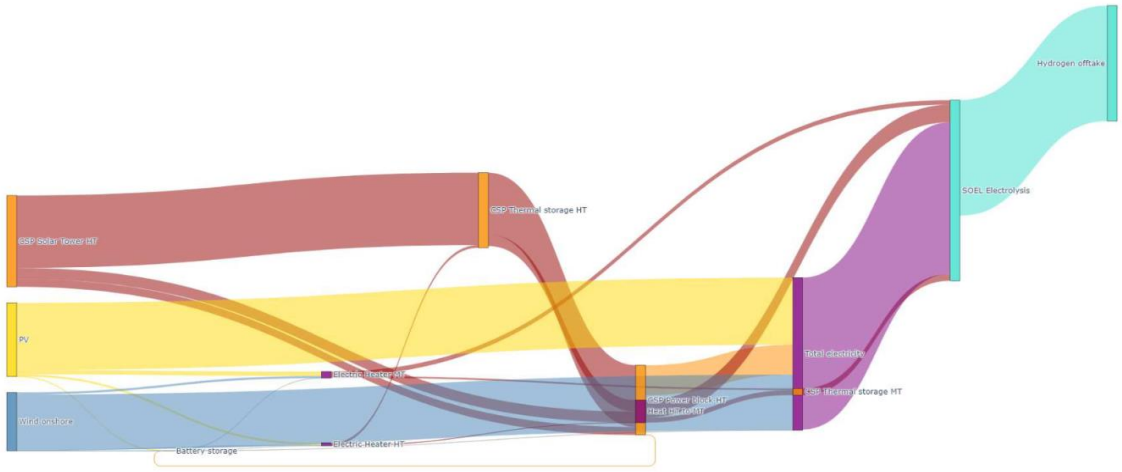
S3 2050			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	85,869.5	85,871.1	148,425.3	326,571.9	285,158.1	453,381.3
PV	OPEX	kEUR	14,067.6	14,067.9	24,315.9	53,500.9	46,716.2	74,275.5
Wind onshore	CAPEX	kEUR	99,414.9	99,408.3	179,687.1	-	-	-
Wind onshore	OPEX	kEUR	16,334.6	16,333.5	29,523.9	-	-	-
CSP Solar Tower	CAPEX	kEUR	79,959.6	79,952.2	115,489.2	8,115.2	41,830.3	44,117.4
CSP Solar Tower	OPEX	kEUR	22,460.9	22,458.8	32,441.3	2,279.6	11,750.2	12,392.7
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	64,289.9	64,290.1	61,958.5	62,756.0	83,535.3	69,051.5
CSP Power block HT	OPEX	kEUR	29,774.4	29,767.3	24,973.3	31,276.5	40,947.0	33,753.6
CSP PowerblockMT	CAPEX	kEUR	-	-	-	24,200.8	-	24,200.8
CSP Power block MT	OPEX	kEUR	-	-	-	10,503.6	-	9,146.8
Electric Heater HT	CAPEX	kEUR	3,741.4	3,745.5	340.1	31,625.2	28,779.1	37,697.7
Electric Heater HT	OPEX	kEUR	231.2	231.4	21.0	1,953.9	1,778.0	2,329.1
Electric Heater MT	CAPEX	kEUR	3,292.2	3,291.8	5,486.0	10,725.6	6,169.4	14,044.1
Electric Heater MT	OPEX	kEUR	247.1	247.1	412.0	805.1	463.1	1,054.2
CSP TES HT	CAPEX	kEUR	59,019.8	59,023.0	50,893.2	63,127.1	75,064.7	69,322.4
CSP TES HT	OPEX	kEUR	20,305.9	20,307.0	17,510.0	21,719.0	25,826.1	23,850.5
CSP TES MT	CAPEX	kEUR	3,684.9	3,684.9	3,511.5	10,586.1	6,442.0	18,602.7
CSP TES MT	OPEX	kEUR	1,056.5	1,056.5	1,007.0	3,035.2	1,847.0	5,333.6
Battery storage	CAPEX	kEUR	1,861.6	1,861.5	3,390.5	-	-	-
Battery storage	OPEX	kEUR	266.8	266.8	483.7	-	-	-
Water demineralization	CAPEX	kEUR	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2

Water demineralization	OPEX	kEUR	693.2	693.2	693.2	693.2	693.2	693.2
Water supply	OPEX	kEUR	359.5	359.5	359.5	359.5	359.5	359.5
AEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	-
AEL Electrolysis	OPEX	kEUR	-	-	-	-	-	-
SOEL Electrolysis	CAPEX	kEUR	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3
SOEL Electrolysis	OPEX	kEUR	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	-	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	-	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	-	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	-	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	-	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	-	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**566,670.3**	**663,758.4**	**842,902.0**	**703,244.4**	**789,609.0**	**1,004,138.3**
Total OPEX		**kEUR**	**165,106.5**	**204,615.6**	**398,023.9**	**185,435.3**	**229,207.0**	**429,471.9**

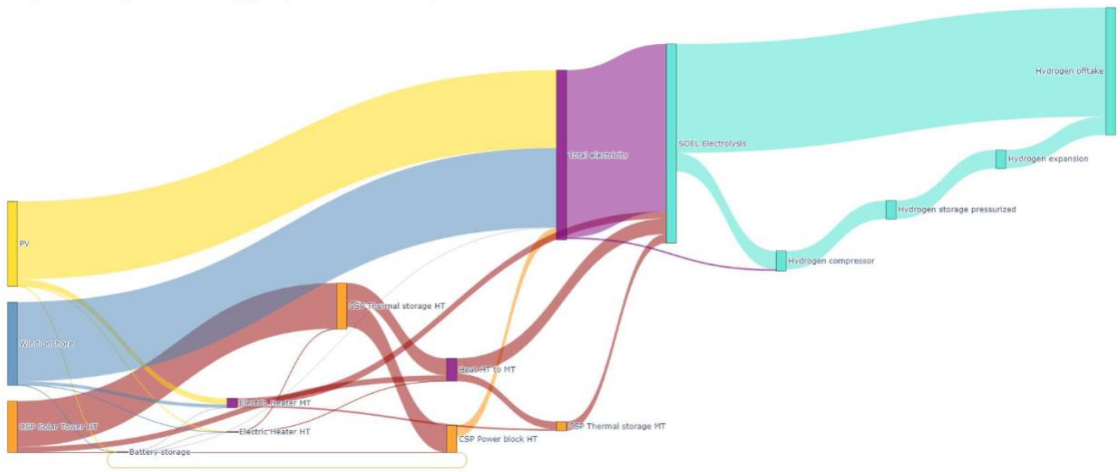
S3, H2, Technology open scenario, 2050



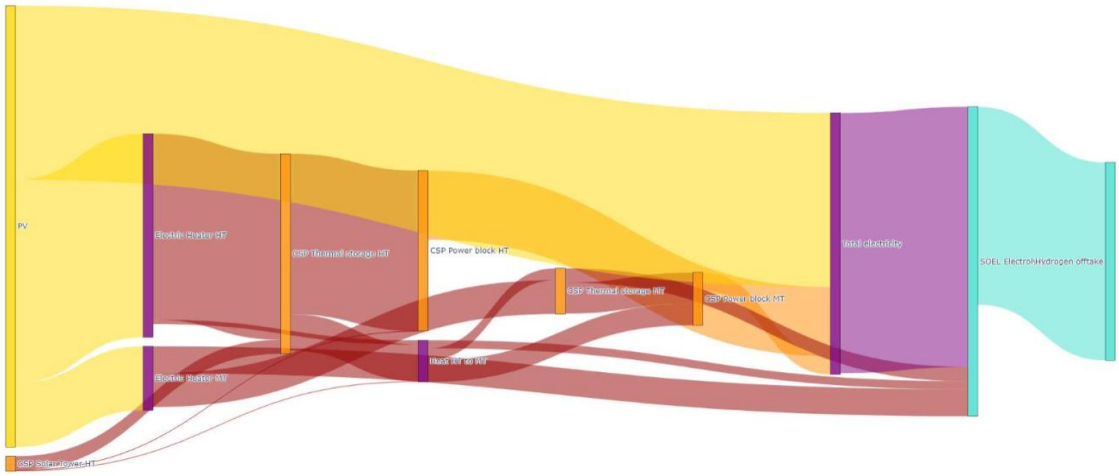
S3, NH3, Technology open scenario, 2050



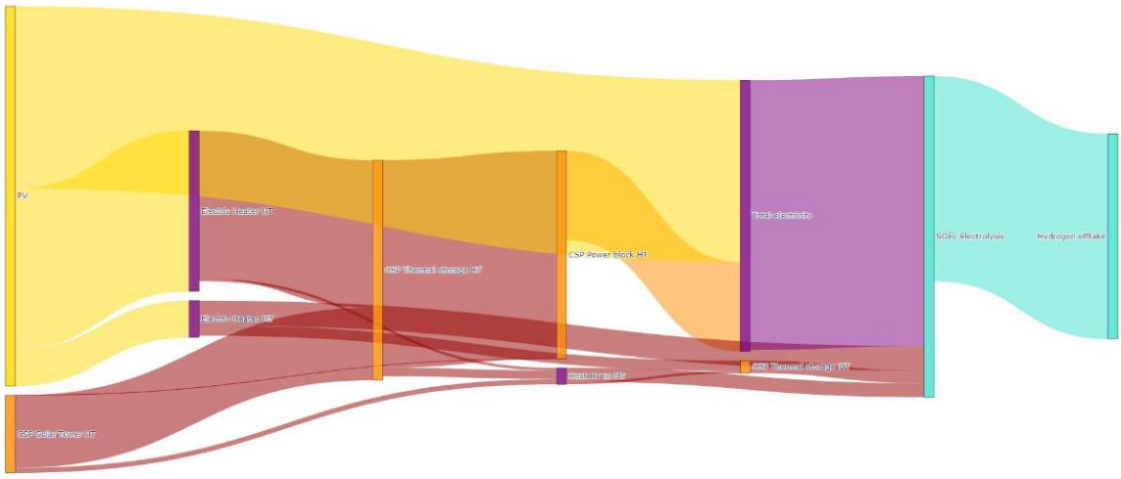
S3, MeOH, Technology open scenario, 2050



