COMPARATIVE ANALYSIS OF ENERGY STORAGE AND HYDROGEN GENERATION SOLUTIONS FOR A (PHOTOVOLTAIC) SOLAR POWER PLANT WITH A PLANNED CAPACITY OF 5 MW

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1. Scope of the analysis

The objective of this work is to model the storage of electric energy produced but not used by the facility for longer-term utilization with the following technologies:

- Li-ion/Lithium Iron Phosphate ($LiFePO_4$),
- VRFB,
- NaS,
- Electrolysis (PEM).

Within the framework of the analysis, we developed two models for each technology with different technical parameters, using empirical consumption data provided by ELI-HU Non-Profit Ltd.

The models present the balance of energy production, storage and consumption as time-series and cumulative data, as well as the financial means required to build and operate the storage capacities and the savings generated by the operation of the new infrastructure in monthly, quarterly and yearly intervals, as well as cumulatively for a 5-year period.

2. Notes on modelling

Table 1. Summary of the modelling methodology

Description	Features	Source
Consumption data	Data provided by ELI-HU Non-Profit Ltd.	-
Energy production data of the solar power plants (“Floating, Tracker, East-West 400V, Large Carport, East-West 800V”)	Modelled value based on NASA’s database, taking into account data provided by ELI-HU Non-Profit Ltd.	-
Evaluation of data	Monthly, quarterly, yearly, five-year intervals	-
Evaluation of modelling	Based on hourly data	-
Calculation of the rated capacities of battery energy storage systems	Based on the average of annual data: 1100 MW	[1]
Calculation of the storage capacities of battery energy storage systems	<u>Scenario 1:</u> short discharge time of up to 2 hours: This corresponds to 2 hours of rated operation at rated output power, which means that in principle the battery can be fully charged and discharged in 2 hours. <u>Scenario 2:</u> long discharge time of up to 6 hours: This corresponds to 6 hours of rated operation at rated output power, which means that in principle the battery can be fully charged and discharged in 6 hours.	[1]
Calculation of the rated power of PEM	Based on the commercially available container technology <u>Scenario 1</u>: lower power ("MC250"), which takes into account the consumption data: 1.25 MW. <u>Scenario 2:</u> higher power ("MC500"), which takes into account the consumption data: 2.5 MW.	[2–4]
Average electricity demand considered for H_2 generation (kWh/kg)	50.4	[2–4]
Electric to electric efficiency considered	Li-ion: 87%, LiFePO4: 88%, NaS: 73%, VRFB: 70% - For LiFePO4, Li-ion and VRFB based technologies, the electric to electric efficiency takes into account cumulatively the average RTE loss of the battery module or cell, the "Balance of Systems" (BOS) loss of the system accessories, and the average effect of auxiliary systems (e.g. cooling, heating). - For NaS based technology, the electric to electric efficiency takes into account cumulatively the average RTE loss of the battery module or cell, the average Balance of Systems (BOS) loss of the system accessories, the average effect of auxiliary systems and heat losses.	[5–17]
Electricity tariff considered, with RHD charge (HUF/kWh)	97.13	-
H_2 sales price considered (kg/USD; kg/HUF)	4.5; 1665	[18]
Was technical depreciation due to battery use considered for the relevant technologies?	Yes	[19]
Was the H_2 loss considered for storage?	Yes, mean value: 5.075%	[20–22]
Capital expenses	Validated by Hungarian and international market players	-

3. Evaluation of the modelling results

3.1. LiFePO4, Scenario 1

Table 1. LiFePO4 model-based energy efficiency analysis, Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system, with LiFePO4 energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with LiFePO4 energy storage (MWh)	Discharge demand of the LiFePO4 battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	414	252	68	26	37	17
February	661	438	395	360	138	88	44	20
March	695	388	335	620	313	252	54	24
April	669	330	270	722	383	315	60	27
May	868	394	331	877	404	332	63	29
June	1010	425	370	979	394	331	55	25
July	1118	470	409	1027	380	311	61	28
August	1136	572	518	918	354	292	55	25
September	802	444	391	642	284	224	52	24
October	714	417	355	566	270	199	62	28
November	622	423	384	322	123	78	39	18
December	648	485	455	219	56	22	30	14
Q1	1991	1278	1143	1232	519	366	135	61
Q2	2546	1149	971	2578	1181	978	178	81
Q3	3055	1486	1318	2587	1018	827	168	76
Q4	1984	1325	1193	1107	448	298	132	60
1 year	9577	5239	4626	7503	3165	2469	612	278
5 years	47885	26195	24097	37514	15824	13440	2098	1392

Table 2. LiFePO4 model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system, with LiFePO4 energy storage (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)
January	100%	71%	65%	100%	27%	10%
February	100%	66%	60%	100%	38%	24%
March	100%	56%	48%	100%	50%	41%
April	100%	49%	40%	100%	53%	44%
May	100%	45%	38%	100%	46%	38%
June	100%	42%	37%	100%	40%	34%
July	100%	42%	37%	100%	37%	30%
August	100%	50%	46%	100%	39%	32%
September	100%	55%	49%	100%	44%	35%
October	100%	58%	50%	100%	48%	35%
November	100%	68%	62%	100%	38%	24%
December	100%	75%	70%	100%	26%	10%
Q1	100%	64%	57%	100%	42%	30%
Q2	100%	45%	38%	100%	46%	38%
Q3	100%	49%	43%	100%	39%	32%
Q4	100%	67%	60%	100%	40%	27%
1 year	100%	55%	48%	100%	42%	33%
5 years	100%	55%	50%	100%	42%	36%

Table 3. LiFePO4 model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 1

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system, with LiFePO4 energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, with LiFePO4 energy storage, in 5 years (HUF million)	Cost saving on the LiFePO4 energy storage system (HUF million)
January	62	44	40	18	22	4
February	64	43	38	22	26	4
March	68	38	33	30	35	5
April	65	32	26	33	39	6
May	84	38	32	46	52	6
June	98	41	36	57	62	5
July	109	46	40	63	69	6
August	110	56	50	55	60	5
September	78	43	38	35	40	5
October	69	41	34	29	35	6
November	60	41	37	19	23	4
December	63	47	44	16	19	3
Q1	193	124	111	69	82	13
Q2	247	112	94	136	153	17
Q3	297	144	128	152	169	16
Q4	193	129	116	64	77	13
1 year	930	509	449	421	481	60
5 years	4651	2544	2341	2107	2311	204

