

Pressurized SOEC CAPEX results

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15/06/2022 VTT – beyond the obvious

Assumptions

Technical assumptions:

Voltage	1.29 V
Current density	-0,9 A/cm ²
Pressure	15 bar
Cells per stack	120
Active area per cell (cm²)	127.8
\$ to € conversion	0.94
Elec price	14 c/kWh
Plant sizes	200 kW; 2 MW; 15 MW; 75 MW
Automation	Production capacity >100 MW/a (size 75 MW)

Size assumptions:

Size	Size explanation
200 kW	Small scale
2 MW	Hydrogen refueling station size
15 MW	Typical modular size
75 MW	Large scale facility

Assumptions

Technical assumptions:

Voltage	1,29 V
Current density	-0,9 A/cm ²
Pressure	15 bar
Cells per stack	30
Active area per cell (cm²)	127,8
\$ to € conversion	0,94
Elec price	14 c/kWh
Plant sizes	200 kW; 2 MW; 15 MW; 75 MW
Automation	Automated when production capacity more than 100 MW/a (size 75 MW)

Size assumptions:

Size	MW	Stacks	Cells	Active area (m²)
200 kW	0,1824	40	1200	15,336
2 MW	2,0064	440	13200	168,696
15 MW	15,048	3300	99000	1265,22
75 MW	74,9664	16440	493200	6303,096

Cost analysis - Pressurized

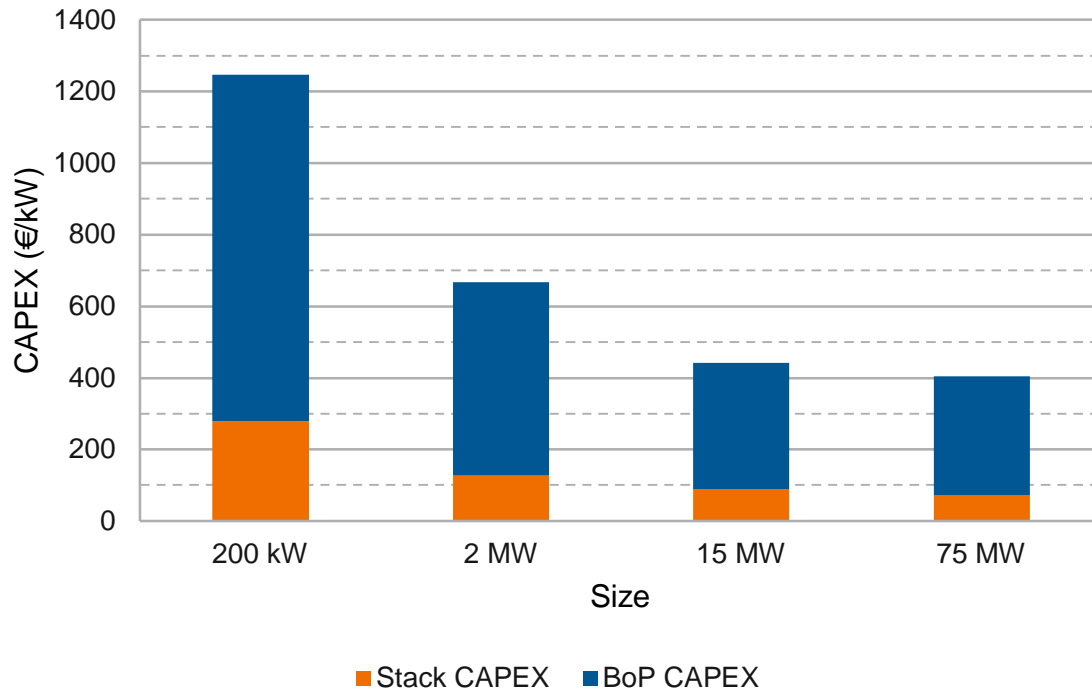
	200 kW (€kW)	(%)	2 MW (€kW)	(%)	15 MW (€kW)	(%)	75 MW (€kW)	(%)
Material costs	49	4 %	49	7 %	49	11 %	49	12 %
Personnel costs	38	3 %	19	3 %	10	2 %	1	0 %
Operation and maintenance costs	20	2 %	16	2 %	16	4 %	15	4 %
Equipment costs	75	6 %	19	3 %	6	1 %	3	1 %
Building costs	98	8 %	25	4 %	8	2 %	4	1 %
Total, Cells and stack production (C)	280	22 %	128	19 %	89	20 %	72	18 %
Heat exchanger	363	29 %	145	22 %	65	15 %	48	12 %
Electrical evaporator	193	16 %	108	16 %	71	16 %	67	16 %
Pressure vessel	79	6 %	79	12 %	79	18 %	79	20 %
Ac/dc converter (rectifier)	320	26 %	202	30 %	135	30 %	135	33 %
Compressor	0	0 %	0	0 %	0	0 %	0	0 %
Other BoP components	11	1 %	6	1 %	4	1 %	4	1 %
Total, BoP (B)	967	78 %	540	81 %	354	80 %	333	82 %
Total pressurized CAPEX (C+B)	1248	100 %	668	100 %	443	100 %	404	100 %