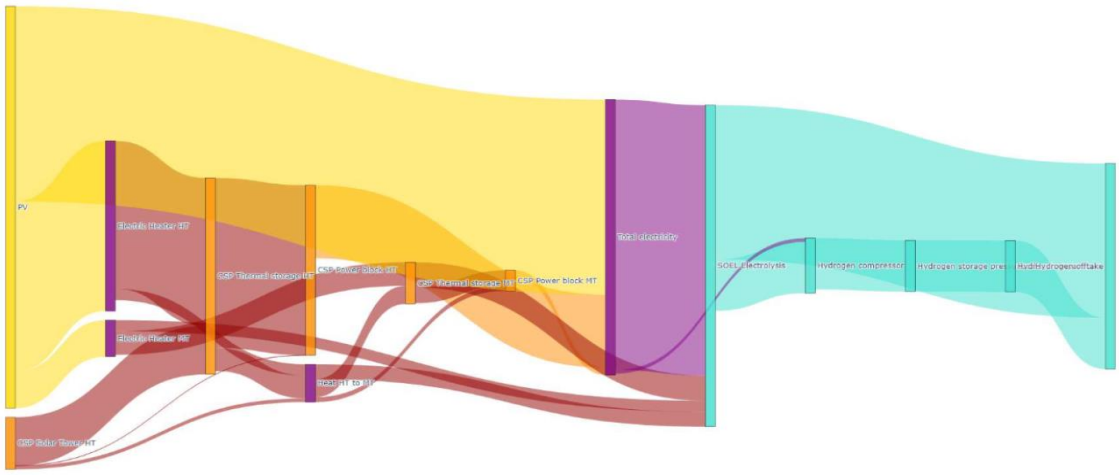
S3, H2, CSP PV hybrid system, 2050



S3, NH3, CSP PV hybrid system, 2050



S3, MeOH, CSP PV hybrid system, 2050



Results Optimized system design: Site S4 for 2030

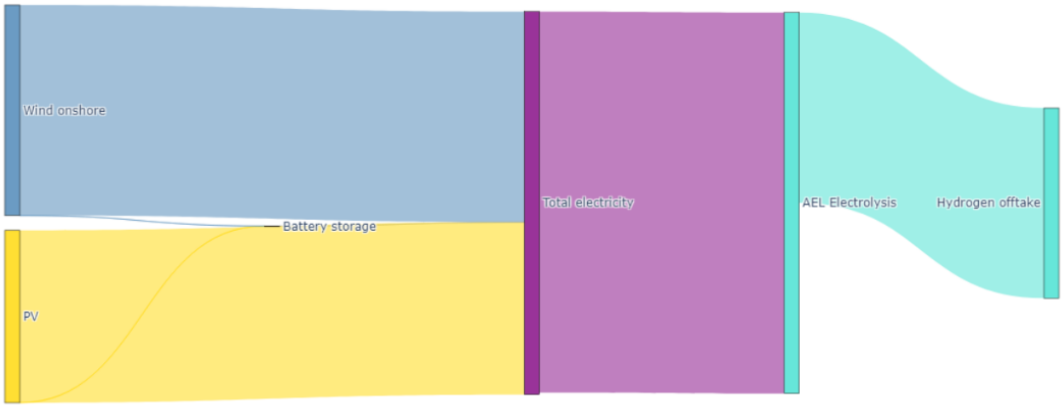
S4 2030			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	217.4	215.1	280.5	300.9	300.6	205.4
PV	capacity factor	%	35.8%	35.8%	35.8%	35.8%	35.8%	35.8%
Wind onshore	capacity	MW	272.8	275.3	359.8	-	-	-
Wind onshore	capacity factor	%	32.8%	32.8%	32.8%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	170.0	663.4	668.4	950.1
CSP Solar Tower	capacity factor	%			1.2%	19.3%	19.6%	11.4%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	-	-	294.4	640.8	645.1	618.1
CSP TES HT		MWh_{th}	-	-	2,944.4	4,091.2	4,132.9	4,200.0
CSP TES HT	capacity factor	%			1.3%	22.9%	21.6%	20.5%
CSP TES MT	capacity	MW_{th}	-	-	-	-	-	142.2
CSP TES MT		MWh_{th}	-	-	-	-	-	1,422.0
CSP TES MT	capacity factor	%						10.6%
CSP Powerblock HT	capacity	MW_{el}	-	-	27.4	105.6	86.7	68.4
CSP Power block HT	capacity factor	%			4.0%	54.0%	60.2%	48.5%
CSP Powerblock MT	capacity	MW_{el}	-	-	-	-	20.0	20.0
CSP Power block MT	capacity factor	%					24.5%	20.1%
Electric Heater HT	capacity	MW_{th}	-	-	55.4	28.9	28.7	8.3
Electric Heater HT	capacity factor	%			1.3%	20.3%	21.7%	10.2%
Electric Heater MT	capacity	MW_{th}	-	-	-	-	-	8.4
Electric Heater MT	capacity factor	%						10.4%
Battery storage	capacity	MW	1.3	1.2	-	-	-	-
Battery storage		MWh	1.8	1.8	-	-	-	-
Battery storage	capacity factor	%	4.7%	4.6%				
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	36.3	36.3	36.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	208.3	208.3	208.3	-
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	0.15	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	0.15	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	4.0	49.0	-	-	49.0

S4 2030			Technology open scenario			CSP PV hybrid scenario		
Commodity flows per year (MoL*) *Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
Water demineralization	Water, desalinated Import	kt	282.1	282.1	282.1	282.1	282.1	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	190.6	190.6	190.6	227.5
PV	Electricity Generation	GWh	682.5	675.3	880.7	944.8	943.9	644.8
Wind onshore	Electricity Generation	GWh	783.4	790.7	1,033.3	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	-	-	17.6	1,123.8	1,146.1	951.0
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	-	-	34.3	1,284.5	1,222.4	1,108.5
CSP TES MT	Heat MT Discharge	GWh	-	-	-	-	-	132.3
CSP Powerblock HT	Electricity Production	GWh	-	-	9.6	500.0	457.2	290.9
CSP Powerblock MT	Electricity Production	GWh	-	-	-	-	43.0	35.2
Electric Heater HT	Heat HAT Production	GWh	-	-	6.4	51.5	54.6	7.4
Electric Heater MT	Heat MT Production	GWh	-	-	-	-	-	7.6
Batterystorage	Electricity Discharge	GWh	0.5	0.5	-	-	-	-
Total PtX	Electricity Consumption	GWh	1,368.4	1,368.9	1,376.4	1,368.4	1,368.4	909.5
RES el.feed-in/Curtail	Electricity Consumption	GWh	89.8	89.4	818.0	124.9	107.6	857.3
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	0.2	2.4	-	-	3.2
Yearly Hydrogen Output (fix)		$kt\ H_2$	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		$kt\ NH_3$	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

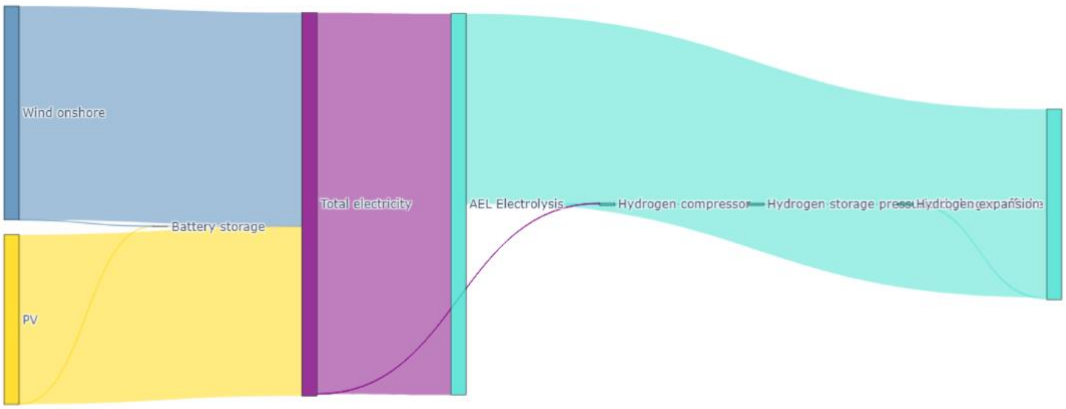
S4 2030			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	198,812.9	196,719.9	256,570.3	275,236.9	274,967.5	187,835.3
PV	OPEX	kEUR	32,570.7	32,227.8	42,032.8	45,090.9	45,046.7	30,772.2
Wind onshore	CAPEX	kEUR	302,394.9	305,192.1	398,839.4	-	-	-
Wind onshore	OPEX	kEUR	38,128.8	38,481.5	50,289.5	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	53,729.5	209,628.6	211,220.5	300,222.6
CSP Solar Tower	OPEX	kEUR	-	-	14,048.3	54,810.4	55,226.7	78,497.5
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerbloc k HT	CAPEX	kEUR	-	-	38,293.4	147,858.0	121,339.5	95,818.4
CSP Power block HT	OPEX	kEUR	(0.0)	(0.0)	13,468.0	67,810.9	57,250.8	42,813.1
CSP Powerbloc kMT	CAPEX	kEUR	-	-	-	-	26,000.0	26,000.0
CSP Power block MT	OPEX	kEUR	-	-	-	-	9,795.0	9,527.5
Electric Heater HT	CAPEX	kEUR	-	-	8,232.2	4,295.2	4,255.5	1,227.9
Electric Heater HT	OPEX	kEUR	-	-	473.0	247.0	244.7	70.6
Electric Heater MT	CAPEX	kEUR	-	-	-	-	-	919.3
Electric Heater MT	OPEX	kEUR	-	-	-	-	-	64.2
CSP TES HT	CAPEX	kEUR	-	-	58,887.8	81,823.5	82,658.6	84,000.0
CSP TES HT	OPEX	kEUR	-	-	18,858.0	26,203.4	26,470.8	26,900.4
CSP TES MT	CAPEX	kEUR	-	-	-	-	-	34,127.3
CSP TES MT	OPEX	kEUR	-	-	-	-	-	9,107.5
Battery storage	CAPEX	kEUR	888.9	880.0	-	-	-	-
Battery storage	OPEX	kEUR	88.8	87.9	-	-	-	-
Water demineraliz ation	CAPEX	kEUR	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3	6,061.2

Water demineralization	OPEX	kEUR	580.8	580.8	580.8	580.8	580.8	693.2
Water supply	OPEX	kEUR	301.2	301.2	301.2	301.2	301.2	359.5
AEL Electrolysis	CAPEX	kEUR	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3	-
AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8	-
SOEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	747,657.1
SOEL Electrolysis	OPEX	kEUR	-	-	-	-	-	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	510.2	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	282.0	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	590.2	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	161.1	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	2,864.2	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	949.6	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**845,517.2**	**947,270.7**	**1,266,157.2**	**1,062,262.7**	**1,160,955.9**	**1,592,053.1**
Total OPEX		**kEUR**	**127,254.1**	**168,173.4**	**402,609.8**	**250,628.4**	**290,018.3**	**465,089.1**