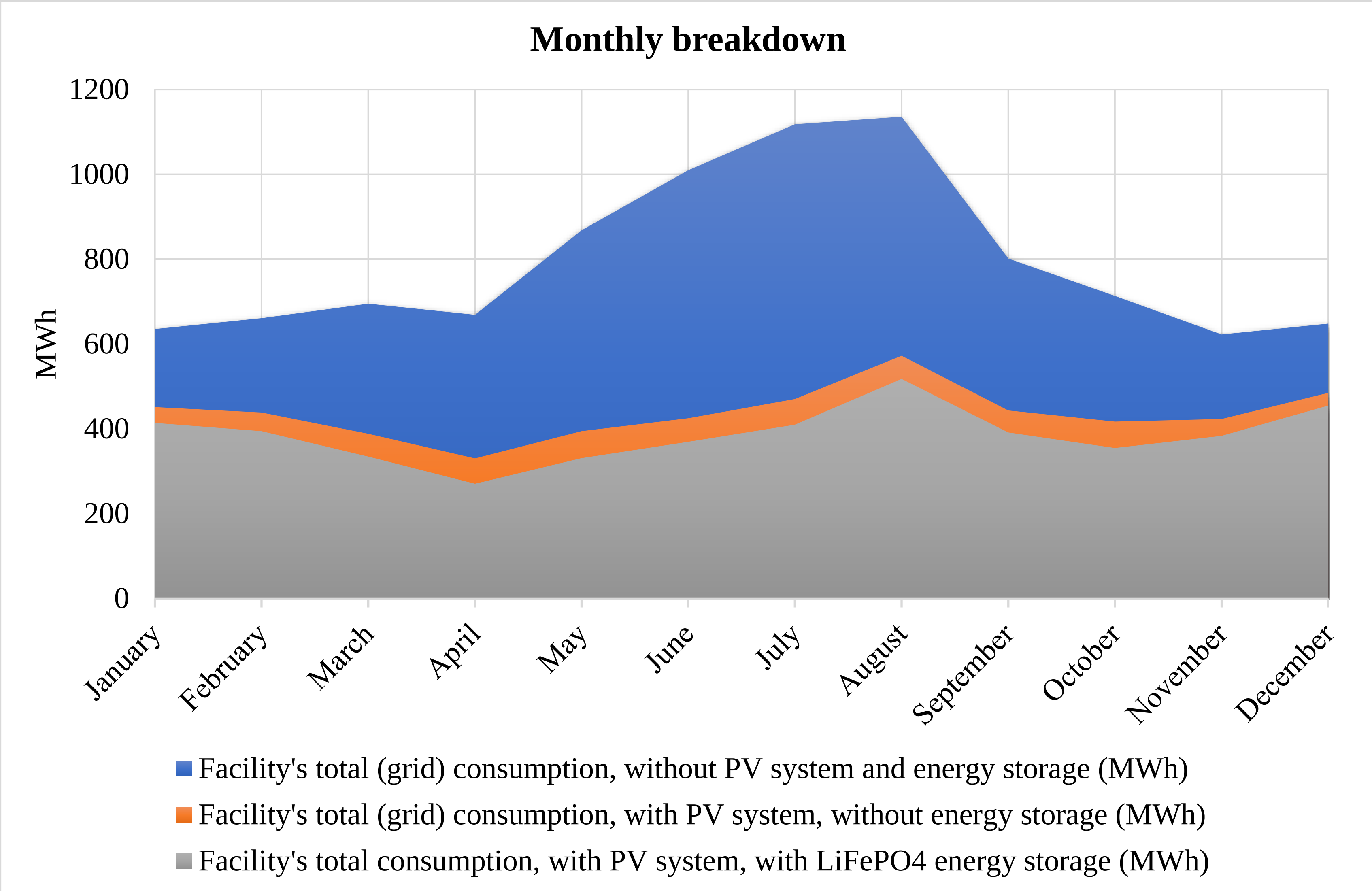

Figure 1. LiFePO4 model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 1

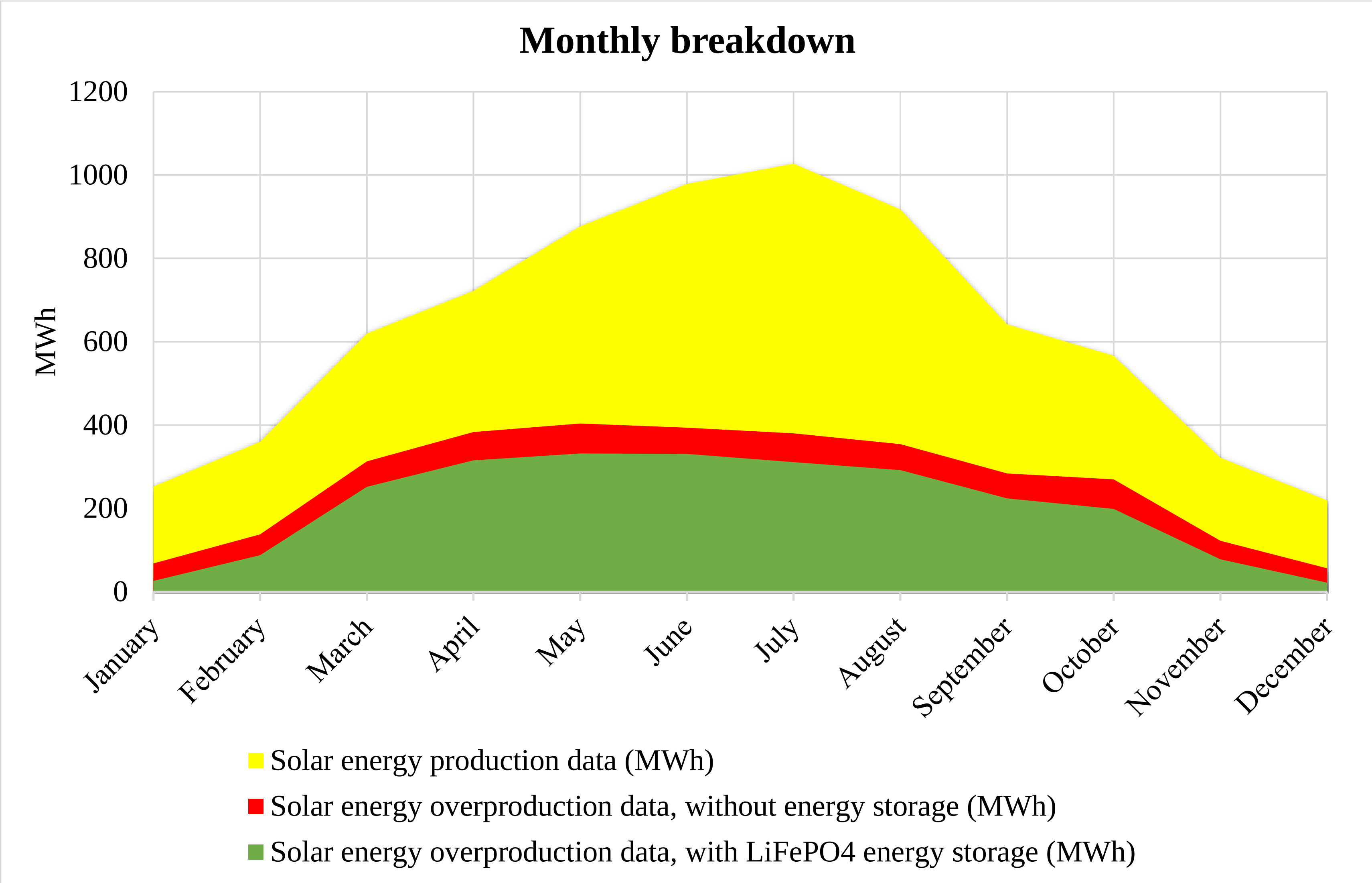

Figure 2. LiFePO4 model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 1

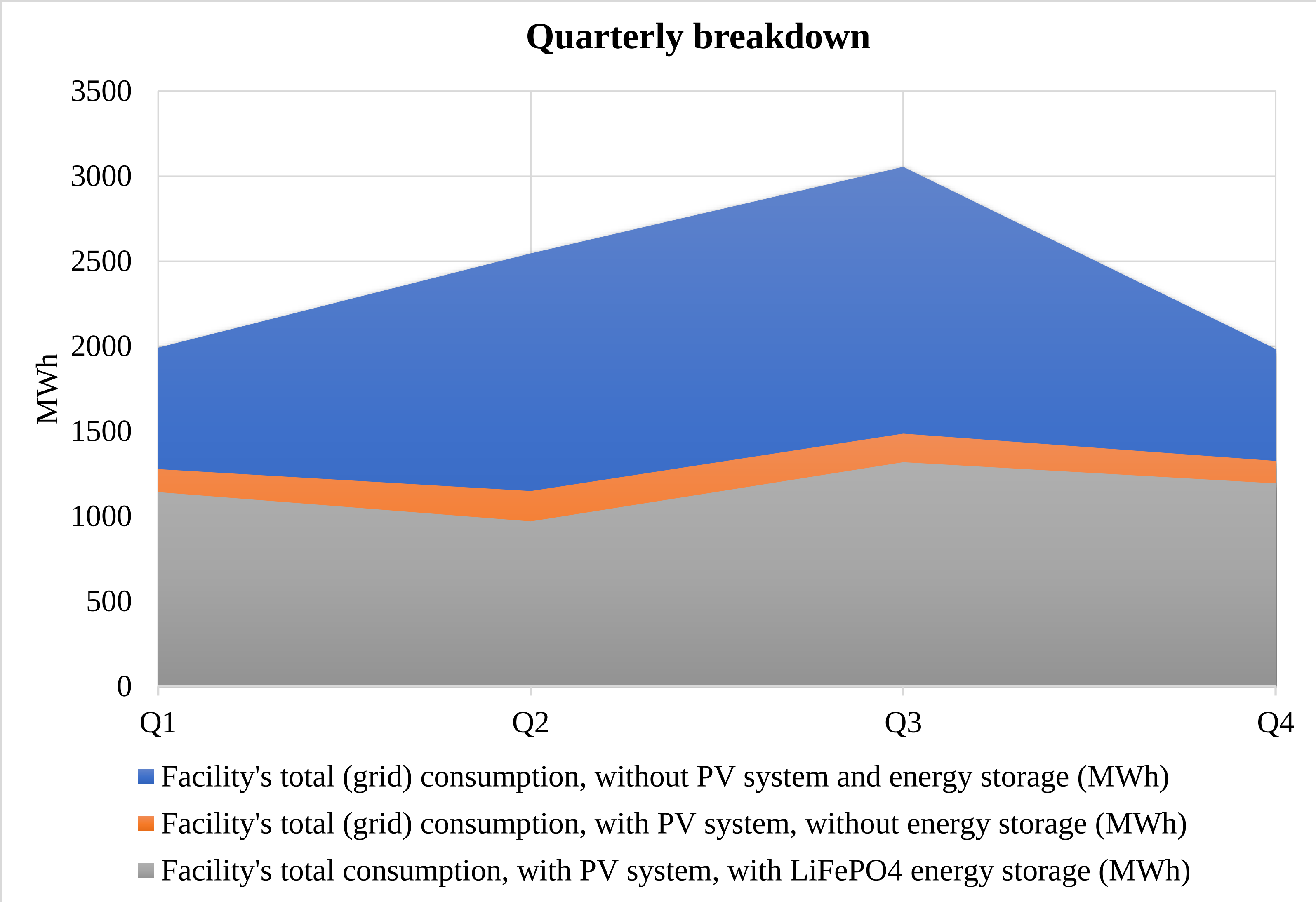

Figure 3. LiFePO4 model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 1

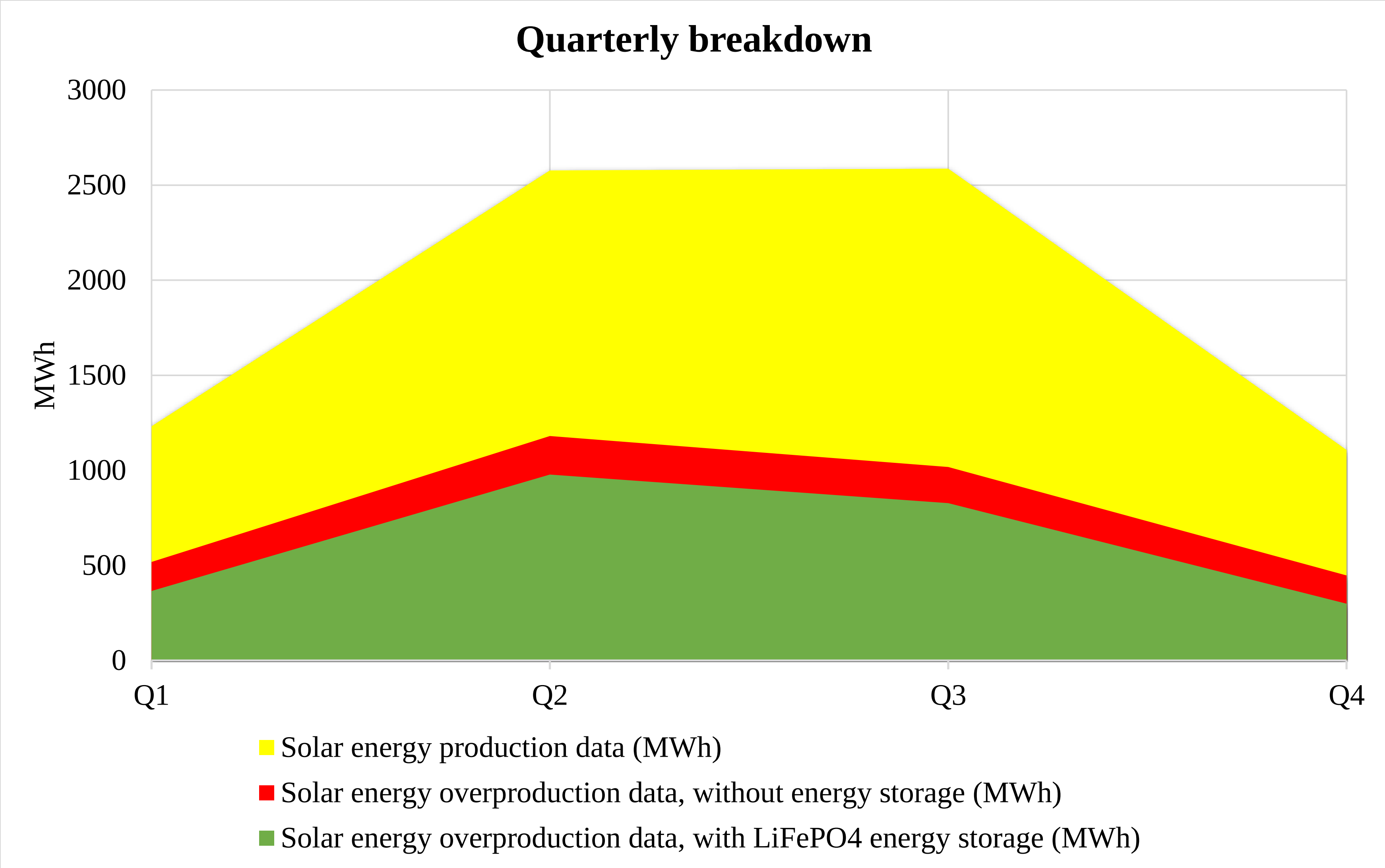

Figure 4. LiFePO4 model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 1

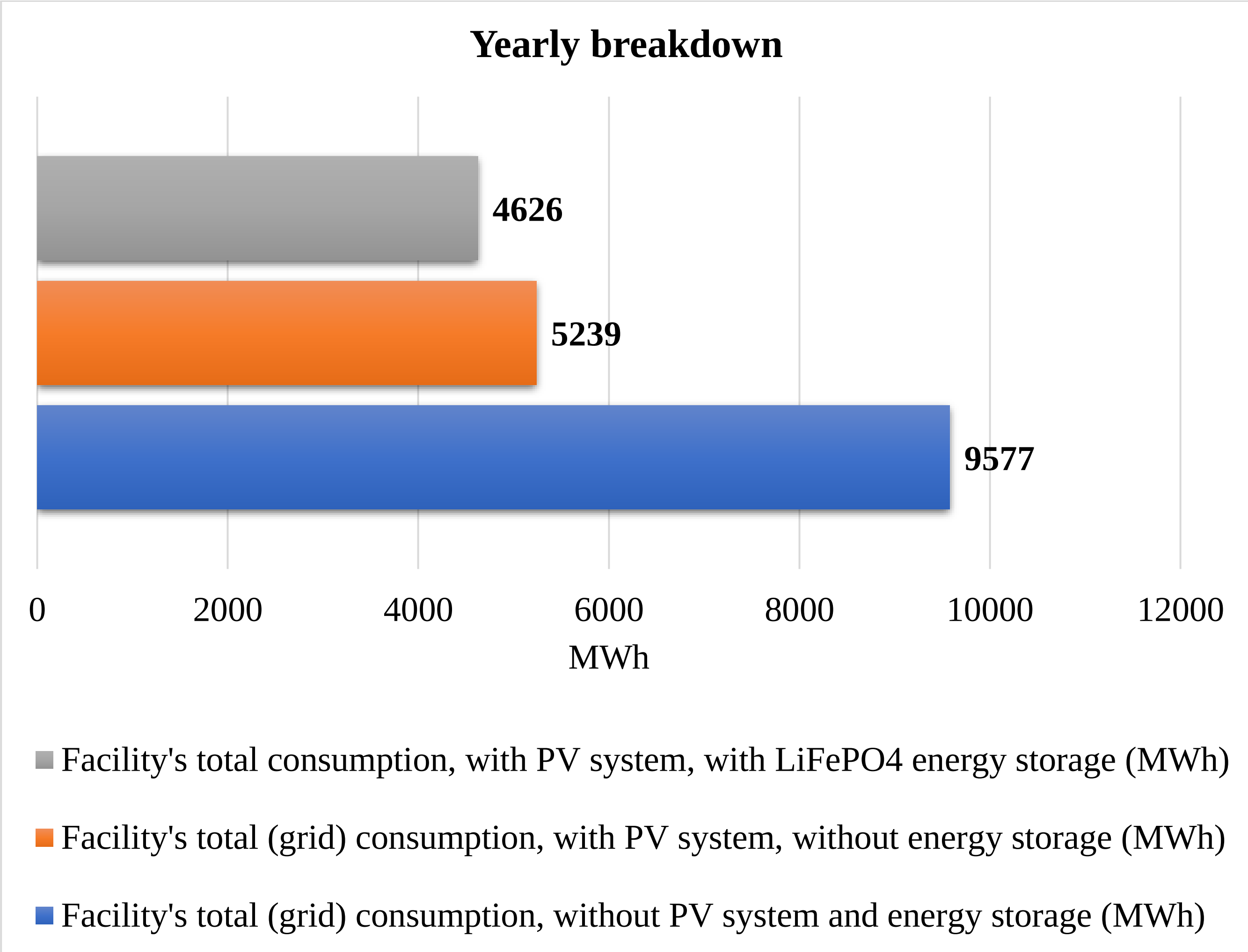

Figure 5. LiFePO4 model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 1

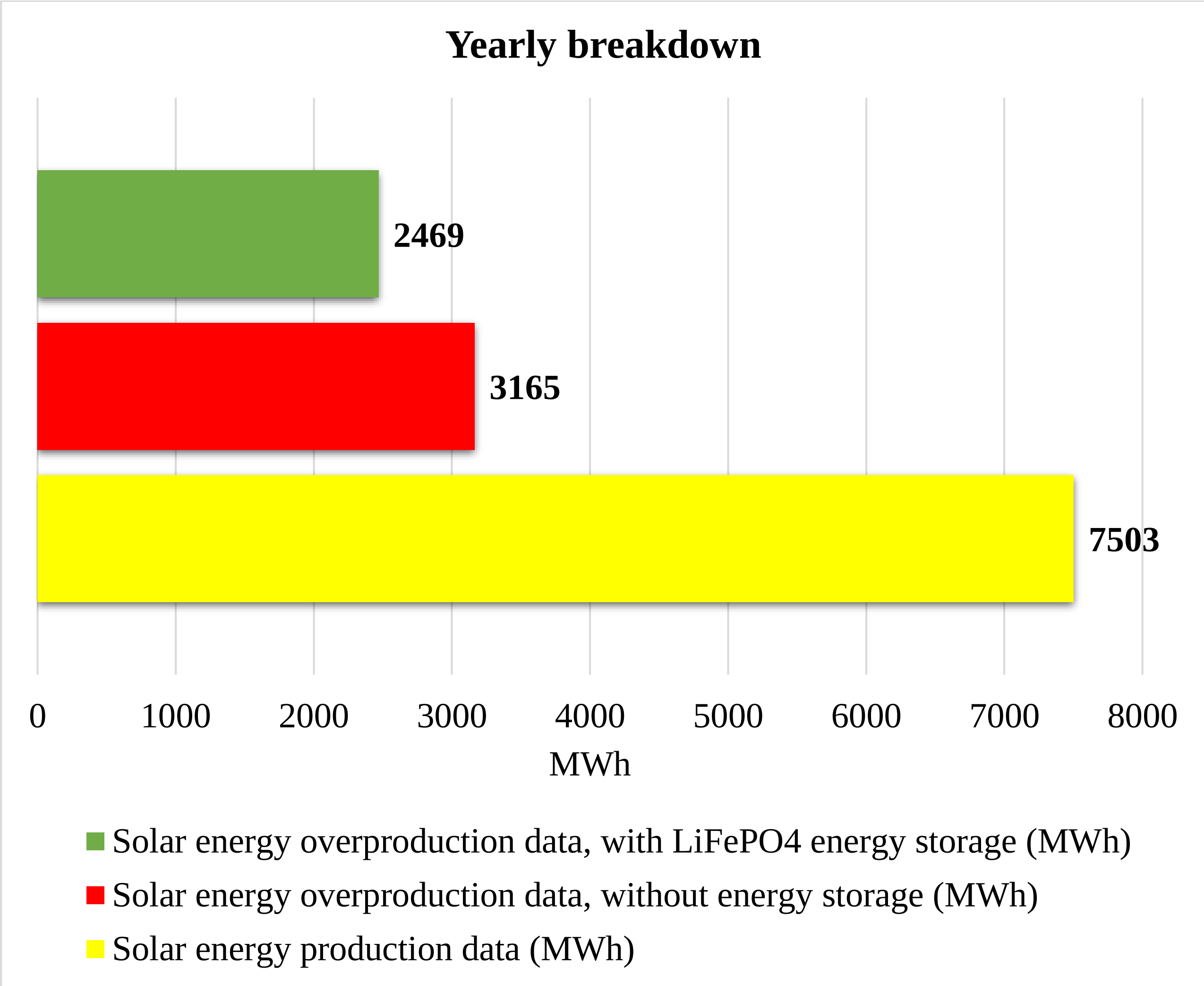