Cost analysis - Atmospheric

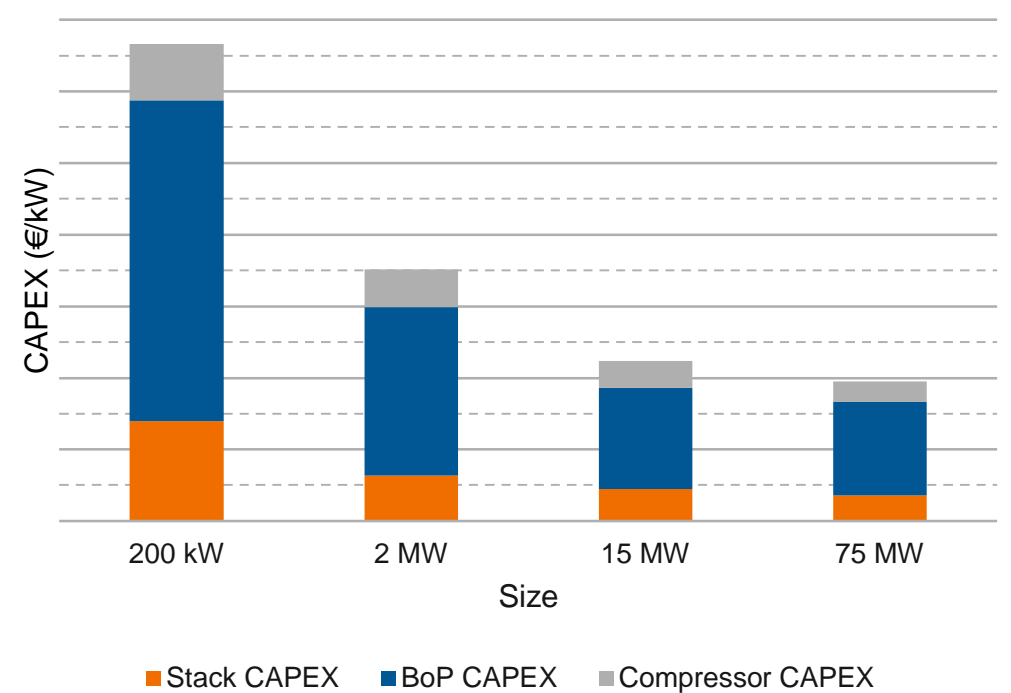
	200 kW (€/kW)	(%)	2 MW (€/kW)	(%)	15 MW (€/kW)	(%)	75 MW (€/kW)	(%)
Material costs	49	4 %	49	7 %	49	11 %	49	13 %
Personnel costs	38	3 %	19	3 %	10	2 %	1	0 %
Operation and maintenance costs	20	2 %	16	2 %	16	3 %	15	4 %
Equipment costs	75	6 %	19	3 %	6	1 %	3	1 %
Building costs	98	7 %	25	4 %	8	2 %	4	1 %
Total, Cells and stack production (C)	280	21 %	128	18 %	89	20 %	72	18 %
Heat exchanger	363	27 %	145	21 %	65	14 %	48	12 %
Electrical evaporator	193	15 %	108	15 %	71	16 %	67	17 %
Pressure vessel	0	0 %	0	0 %	0	0 %	0	0 %
Ac/dc converter (rectifier)	320	24 %	202	29 %	135	30 %	135	35 %
Compressor	156	12 %	106	15 %	76	17 %	58	15 %
Other BoP components	19	1 %	14	2 %	12	3 %	12	3 %
Total, BoP (B)	1052	79 %	575	82 %	358	80 %	320	82 %
Total non-pressurized CAPEX (C+B)	1333	100 %	704	100 %	448	100 %	391	100 %