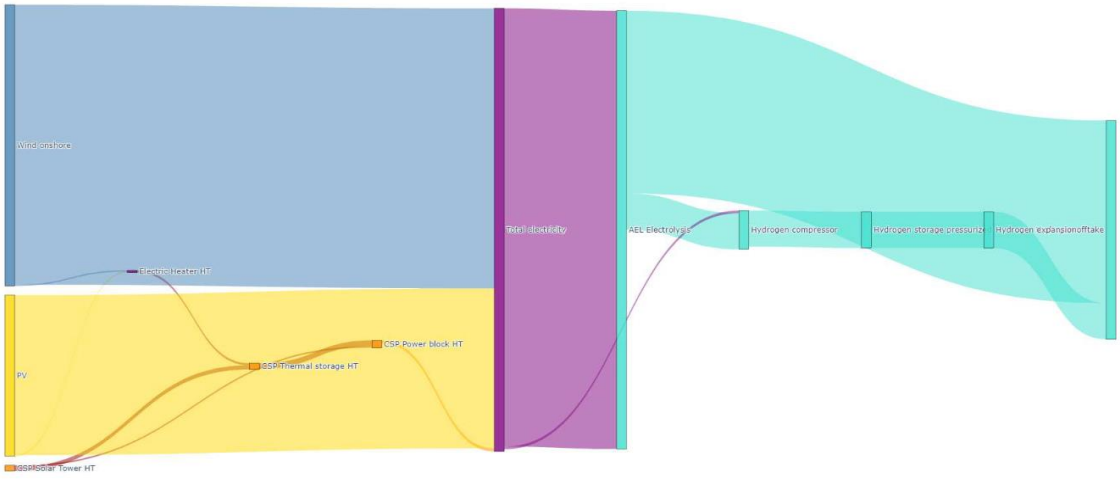
S4, H2, Technology open scenario, 2030



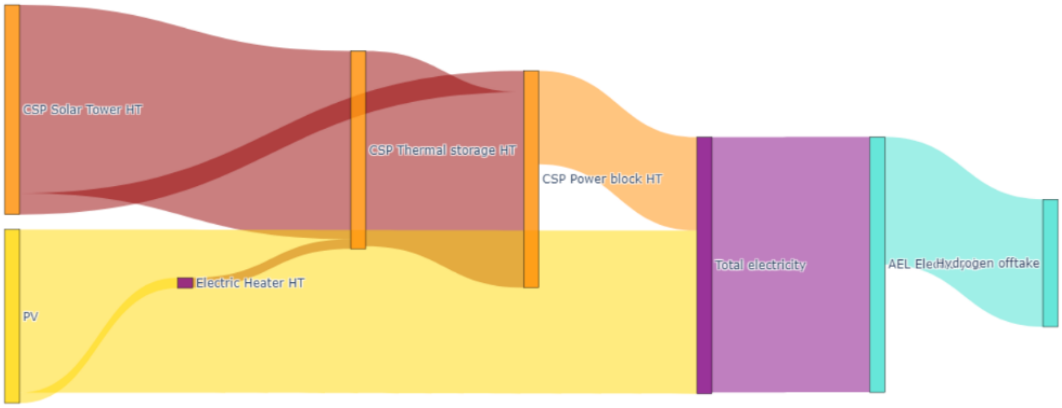
S4, NH3, Technology open scenario, 2030



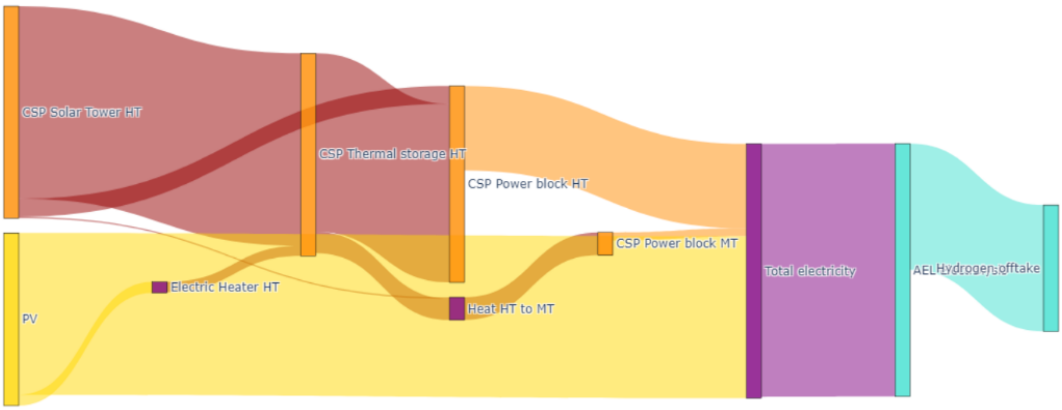
S4, MeOH, Technology open scenario, 2030



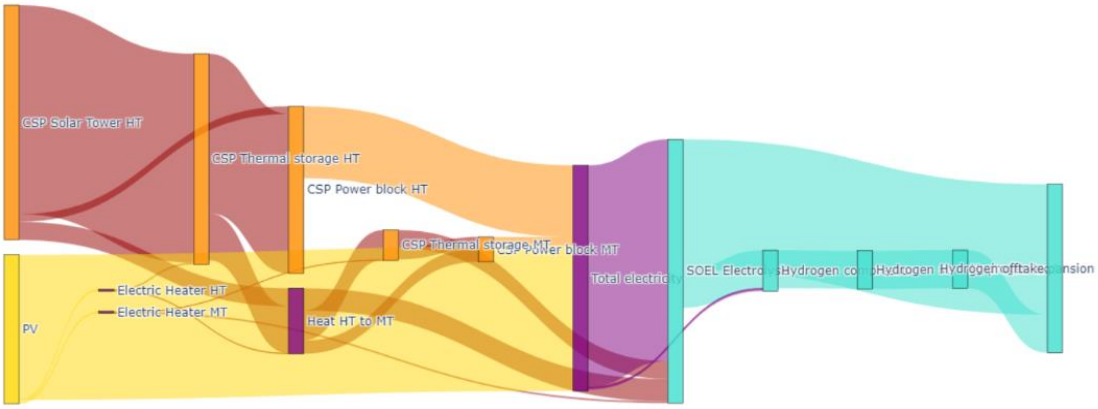
S4, H2, CSP PV hybrid system, 2030



S4, NH3, CSP PV hybrid system, 2030



S4, MeOH, CSP PV hybrid system, 2030



Results Optimized system design: Site S4 for 2050

S4 2050			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	147.8	147.8	187.0	269.0	275.9	283.9
PV	capacity factor	%	35.8%	35.8%	35.8%	35.8%	35.8%	35.8%
Wind onshore	capacity	MW	165.5	165.5	231.0	-	-	-
Wind onshore	capacity factor	%	32.8%	32.8%	32.8%			
CSP Solar Tower HT	capacity	MW_{th}	119.9	119.9	240.3	410.0	393.8	798.7
CSP Solar Tower	capacity factor	%	21.2%	21.2%	9.1%	20.2%	19.9%	12.1%
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	192.2	192.2	211.2	388.6	401.1	595.9
CSP TES HT		MWh_{th}	1,922.1	1,922.1	2,112.3	3,089.6	3,209.5	4,200.0
CSP TES HT	capacity factor	%	18.3%	23.4%	12.3%	22.1%	30.8%	18.9%
CSP TES MT	capacity	MW_{th}	-	-	-	73.9	37.5	156.4
CSP TES MT		MWh_{th}	-	-	-	370.2	154.6	1,564.0
CSP TES MT	capacity factor	%				24.1%	12.9%	16.4%
CSP Powerblock HT	capacity	MW_{el}	45.6	45.6	26.3	46.5	63.3	73.1
CSP Power block HT	capacity factor	%	14.6%	14.6%	12.0%	61.3%	55.8%	46.4%
CSP Powerblock MT	capacity	MW_{el}	-	-	20.0	20.0	-	-
CSP Power block MT	capacity factor	%			3.3%	36.1%		
Electric Heater HT	capacity	MW_{th}	96.3	96.3	-	125.4	148.3	83.3
Electric Heater HT	capacity factor	%	7.7%	7.7%		8.9%	11.6%	5.3%
Electric Heater MT	capacity	MW_{th}	9.7	9.7	32.4	53.9	31.1	-
Electric Heater MT	capacity factor	%	26.8%	26.8%	22.2%	25.7%	23.8%	
Battery storage	capacity	MW	5.1	5.1	4.0	-	-	-
Battery storage		MWh	23.6	23.6	11.0	-	-	-
Battery storage	capacity factor	%	12.5%	12.5%	17.8%			
Waterdemineralization	capacity	t_{H2O}/h	43.3	43.3	43.3	43.3	43.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	-
SOEL Electrolysis (fix)	capacity	MW_{el}	160.7	160.7	160.7	160.7	160.7	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	-	1.56	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	-	49.0	-	-	49.0

S4 2050			Technology open scenario			CSP PV hybrid scenario		

Commodity flows per year (MoL*)