Figure 6. LiFePO4 model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 1

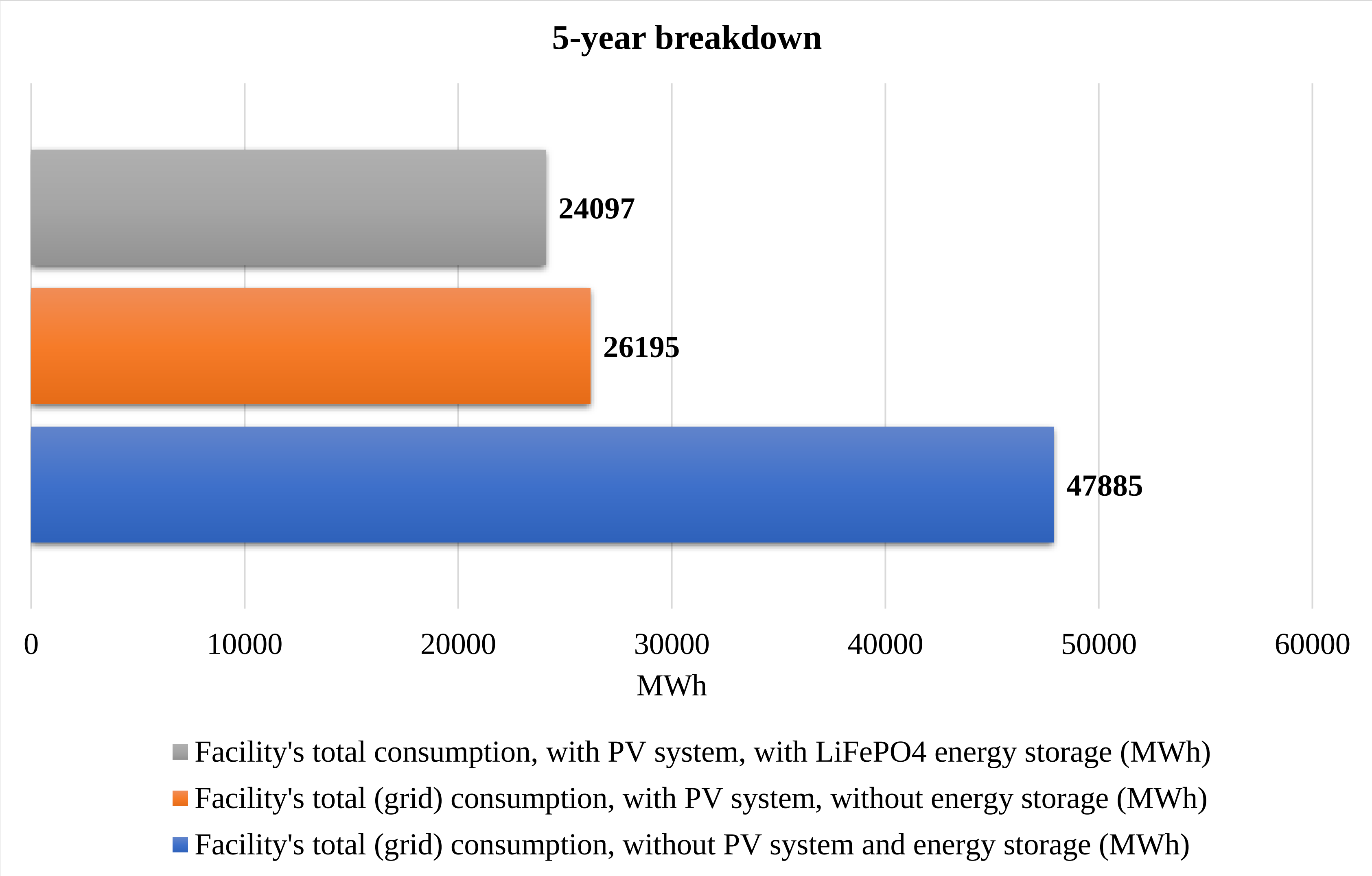

Figure 7. LiFePO4 model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 1

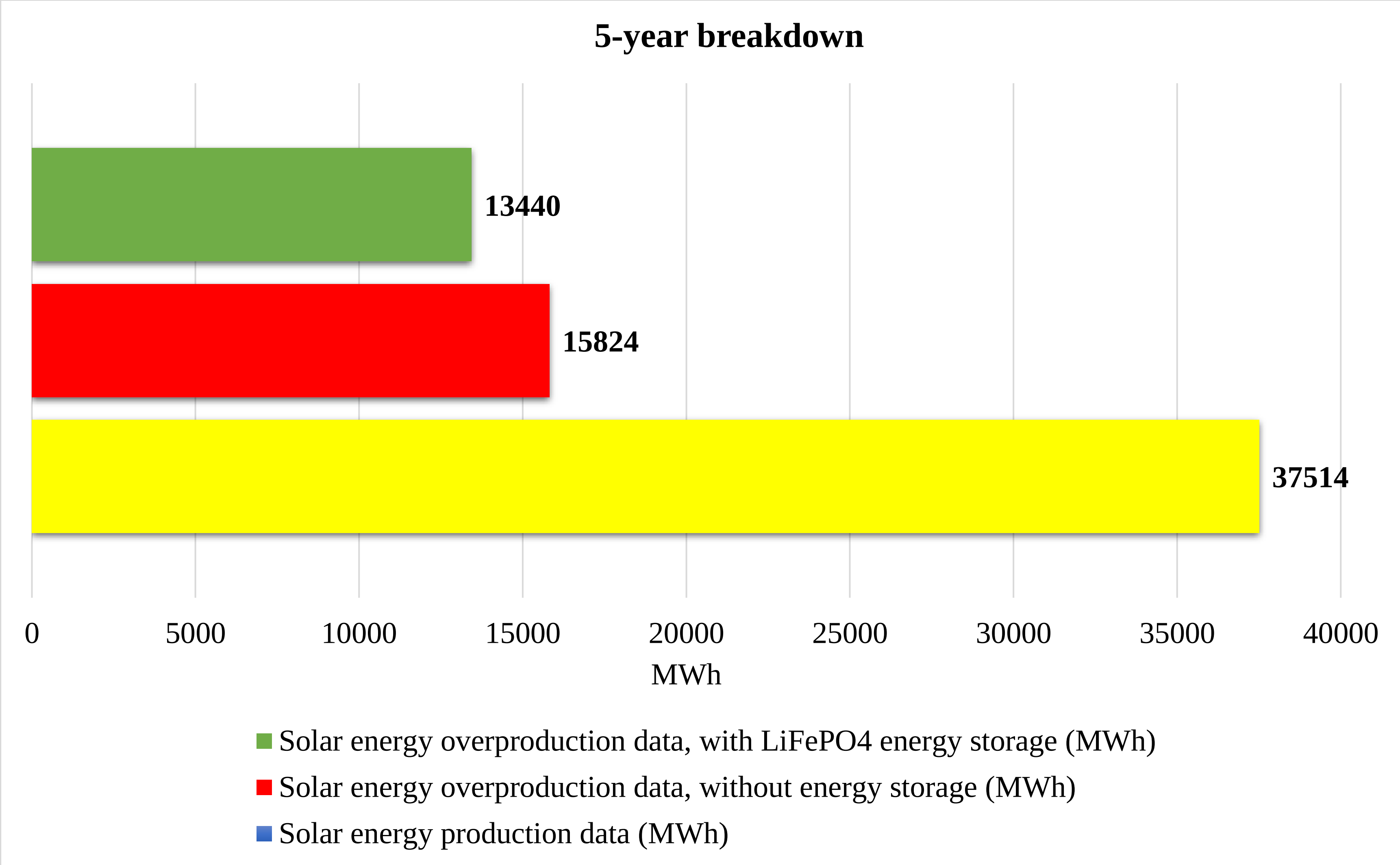

Figure 8. LiFePO4 model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 1

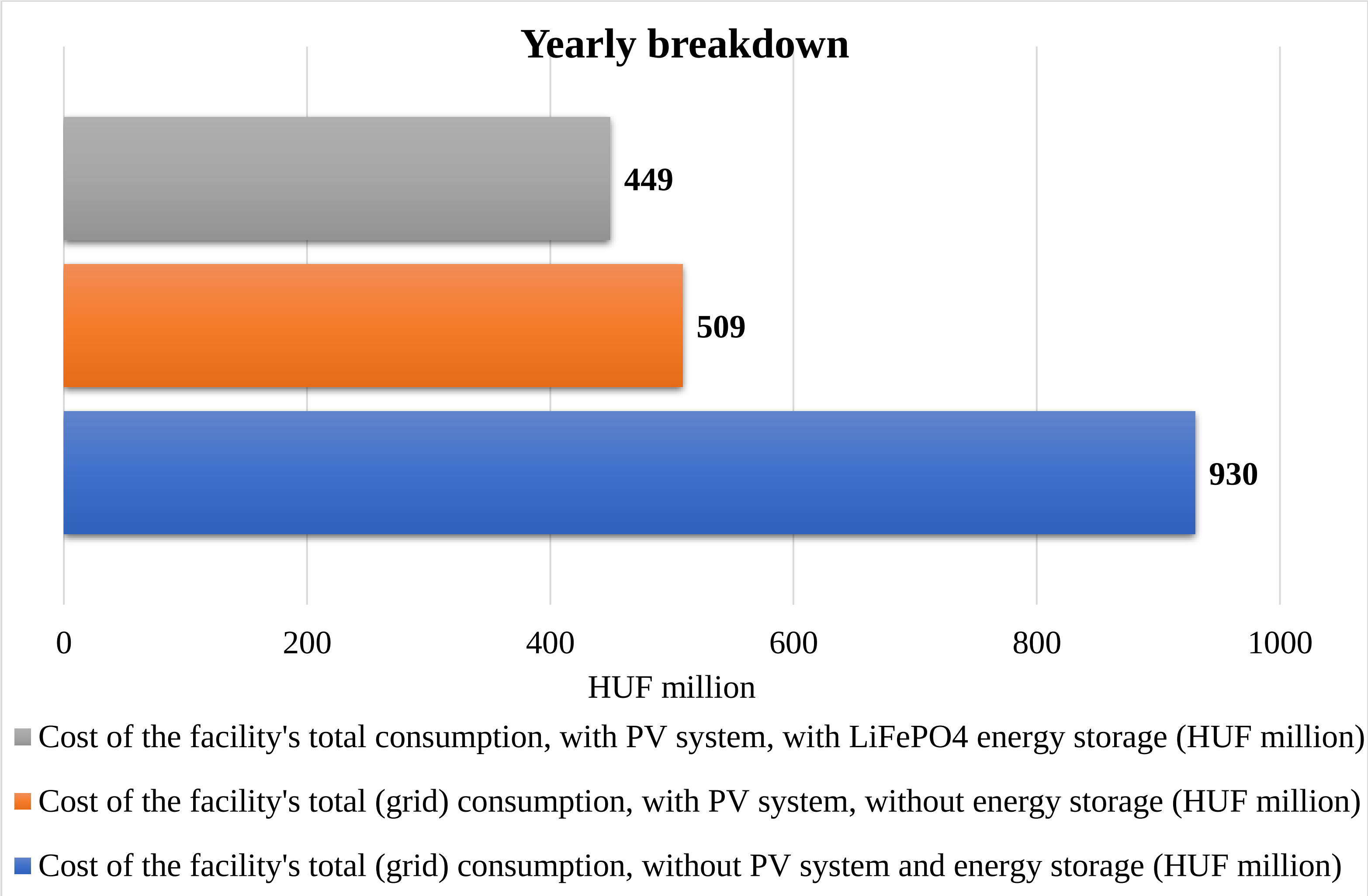

Figure 9. LiFePO4 model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 1

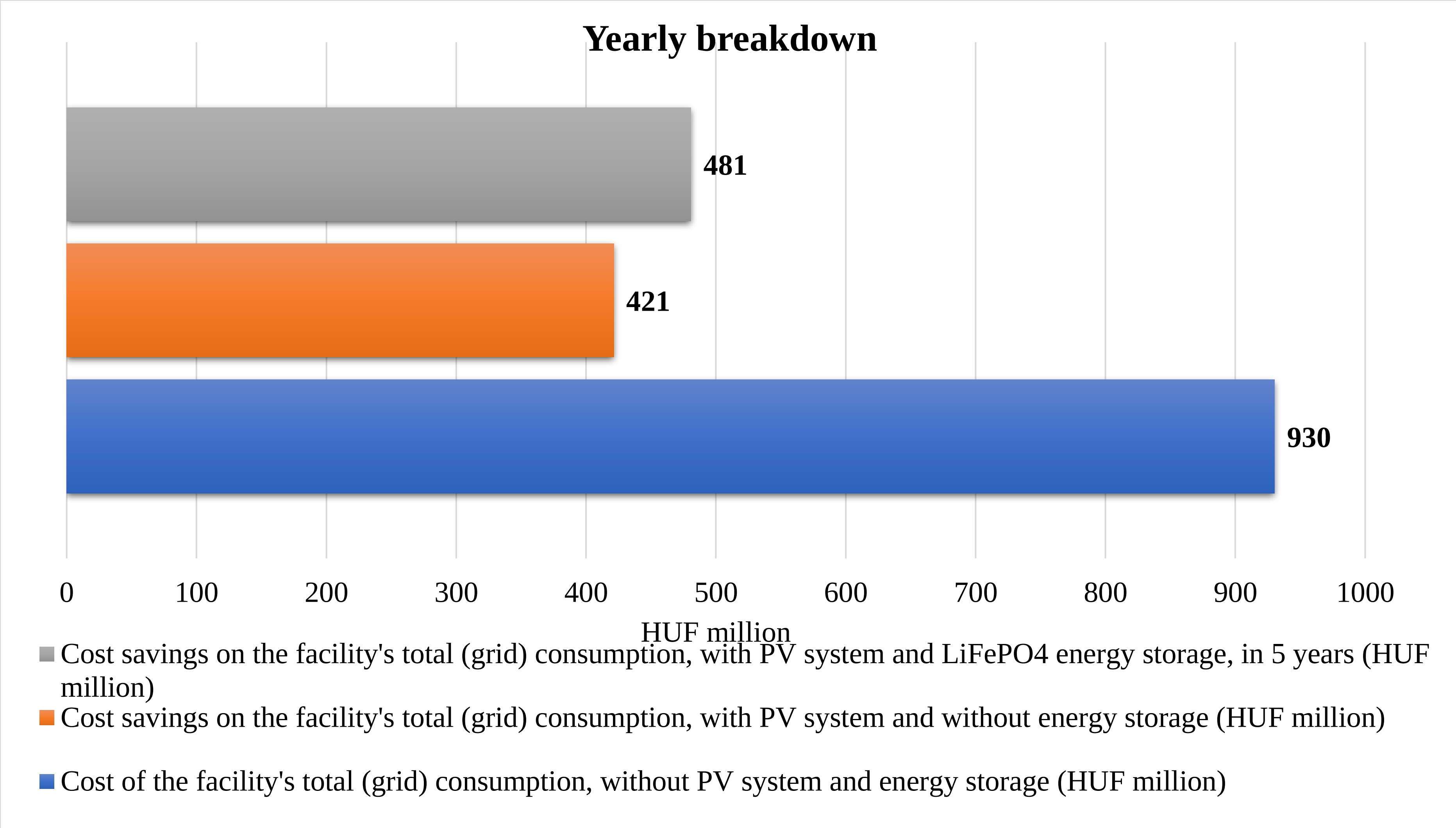

Figure 10. LiFePO4 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 1

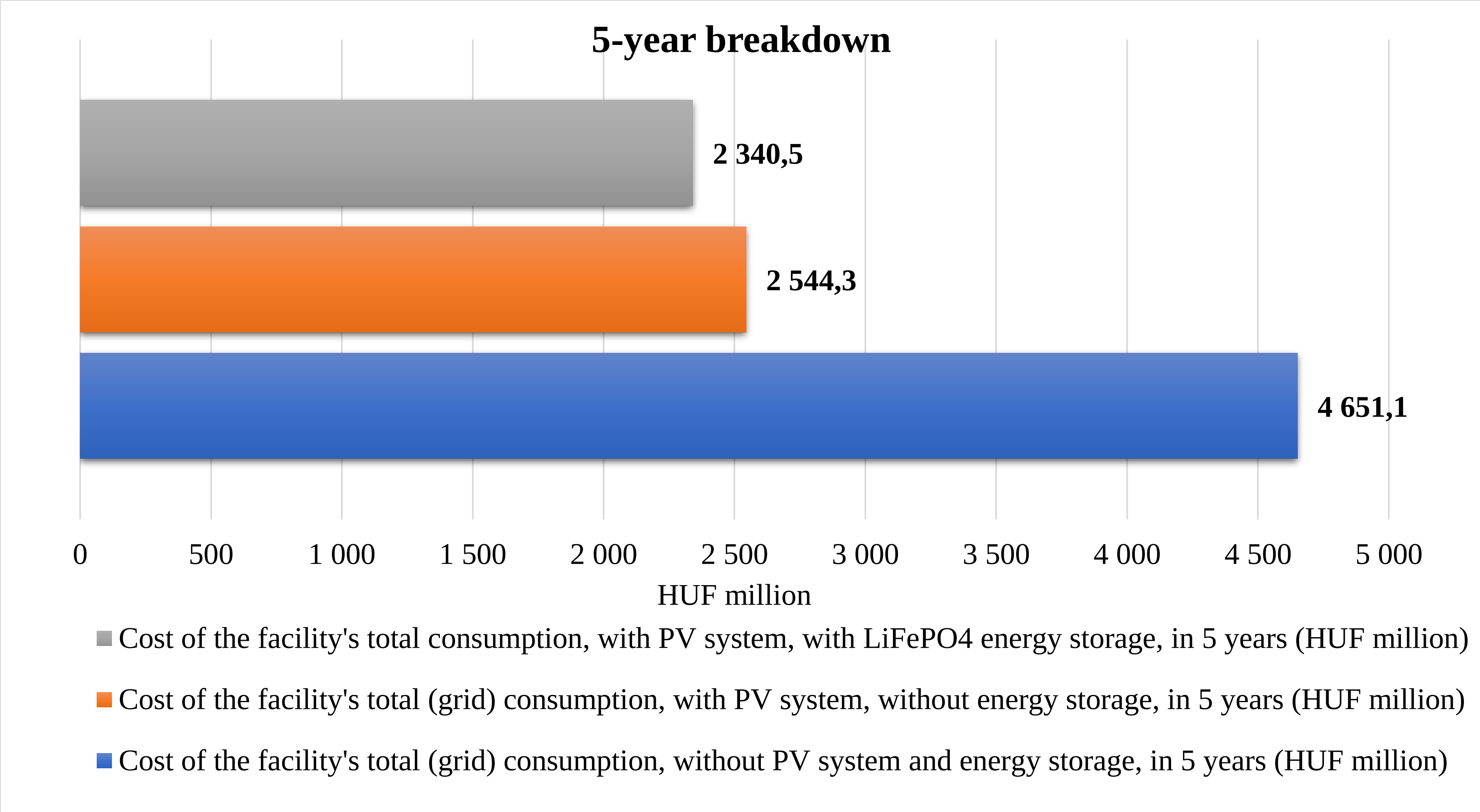

Figure 11. LiFePO4 model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 1