Results

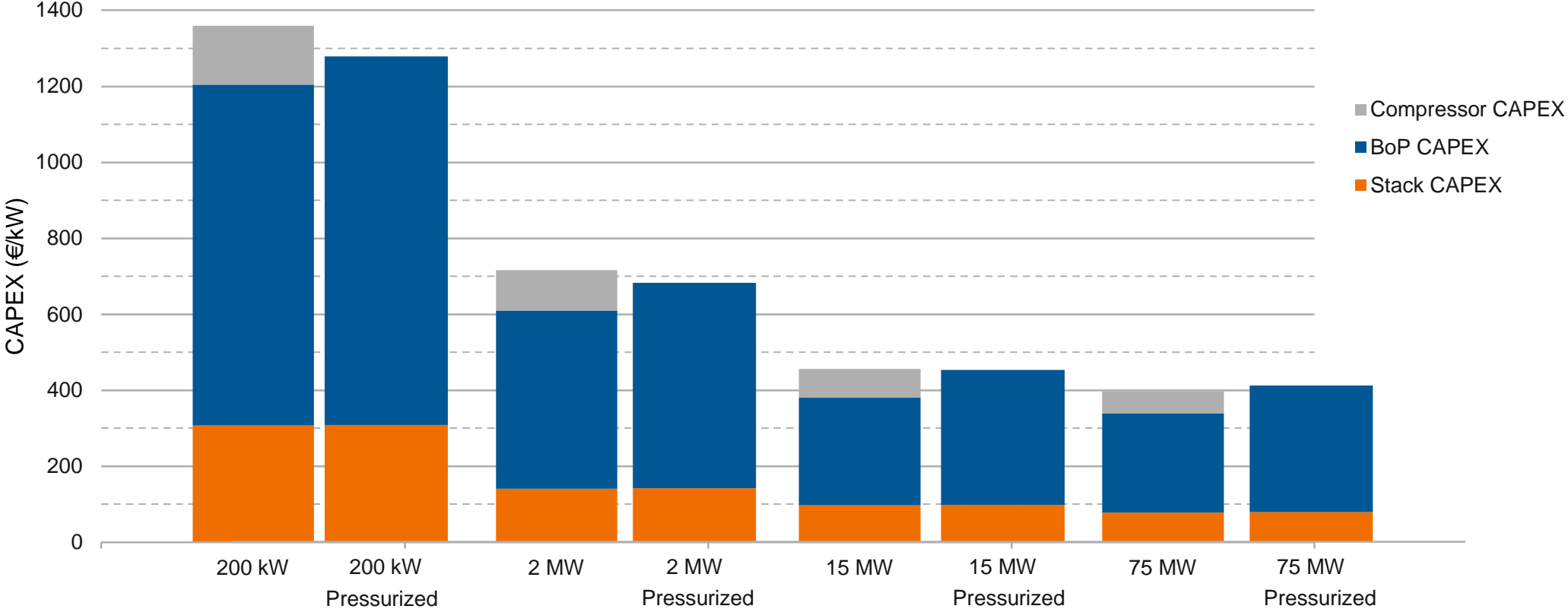
Pressurized system CAPEX:



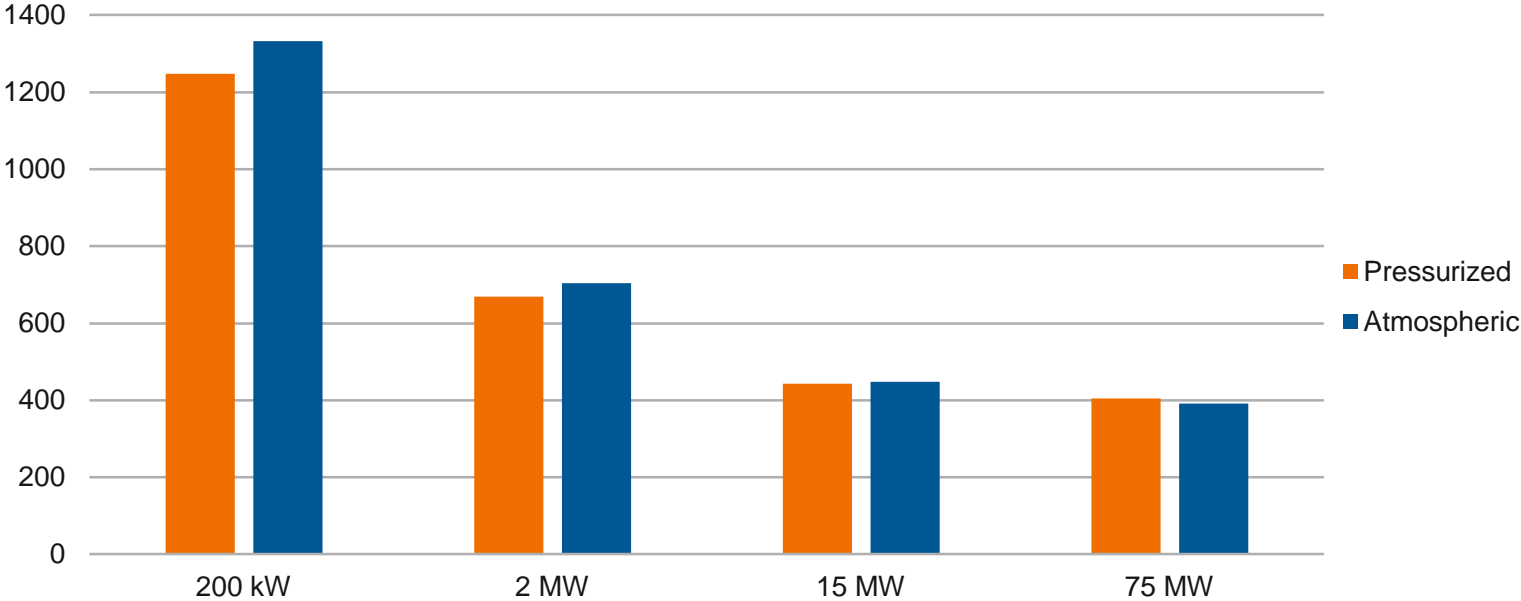
Atmospheric system CAPEX:



Results



Summary



	CAPEX			
Unit size (MW)	0.2	2	15	75
Pressurized (€/kW)	1248	668	443	404
Atmospheric (€/kW)	1333	704	448	391

Extra: calculations

Scaling relation used:

$$\frac{C_1}{C_2} = \left(\frac{P_1}{P_2}\right)^a$$

Annuity equation:

$$A = \frac{K \cdot r \cdot (1 + r)^n}{(1 + r)^n - 1}$$

Cell and stack manufacturing;

$$C = M + P + O + E + B$$

Compressor costs:

$$P_{multi\ stage} = N \left(\frac{k}{k-1}\right) \left(\frac{z}{\eta_{isen}}\right) T_{suc}(q_M) R \left[\left(\frac{P_{disc}}{P_{suc}}\right)^{\frac{k-1}{Nk}} - 1 \right]$$

Total installed costs (TIC) = Uninstalled costs (UC) · Installation factor (IF)

$$UC = P_{compressor}^{SF}$$

$$IF = 1.3 - 2$$

SF 0.4603, 0.6038, 0.8335



Extra: calculations

	thickness (10 ⁻⁶ *m)	density (g/cm ³)	area (cm ²)	volume (cm ³)	requirement (g/cell)	requirement + scrap(12%)	requirement + scrap(15%)	cost	cost per cell (€/cell)	cost per cell (€/cell)	€/stack	€/stack
LSCF	25	6,3	167	0,4175	2,63025	2,94588	3,0247875	53	0,22304520	0,229019625	26,76542	27,48236
8YSZ	130	6,1	167	2,171	13,2431	14,832272	15,229565	37,60	0,796704896	0,818045206	95,60459	98,16542
CGO (same as gadolinium-doped ceria)	10	7,9	167	0,167	1,3193	1,477616	1,517195	42	0,17731392	0,1820634	21,27767	21,84761
NiO/CGO (50%/50%- vol)	25		167	0,4175	3,0414875	3,4064663	3,497710625	23/42	0,162060140	0,166401037	19,44722	19,96812
Organic solvents									0,26	0,26	31,2	31,2
Total									1,619124156	1,655529267	194,2949	198,6635

Interconnect material	kg/stack	Cost (\$/kg)	Cost (€/stack)
Crofer 22 APU		29,68	25 697,48



Extra (compressor)

	200kW	2MW	15MW	75 MW	
CAPEX (€)	31225,62077	212819,3	1141234	4364818,031	
CAPEX (€/kW)	156,1281039	106,4097	76,08226	58,19757374	
massavirta (kg/h)		5	50	375	1875

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Process	Pressure requirement
FT with cobalt catalyst	20-30 bar
FT with iron catalyst + WGS	8 bar
Methanation (high temp)	15 bar
Methanol synthesis (low pressure)	60-80 bar
Hydrogen reduction	3-5 bar
Ammonia	150+ bar