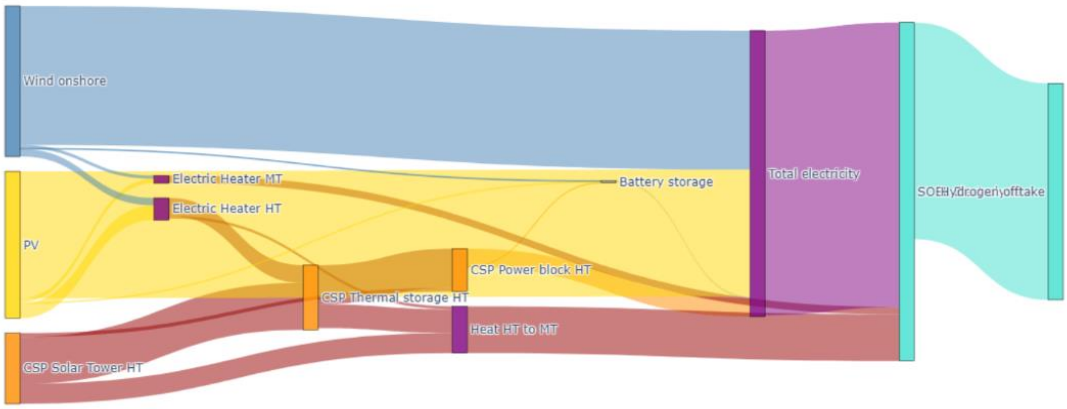
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
Water demineralization	Water, desalinated Import	kt	336.7	336.7	336.7	336.7	336.7	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	227.5	227.5	227.5	227.5	227.5	227.5
PV	Electricity Generation	GWh	464.0	464.0	587.0	844.8	866.4	891.3
Wind onshore	Electricity Generation	GWh	475.4	475.4	663.5	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	223.2	223.2	191.1	724.9	687.5	844.9
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	307.4	394.0	228.5	752.5	1,083.1	984.9
CSP TES MT	Heat MT Discharge	GWh	-	-	-	155.8	42.5	224.5
CSP Powerblock HT	Electricity Production	GWh	58.3	58.3	27.6	249.5	309.7	297.2
CSP Powerblock MT	Electricity Production	GWh	-	-	5.8	63.3	-	-
Electric Heater HT	Heat HAT Production	GWh	64.9	64.9	-	97.6	150.4	38.8
Electric Heater MT	Heat MT Production	GWh	22.8	22.8	62.9	121.5	64.7	-
Batterystorage	Electricity Discharge	GWh	5.6	5.6	6.3	-	-	-
Total PtX	Electricity Consumption	GWh	898.6	898.6	905.1	898.6	898.6	910.3
RES el.feed-in/Curtail	Electricity Consumption	GWh	0.2	0.2	554.1	59.6	88.5	858.8
AEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	(0.0)
SOEL Electrolysis (fix)	Electricity Consumption	GWh	898.4	898.4	898.4	898.4	898.4	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	-	1.9	-	-	3.5
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

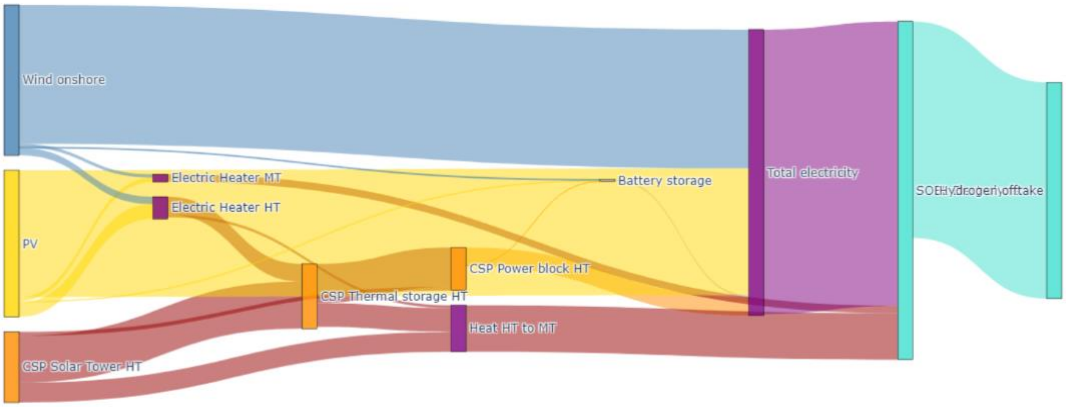
S4 2050			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	93,371.2	93,370.2	118,129.1	170,000.0	174,344.9	179,365.5
PV	OPEX	kEUR	15,296.6	15,296.4	19,352.6	27,850.4	28,562.2	29,384.7
Wind onshore	CAPEX	kEUR	140,814.4	140,817.1	196,525.5	-	-	-
Wind onshore	OPEX	kEUR	23,136.9	23,137.3	32,290.6	-	-	-
CSP Solar Tower	CAPEX	kEUR	35,276.5	35,276.2	70,686.7	120,598.2	115,835.7	234,913.8
CSP Solar Tower	OPEX	kEUR	9,909.3	9,909.2	19,856.1	33,876.4	32,538.6	65,988.0
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	59,427.2	59,427.1	34,336.1	60,559.9	82,502.3	95,281.3
CSP Power block HT	OPEX	kEUR	23,898.3	23,898.4	13,600.8	30,847.2	40,991.2	45,274.1
CSP PowerblockMT	CAPEX	kEUR	-	-	24,200.8	24,200.8	-	-
CSP Power block MT	OPEX	kEUR	-	-	8,523.0	10,489.5	-	-
Electric Heater HT	CAPEX	kEUR	13,308.1	13,308.0	-	17,334.6	20,501.9	11,510.9
Electric Heater HT	OPEX	kEUR	822.2	822.2	-	1,071.0	1,266.7	711.2
Electric Heater MT	CAPEX	kEUR	994.4	994.4	3,314.6	5,522.2	3,182.5	-
Electric Heater MT	OPEX	kEUR	74.6	74.6	249.0	414.5	238.9	-
CSP TES HT	CAPEX	kEUR	35,781.6	35,781.1	39,322.3	57,516.7	59,748.2	78,187.2
CSP TES HT	OPEX	kEUR	12,310.7	12,310.6	13,529.0	19,788.7	20,556.5	26,900.4
CSP TES MT	CAPEX	kEUR	-	-	-	8,269.9	3,452.9	34,938.1
CSP TES MT	OPEX	kEUR	-	-	-	2,371.1	990.0	10,017.1
Battery storage	CAPEX	kEUR	7,760.0	7,760.1	3,782.8	-	-	-
Battery storage	OPEX	kEUR	1,118.6	1,118.7	531.5	-	-	-
Water demineralization	CAPEX	kEUR	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2	6,061.2

Water demineralization	OPEX	kEUR	693.2	693.2	693.2	693.2	693.2	693.2
Water supply	OPEX	kEUR	359.5	359.5	359.5	359.5	359.5	359.5
AEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	(0.0)
AEL Electrolysis	OPEX	kEUR	-	-	-	-	-	-
SOEL Electrolysis	CAPEX	kEUR	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3
SOEL Electrolysis	OPEX	kEUR	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	-	5,274.1	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	-	2,914.9	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	-	6,101.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	-	1,665.7	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	-	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	-	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**552,269.9**	**649,364.4**	**764,018.4**	**629,538.8**	**722,198.8**	**907,917.2**
Total OPEX		**kEUR**	**146,928.8**	**186,446.6**	**375,268.5**	**187,070.3**	**225,023.3**	**445,611.3**

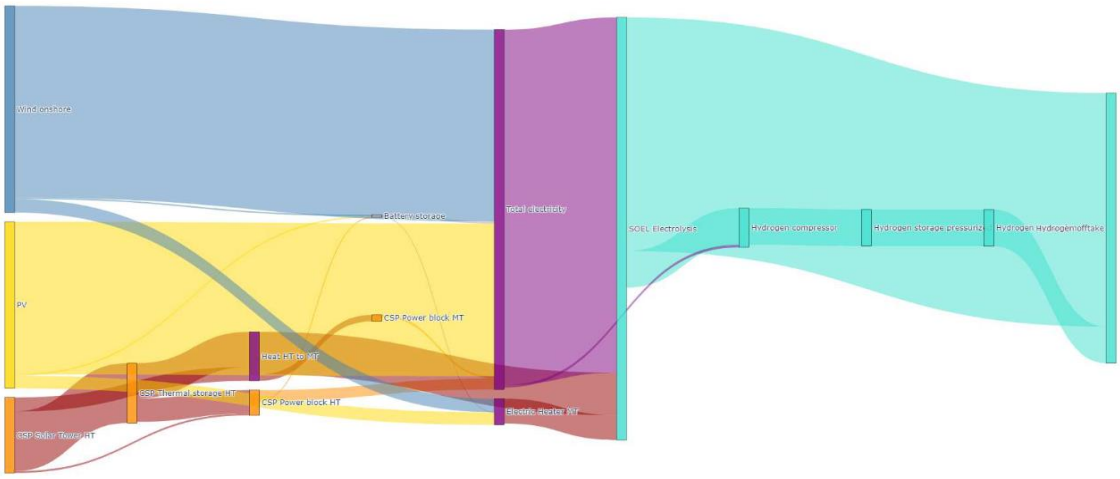
S4, H2, Technology open scenario, 2050



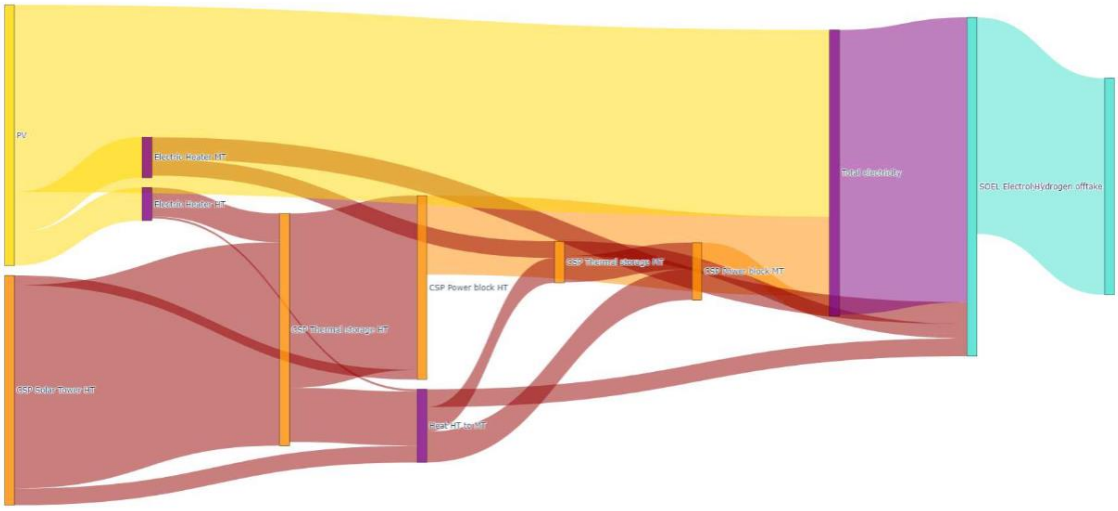
S4, NH3, Technology open scenario, 2050



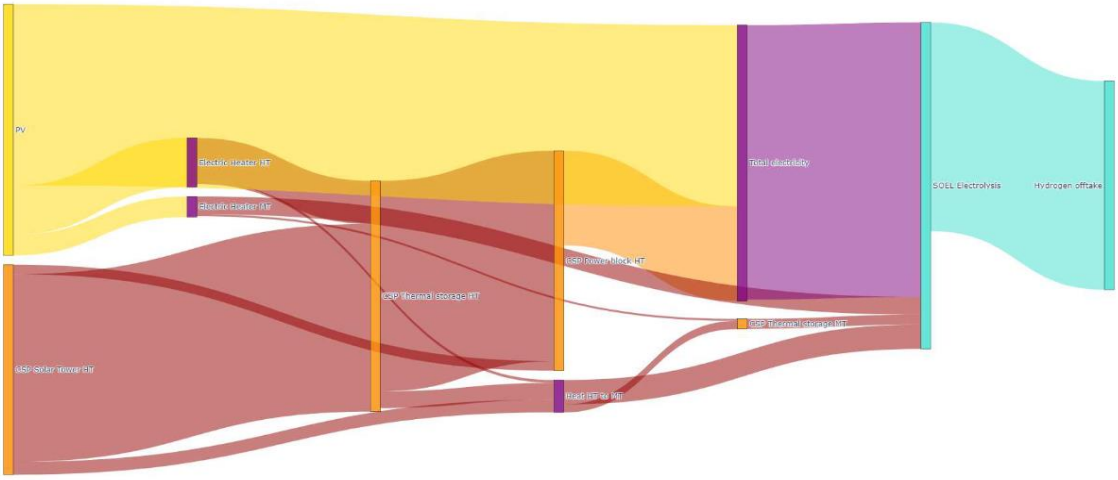
S4, MeOH, Technology open scenario, 2050