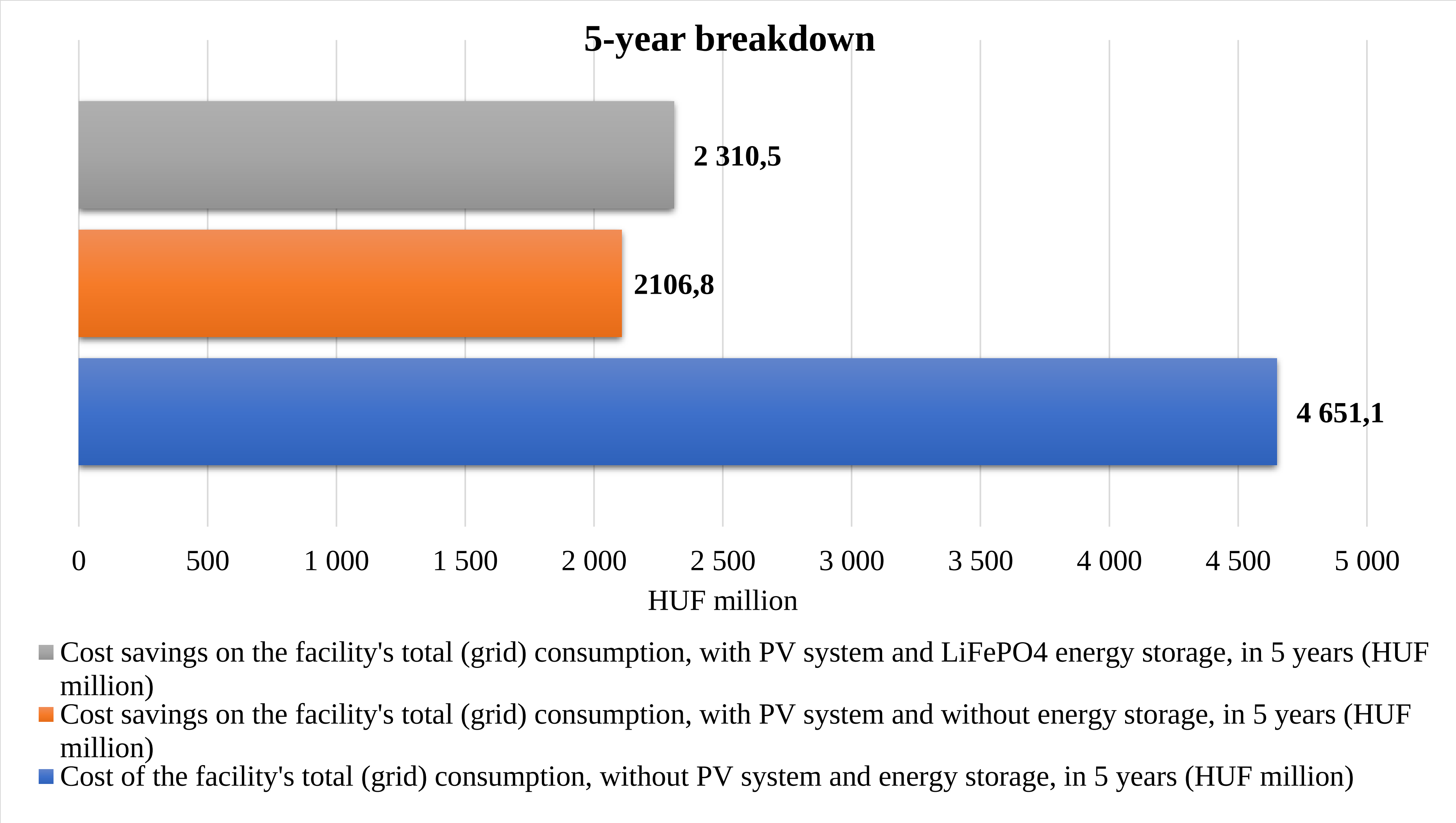

Figure 12. LiFePO4 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 1

3.2. LiFePO4, Scenario 2

Table 4. LiFePO4 model-based energy efficiency analysis, Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system, with LiFePO4 energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with LiFePO4 energy storage (MWh)	Discharge demand of the LiFePO4 battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	392	252	68	1	59	9
February	661	438	345	360	138	32	93	14
March	695	388	240	620	313	144	148	22
April	669	330	174	722	383	206	156	24
May	868	394	233	877	404	221	161	24
June	1010	425	279	979	394	228	146	22