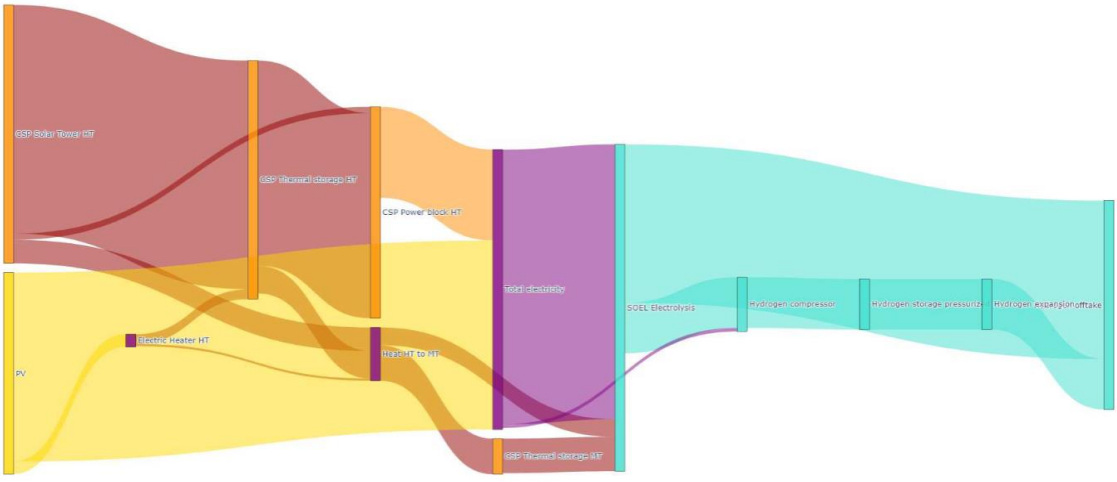
S4, H2, CSP PV PV hybrid system, 2050



S4, NH3, CSP PV hybrid system, 2050



S4, MeOH, CSP PV hybrid system, 2050



Results Optimized system design: Site S5 for 2030

S5 2030			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	183.6	178.8	277.8	670.4	666.9	1,108.4
PV	capacity factor	%	32.5%	32.5%	32.5%	32.5%	32.5%	32.5%
Wind onshore	capacity	MW	321.3	324.7	522.3	-	-	-
Wind onshore	capacity factor	%	33.5%	33.5%	33.5%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	-	147.8	165.3	-
CSP Solar Tower	capacity factor	%				13.3%	13.1%	
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	-	-	420.0	481.5	491.5	420.0
CSP TES HT		MWh_{th}	-	-	4,200.0	4,115.2	4,180.4	4,200.0
CSP TES HT	capacity factor	%						
CSP TES MT	capacity	MW_{th}	0.0	-	350.4	-	-	358.1
CSP TES MT		MWh_{th}	-	-	3,504.0	-	-	3,580.8
CSP TES MT	capacity factor	%						
CSP Powerblock HT	capacity	MW_{el}	-	-	20.0	127.4	126.0	57.0
CSP Power block HT	capacity factor	%			5.2%	37.4%	37.8%	47.6%
CSP Powerblock MT	capacity	MW_{el}	-	-	20.0	-	-	20.0
CSP Power block MT	capacity factor	%			4.1%			19.5%
Electric Heater HT	capacity	MW_{th}	-	-	13.9	365.0	361.8	332.7
Electric Heater HT	capacity factor	%			38.4%	25.3%	25.1%	21.6%
Electric Heater MT	capacity	MW_{th}	-	-	13.6	-	-	363.0
Electric Heater MT	capacity factor	%	0.0%		1.6%			28.9%
Battery storage	capacity	MW	0.7	0.7	-	-	-	-
Battery storage		MWh	1.1	1.0	-	-	-	-
Battery storage	capacity factor	%	5.3%	5.0%				
Waterdemineralization	capacity	t_{H2O}/h	36.3	36.3	36.3	36.3	36.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	208.3	208.3	208.3	208.3	208.3	-
SOEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	0.07	1.56	-	0.35	1.56
Hydrogen compressor HP		t_{H2}/h	-	0.07	1.56	-	0.35	1.56
Hydrogen storage pressurized		t_{H2}	-	8.8	49.0	-	3.5	49.0

S5 2030	Technology open scenario	CSP PV hybrid scenario

Commodity flows per year (MoL*)

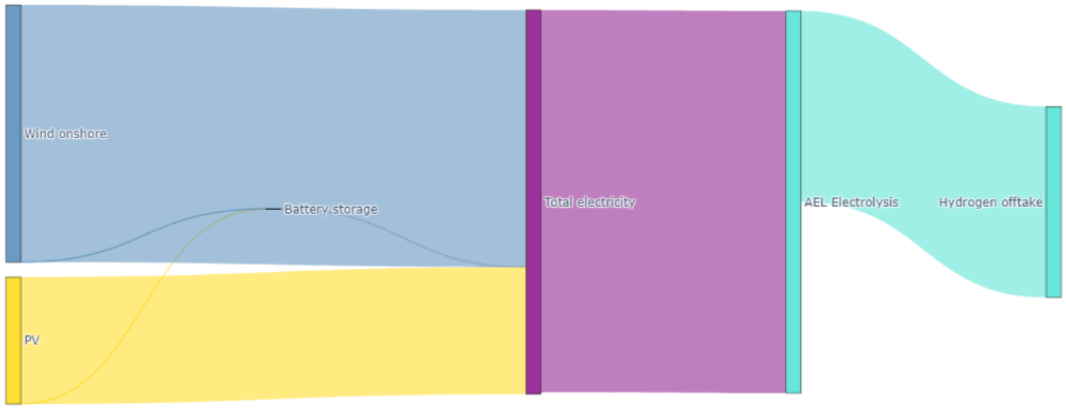
*Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).

Technology		Unit	H_2	NH_3	MeOH	H_2	NH_3	MeOH
Water demineralization	Water, desalinated Import	kt	282.1	282.1	282.1	282.1	282.1	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	190.6	190.6	190.6	190.6	190.6	227.5
PV	Electricity Generation	GWh	522.6	509.2	790.9	1,908.6	1,898.7	3,155.7
Wind onshore	Electricity Generation	GWh	942.3	952.2	1,531.5	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	0.0	-	-	171.6	189.6	-
CSP Trough	Heat MT Generation	GWh	0.0	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	0.0	-	87.5	997.9	996.9	994.0
CSP TES MT	Heat MT Discharge	GWh	0.0	-	48.9	-	-	906.7
CSP Powerblock HT	Electricity Production	GWh	-	-	9.1	416.9	417.7	237.8
CSP Powerblock MT	Electricity Production	GWh	-	-	7.1	-	-	34.1
Electric Heater HT	Heat HAT Production	GWh	0.0	-	46.8	809.2	795.7	629.4
Electric Heater MT	Heat MT Production	GWh	0.0	-	21.8	-	-	220.7
Batterystorage	Electricity Discharge	GWh	0.3	0.3	-	-	-	-
Total PtX	Electricity Consumption	GWh	1,368.4	1,368.8	1,373.5	1,368.4	1,369.0	910.6
RES el.feed-in/Curtail	Electricity Consumption	GWh	88.9	84.7	288.8	90.7	96.6	1,556.5
AEL Electrolysis (fix)	Electricity Consumption	GWh	1,368.3	1,368.3	1,368.3	1,368.3	1,368.3	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	0.1	1.5	-	0.2	3.5
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

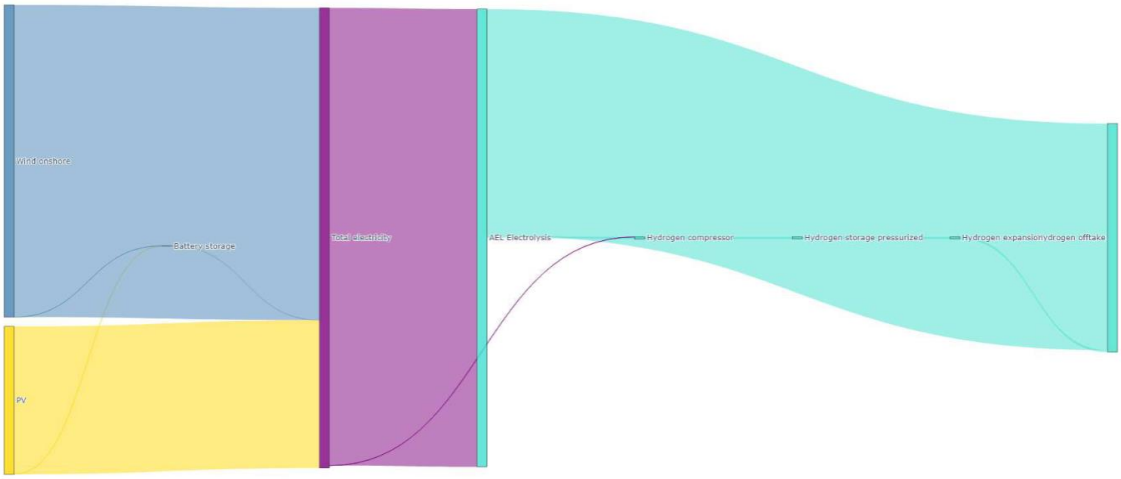
S5 2030			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	167,906.3	163,587.7	254,074.3	613,173.7	609,985.8	1,013,800.9
PV	OPEX	kEUR	27,507.4	26,799.9	41,623.9	100,453.6	99,931.3	166,086.6
Wind onshore	CAPEX	kEUR	356,170.8	359,932.0	578,880.2	-	-	-
Wind onshore	OPEX	kEUR	44,909.4	45,383.6	72,990.7	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	-	46,704.2	52,235.3	-
CSP Solar Tower	OPEX	kEUR	-	-	-	12,211.5	13,657.7	-
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerblock HT	CAPEX	kEUR	-	-	28,000.0	178,294.6	176,392.0	79,850.2
CSP Power block HT	OPEX	kEUR	(0.0)	(0.0)	9,917.4	75,417.5	74,793.2	35,521.2
CSP Powerblock MT	CAPEX	kEUR	0.0	-	26,000.0	-	-	26,000.0
CSP Power block MT	OPEX	kEUR	-	-	8,569.0	-	-	9,492.4
Electric Heater HT	CAPEX	kEUR	-	-	2,065.7	54,198.3	53,727.6	49,398.7
Electric Heater HT	OPEX	kEUR	-	-	119.0	3,116.8	3,089.7	2,840.8
Electric Heater MT	CAPEX	kEUR	-	-	1,493.0	-	-	39,928.0
Electric Heater MT	OPEX	kEUR	-	-	104.0	-	-	2,789.8
CSP TES HT	CAPEX	kEUR	-	-	84,000.0	82,304.1	83,607.4	84,000.0
CSP TES HT	OPEX	kEUR	-	-	26,900.0	26,357.3	26,774.7	26,900.4
CSP TES MT	CAPEX	kEUR	(0.0)	-	84,096.6	-	-	85,939.2
CSP TES MT	OPEX	kEUR	-	-	22,443.0	-	-	22,934.5
Battery storage	CAPEX	kEUR	520.3	490.1	-	0.0	-	-
Battery storage	OPEX	kEUR	52.3	49.1	-	0.0	-	-
Water demineralization	CAPEX	kEUR	5,078.3	5,078.3	5,078.3	5,078.3	5,078.3	6,061.2

Water demineralization	OPEX	kEUR	580.8	580.8	580.8	580.8	580.8	693.2
Water supply	OPEX	kEUR	301.2	301.2	301.2	301.2	301.2	359.5
AEL Electrolysis	CAPEX	kEUR	338,342.3	338,342.3	338,342.3	338,342.3	338,342.3	-
AEL Electrolysis	OPEX	kEUR	55,583.8	55,583.8	55,583.8	55,583.8	55,583.8	-
SOEL Electrolysis	CAPEX	kEUR	-	-	-	(0.0)	-	747,657.1
SOEL Electrolysis	OPEX	kEUR	-	-	-	(0.0)	-	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	243.7	5,274.1	-	1,187.1	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	134.7	2,914.9	-	656.1	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	281.9	6,101.1	-	1,373.3	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	77.0	1,665.7	-	374.9	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	6,268.0	34,704.8	0.0	2,487.6	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	2,078.2	11,506.3	-	824.8	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO_2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**868,017.9**	**971,317.8**	**1,510,214.4**	**1,318,095.4**	**1,421,510.3**	**2,240,819.3**
Total OPEX		**kEUR**	**128,934.9**	**170,505.9**	**446,107.2**	**274,022.5**	**316,085.9**	**533,901.6**

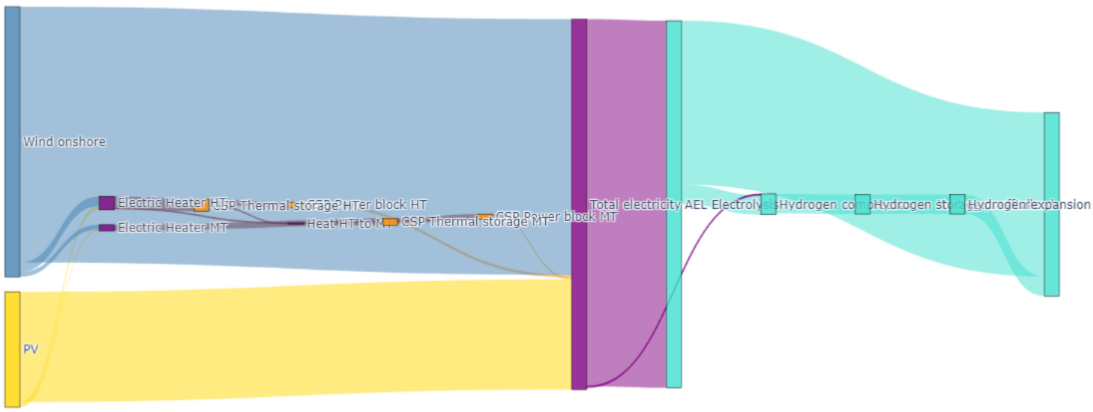
S5, H2, Technology open scenario, 2030



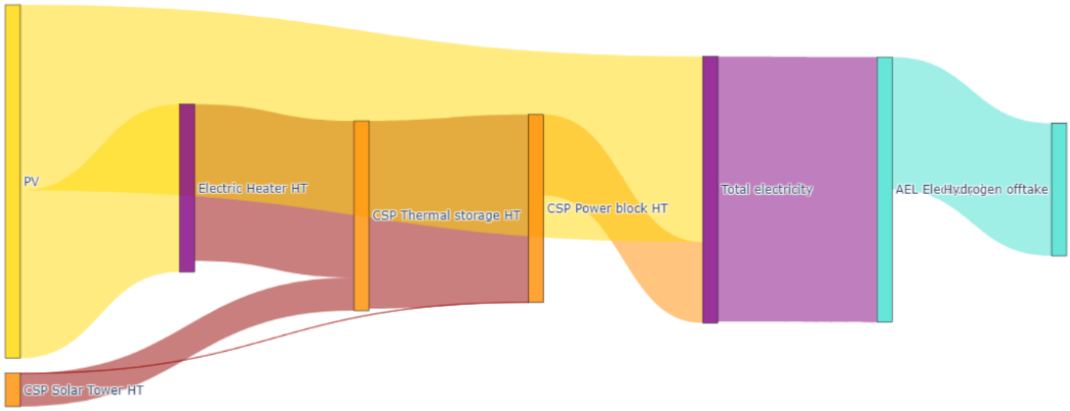
S5, NH3, Technology open scenario, 2030



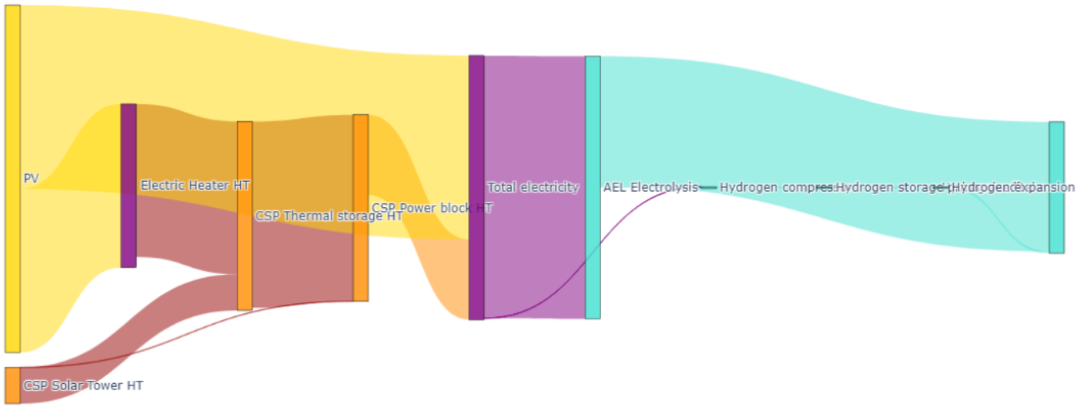
S5, MeOH, Technology open scenario, 2050