July	1118	470	308	1027	380	196	162	25
August	1136	572	435	918	354	198	137	21
September	802	444	311	642	284	133	133	20
October	714	417	278	566	270	111	139	21
November	622	423	332	322	123	19	91	14
December	648	485	439	219	56	3	47	7
Q1	1991	1278	977	1232	519	177	301	46
Q2	2546	1149	686	2578	1181	654	463	70
Q3	3055	1486	1054	2587	1018	527	432	65
Q4	1984	1325	1048	1107	448	133	277	42
1 year	9577	5239	3766	7503	3165	1491	1473	223
5 years	47885	26195	19460	37514	15824	8171	6735	1116

Table 5. LiFePO4 model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system, with LiFePO4 energy storage (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)
January	100%	71%	65%	100%	27%	10%
February	100%	66%	60%	100%	38%	24%
March	100%	56%	48%	100%	50%	41%
April	100%	49%	40%	100%	53%	44%
May	100%	45%	38%	100%	46%	38%
June	100%	42%	37%	100%	40%	34%
July	100%	42%	37%	100%	37%	30%
August	100%	50%	46%	100%	39%	32%
September	100%	55%	49%	100%	44%	35%
October	100%	58%	50%	100%	48%	35%
November	100%	68%	62%	100%	38%	24%
December	100%	75%	70%	100%	26%	10%
Q1	100%	64%	57%	100%	42%	30%
Q2	100%	45%	38%	100%	46%	38%
Q3	100%	49%	43%	100%	39%	32%
Q4	100%	67%	60%	100%	40%	27%
1 year	100%	55%	48%	100%	42%	33%
5 years	100%	55%	50%	100%	42%	36%

Table 6. LiFePO4 model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 2

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system, with LiFePO4 energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, with LiFePO4 energy storage, in 5 years (HUF million)	Cost saving on the LiFePO4 energy storage system (HUF million)
January	62	44	40	18	22	4
February	64	43	38	22	26	4
March	68	38	33	30	35	5
April	65	32	26	33	39	6
May	84	38	32	46	52	6
June	98	41	36	57	62	5
July	109	46	40	63	69	6
August	110	56	50	55	60	5
September	78	43	38	35	40	5
October	69	41	34	29	35	6
November	60	41	37	19	23	4
December	63	47	44	16	19	3
Q1	193	124	111	69	82	13
Q2	247	112	94	136	153	17
Q3	297	144	128	152	169	16
Q4	193	129	116	64	77	13
1 year	930	509	449	421	481	60
5 years	4651	2544	2341	2107	2311	204