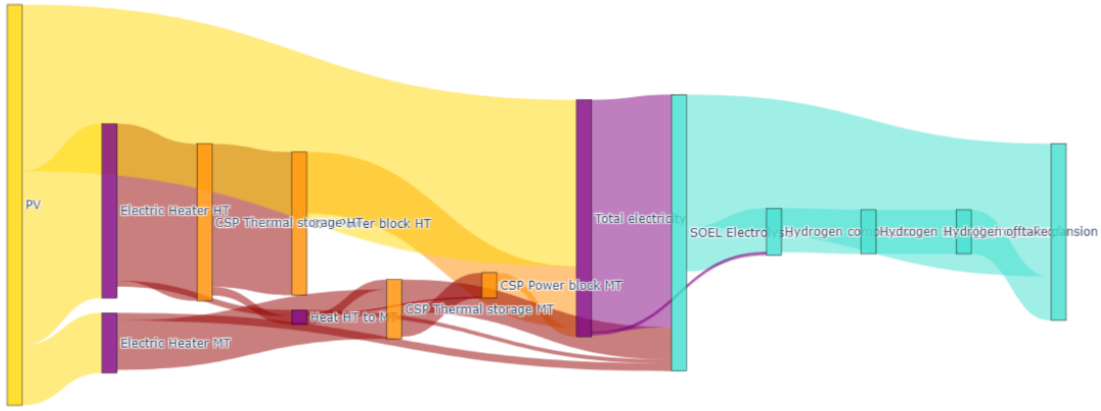
S5, H2, CSP PV hybrid system, 2030



S5, NH3, CSP PV hybrid system, 2030



S5, MeOH, CSP PV hybrid system, 2030



Results Optimized system design: Site S5 for 2050

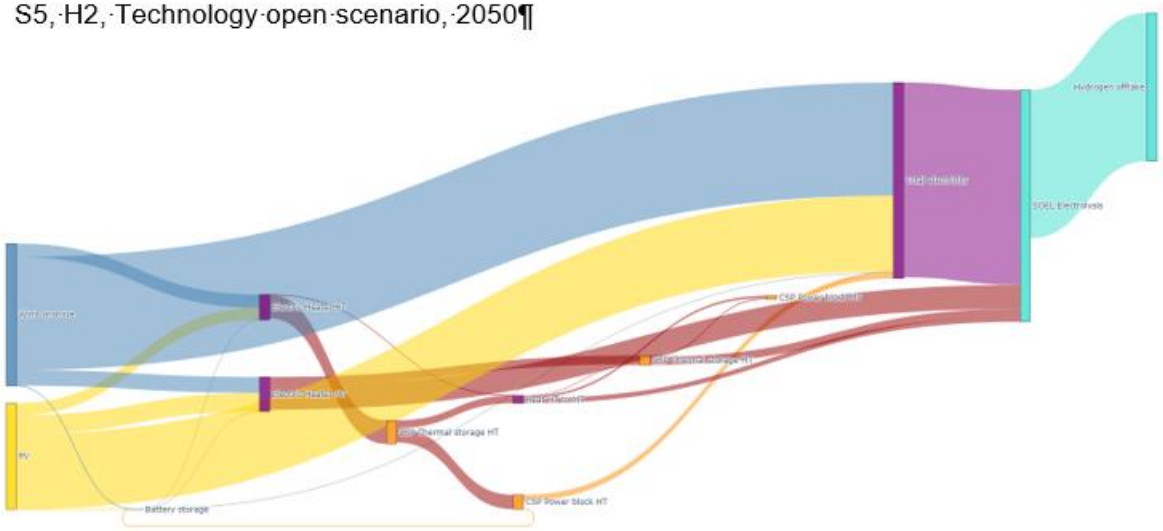
S5 2050			Technology open scenario			CSP PV hybrid scenario		
Capacities & Capacity factor								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	capacity	MWAC	176.9	176.8	251.1	586.5	519.4	1,064.9
PV	capacity factor	%	32.5%	32.5%	32.5%	32.5%	32.5%	32.5%
Wind onshore	capacity	MW	224.6	224.6	388.5	-	-	-
Wind onshore	capacity factor	%	33.5%	33.5%	33.5%			
CSP Solar Tower HT	capacity	MW_{th}	-	-	-	-	-	-
CSP Solar Tower	capacity factor	%	-	-	-	-	-	-
CSP Trough MT	capacity	MW_{th}	-	-	-	-	-	-
CSP Trough	capacity factor	%	-	-	-	-	-	-
CSP TES HT	capacity	MW_{th}	362.8	362.7	341.6	420.0	420.0	420.0
CSP TES HT		MWh_{th}	3,627.5	3,626.6	3,416.3	4,200.0	4,200.0	4,200.0
CSP TES HT	capacity factor	%	5.3%	6.9%	3.4%	16.9%	10.8%	21.1%
CSP TES MT	capacity	MW_{th}	38.4	38.5	40.0	163.2	66.5	304.9
CSP TES MT		MWh_{th}	164.9	166.1	291.0	1,631.8	665.0	3,048.8
CSP TES MT	capacity factor	%	14.7%	12.4%	12.3%	16.3%	17.0%	11.5%
CSP Powerblock HT	capacity	MW_{el}	28.9	28.9	27.2	36.3	37.1	47.4
CSP Power block HT	capacity factor	%	11.3%	11.3%	5.6%	57.6%	47.9%	43.3%
CSP Powerblock MT	capacity	MW_{el}	20.0	20.0	20.0	20.0	-	20.0
CSP Power block MT	capacity factor	%	3.2%	3.2%	2.4%	35.4%		22.4%
Electric Heater HT	capacity	MW_{th}	48.6	48.5	38.2	213.4	154.9	280.8
Electric Heater HT	capacity factor	%	25.6%	25.5%	27.8%	29.2%	28.7%	22.1%
Electric Heater MT	capacity	MW_{th}	48.1	48.2	60.0	130.0	70.0	313.3
Electric Heater MT	capacity factor	%	35.7%	35.7%	24.3%	21.6%	25.4%	6.6%
Battery storage	capacity	MW	1.3	1.3	2.1	54.4	113.3	43.2
Battery storage		MWh	3.8	3.8	4.7	321.8	681.7	207.3
Battery storage	capacity factor	%	7.2%	6.5%	14.4%	18.1%	19.0%	15.7%
Waterdemineralization	capacity	t_{H2O}/h	43.3	43.3	36.5	43.3	43.3	43.3
Water demineralization	capacity factor	%	60.0%	60.0%	71.1%	60.0%	60.0%	60.0%
AEL Electrolysis (fix)	capacity	MW_{el}	-	-	-	-	-	-
SOEL Electrolysis (fix)	capacity	MW_{el}	160.7	160.7	160.7	160.7	160.7	160.7
Electrolysis (fix)		t_{H2}/h	3.9	3.9	3.9	3.9	3.9	3.9
Electrolysis (fix)	capacity factor	%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%
Hydrogen compressor LP		t_{H2}/h	-	-	0.95	-	-	1.56
Hydrogen compressor HP		t_{H2}/h	-	-	0.95	-	-	1.56
Hydrogen storage pressurized		t_{H2}	-	-	49.0	-	-	49.0

S5 2050			Technology open scenario			CSP PV hybrid scenario		
Commodity flows per year (MoL*) *Middle of Lifetime – The values shown in this table represent the average efficiencies of all components, which degrades over their lifetime (applies mostly to electrolyzers).								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
Water demineralization	Water, desalinated Import	kt	336.7	336.7	336.7	336.7	336.7	336.7
Water demineralization	Electricity Consumption	GWh	0.1	0.1	0.1	0.1	0.1	0.1
Water demineralization	Water, demineralized Production	kt	227.5	227.5	227.5	227.5	227.5	227.5
PV	Electricity Generation	GWh	503.5	503.4	714.9	1,669.9	1,478.7	3,031.9
Wind onshore	Electricity Generation	GWh	658.6	658.6	1,139.4	-	-	-
CSP Solar Tower	Heat HT Generation	GWh	-	-	-	-	-	-
CSP Trough	Heat MT Generation	GWh	-	-	-	-	-	-
CSP TES HT	Heat HT Discharge	GWh	169.3	218.8	102.9	621.1	395.9	775.3
CSP TES MT	Heat MT Discharge	GWh	49.5	42.0	43.2	232.7	99.3	307.2
CSP Powerblock HT	Electricity Production	GWh	28.5	28.5	13.4	183.4	155.5	179.7
CSP Powerblock MT	Electricity Production	GWh	5.5	5.5	4.1	62.1	-	39.2
Electric Heater HT	Heat HAT Production	GWh	108.9	108.6	92.9	546.5	389.3	542.5
Electric Heater MT	Heat MT Production	GWh	150.4	150.6	127.4	245.5	156.0	181.9
Batterystorage	Electricity Discharge	GWh	0.8	0.8	2.6	86.3	188.8	59.2
Total PtX	Electricity Consumption	GWh	898.6	898.6	902.1	898.6	898.6	910.6
RES el.feed-in/Curtail	Electricity Consumption	GWh	17.7	18.0	691.3	144.2	109.1	198.6
AEL Electrolysis (fix)	Electricity Consumption	GWh	-	-	-	-	-	-
AEL Electrolysis (fix)	Hydrogen Production	ktH_2	-	-	-	-	-	-
SOEL Electrolysis (fix)	Electricity Consumption	GWh	898.4	898.4	898.4	898.4	898.4	898.4
SOEL Electrolysis (fix)	Hydrogen Production	ktH_2	20.5	20.5	20.5	20.5	20.5	20.5
Hydrogen compressor	Electricity Consumption	GWh	-	-	1.1	-	-	3.6
Yearly Hydrogen Output (fix)		kt H_2	20.5	20.5	20.5	20.5	20.5	20.5
Yearly Ammonia Output (fix)		kt NH_3	-	113.9	-	-	113.9	-
Yearly Methanol Output (fix)		kt MeOH	-	-	107.9	-	-	107.9

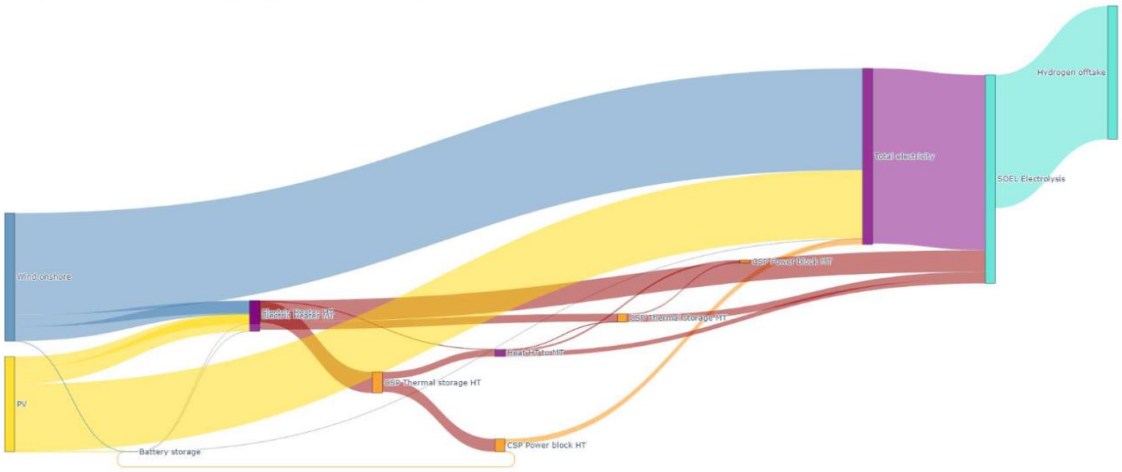
S5 2050			Technology open scenario			CSP PV hybrid scenario		
CAPEX (Whole lifecycle, discounted) and OPEX (discounted)								
Technology		**Unit**	**H_2**	**NH_3**	**MeOH**	**H_2**	**NH_3**	**MeOH**
PV	CAPEX	kEUR	111,749.6	111,723.3	158,653.7	370,590.6	328,166.9	672,864.0
PV	OPEX	kEUR	18,307.4	18,303.1	25,991.5	60,712.2	53,762.2	110,232.4
Wind onshore	CAPEX	kEUR	191,034.9	191,034.9	330,494.6	-	-	-
Wind onshore	OPEX	kEUR	31,388.4	31,388.4	54,302.7	-	-	-
CSP Solar Tower	CAPEX	kEUR	-	-	-	-	-	-
CSP Solar Tower	OPEX	kEUR	-	-	-	-	-	-
CSP Trough	CAPEX	kEUR	-	-	-	-	-	-
CSP Trough	OPEX	kEUR	-	-	-	-	-	-
CSP Powerbloc k HT	CAPEX	kEUR	37,610.7	37,610.7	35,388.8	47,319.2	48,295.3	61,734.0
CSP Power block HT	OPEX	kEUR	14,836.8	14,836.8	13,502.6	23,707.0	23,115.3	28,896.4
CSP Powerbloc kMT	CAPEX	kEUR	24,200.8	24,200.8	24,200.8	24,200.8	-	24,200.8
CSP Power block MT	OPEX	kEUR	8,515.4	8,515.5	8,467.0	10,447.7	-	9,665.6
Electric Heater HT	CAPEX	kEUR	6,724.5	6,707.1	5,275.1	29,496.7	21,413.3	38,816.4
Electric Heater HT	OPEX	kEUR	415.5	414.4	326.0	1,822.4	1,323.0	2,398.2
Electric Heater MT	CAPEX	kEUR	4,926.2	4,938.0	6,138.5	13,311.7	7,171.8	32,075.2
Electric Heater MT	OPEX	kEUR	369.8	370.7	461.0	999.3	538.4	2,407.7
CSP TES HT	CAPEX	kEUR	67,530.1	67,512.7	63,597.6	78,187.2	78,187.2	78,187.2
CSP TES HT	OPEX	kEUR	23,233.9	23,227.9	21,881.0	26,900.4	26,900.4	26,900.4
CSP TES MT	CAPEX	kEUR	3,684.4	3,711.6	6,501.5	36,453.6	14,855.9	68,107.8
CSP TES MT	OPEX	kEUR	1,056.4	1,064.1	1,864.0	10,451.6	4,259.3	19,527.2
Battery storage	CAPEX	kEUR	1,299.7	1,299.7	1,661.0	104,511.2	221,201.2	68,088.7
Battery storage	OPEX	kEUR	183.0	183.0	230.8	15,195.8	32,178.8	9,831.0
Water demineraliz ation	CAPEX	kEUR	6,061.2	6,061.2	5,113.3	6,061.2	6,061.2	6,061.2

Water demineralization	OPEX	kEUR	693.2	693.2	584.8	693.2	693.2	693.2
Water supply	OPEX	kEUR	359.5	359.5	359.5	359.5	359.5	359.5
AEL Electrolysis	CAPEX	kEUR	-	-	-	-	-	-
AEL Electrolysis	OPEX	kEUR	-	-	-	-	-	-
SOEL Electrolysis	CAPEX	kEUR	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3	159,475.3
SOEL Electrolysis	OPEX	kEUR	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9	59,308.9
Hydrogen compressor LP	CAPEX	kEUR	-	-	3,212.4	-	-	5,274.1
Hydrogen compressor LP	OPEX	kEUR	-	-	1,775.4	-	-	2,914.9
Hydrogen compressor HP	CAPEX	kEUR	-	-	3,716.1	-	-	6,101.1
Hydrogen compressor HP	OPEX	kEUR	-	-	1,014.5	-	-	1,665.7
Hydrogen storage pressurized	CAPEX	kEUR	-	-	34,704.8	-	-	34,704.8
Hydrogen storage pressurized	OPEX	kEUR	-	-	11,506.3	-	-	11,506.3
Air separationunit	CAPEX	kEUR	-	33,718.8	-	-	33,718.8	-
Air separation unit	OPEX	kEUR	-	6,790.8	-	-	6,790.8	-
Haber-Bosch reactor	CAPEX	kEUR	-	63,375.0	-	-	63,375.0	-
Haber-Bosch reactor	OPEX	kEUR	-	32,726.9	-	-	32,726.9	-
Methanol synthesis plant	CAPEX	kEUR	-	-	62,104.0	-	-	62,104.0
Methanol synthesis plant	OPEX	kEUR	-	-	12,284.2	-	-	12,284.2
CO2 supply (biogenic)	OPEX	kEUR	-	-	178,603.3	-	-	178,603.3
Total CAPEX		**kEUR**	**614,297.4**	**711,369.0**	**900,237.4**	**869,607.4**	**981,921.9**	**1,317,794.6**
Total OPEX		**kEUR**	**158,668.2**	**198,183.2**	**392,463.5**	**210,598.0**	**241,956.6**	**477,194.8**

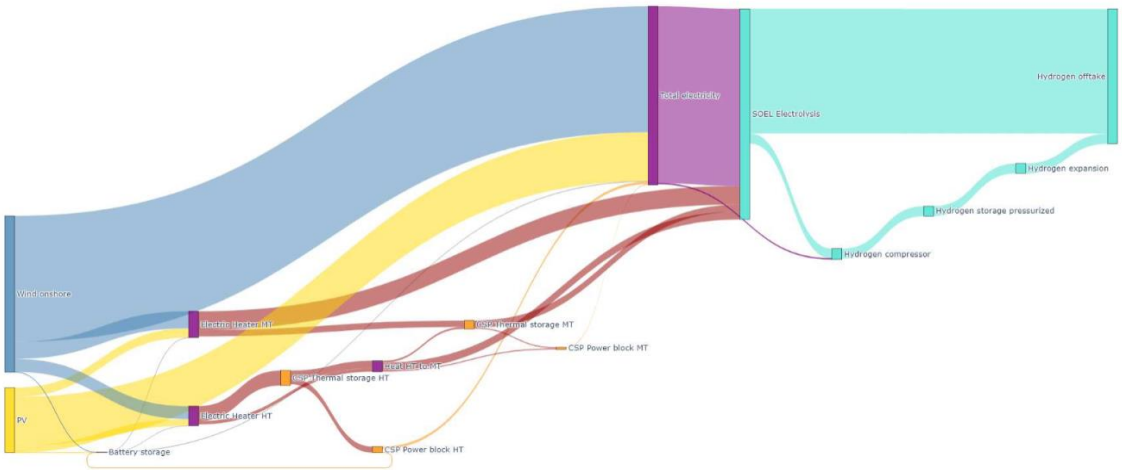
S5, H2, Technology open scenario, 2050



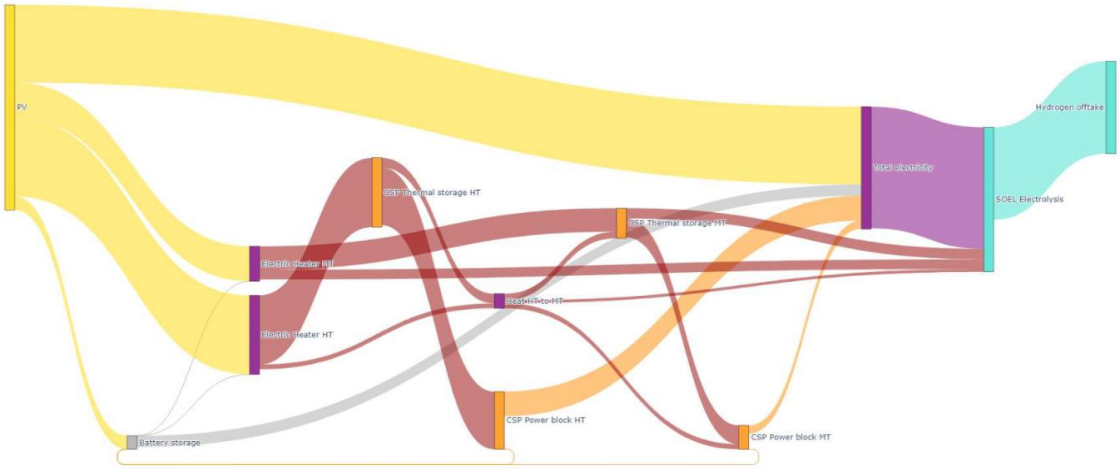
S5, NH3, Technology open scenario, 2050



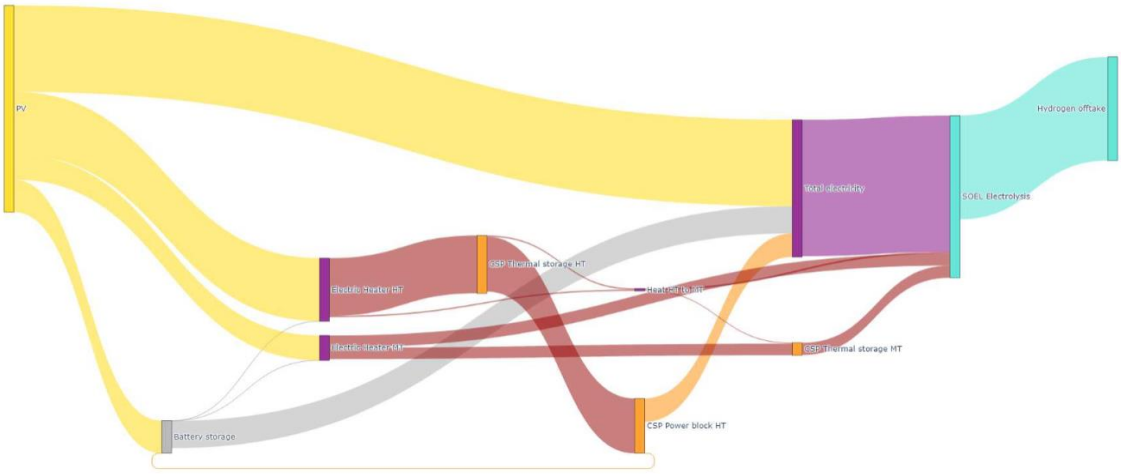
S5, MeOH, Technology open scenario, 2050



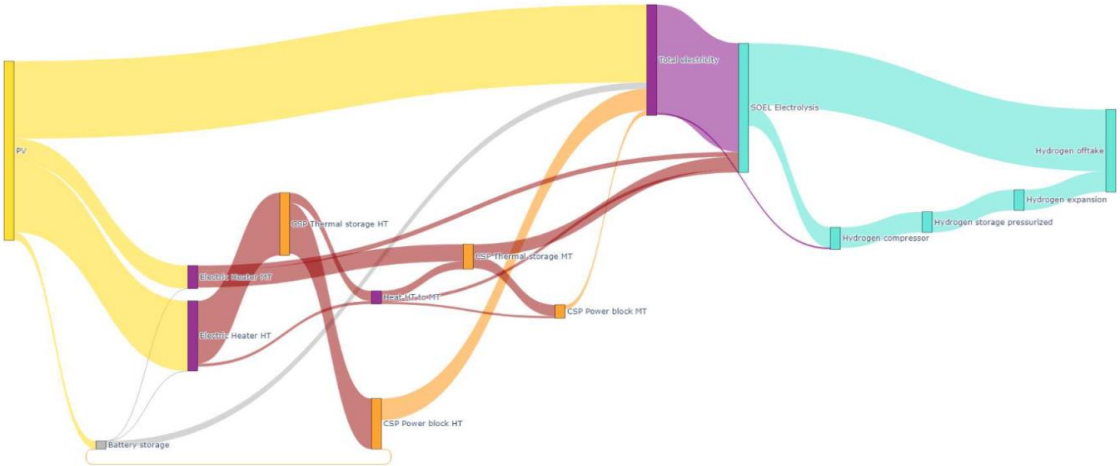
S5, H2, CSP PV hybrid system, 2050



S5, NH3, CSP PV hybrid system, 2050



S5, MeOH, CSP PV hybrid system, 2050



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