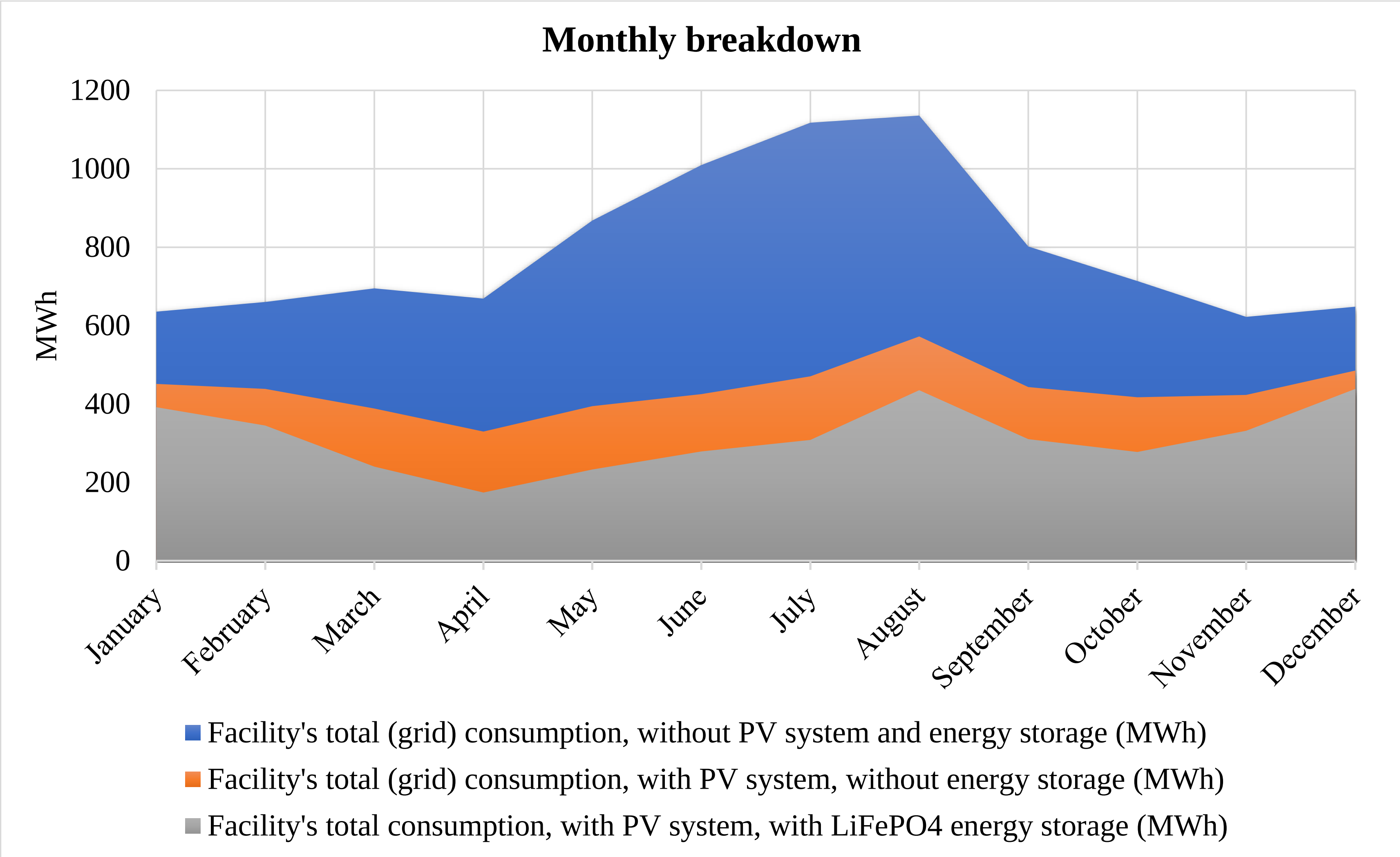

Figure 13. LiFePO4 model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 2

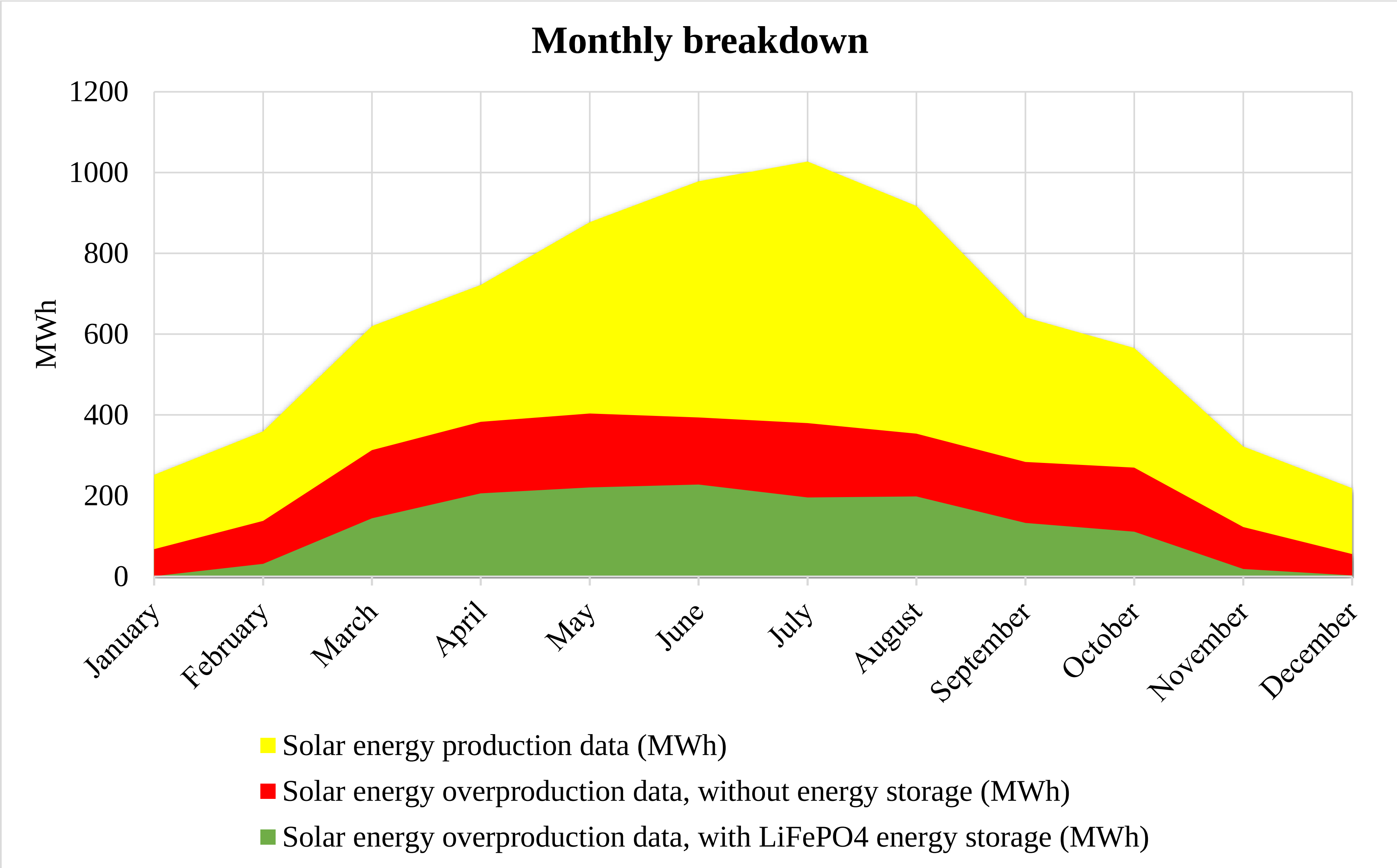

Figure 14. LiFePO4 model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 2

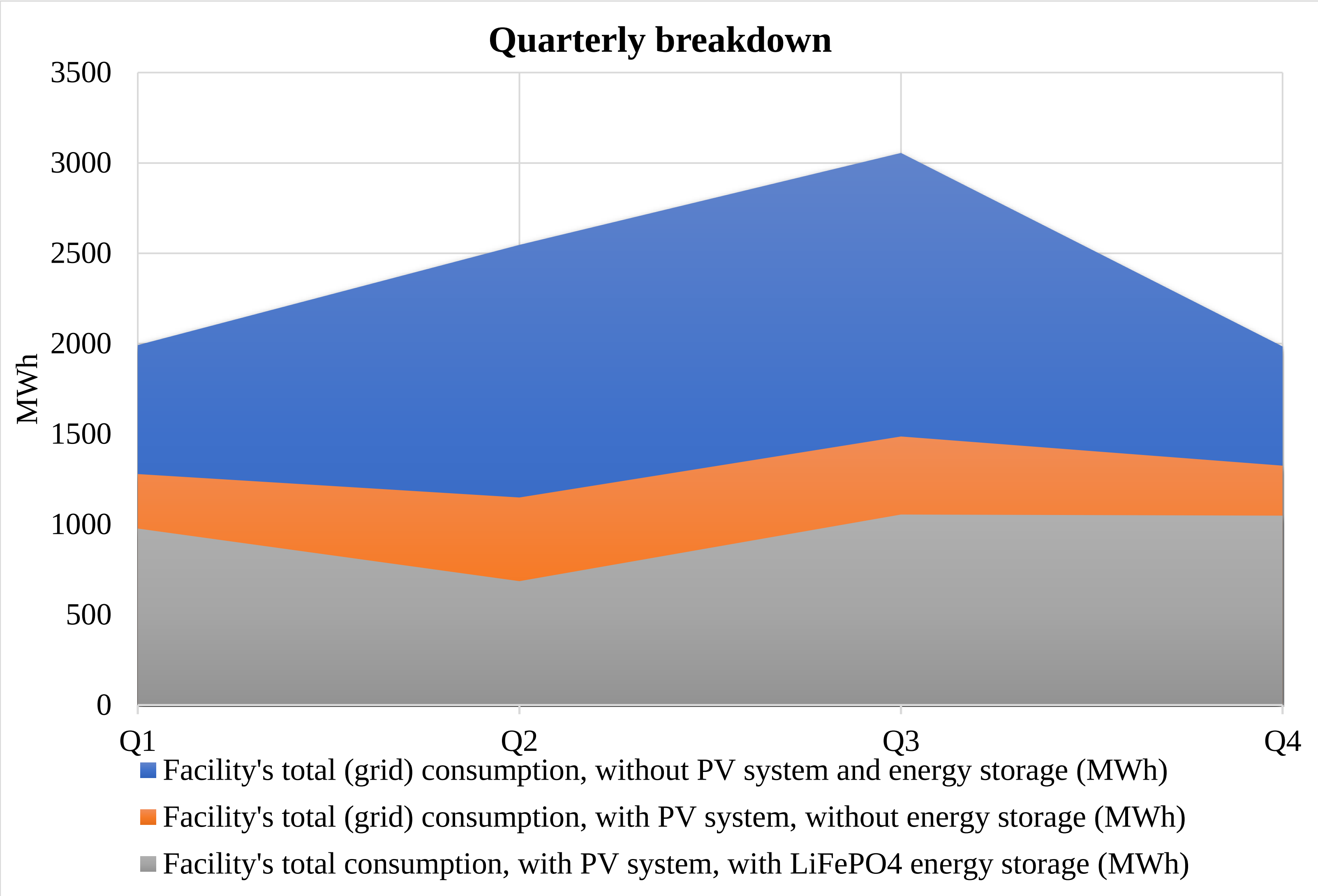

Figure 15. LiFePO4 model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 2

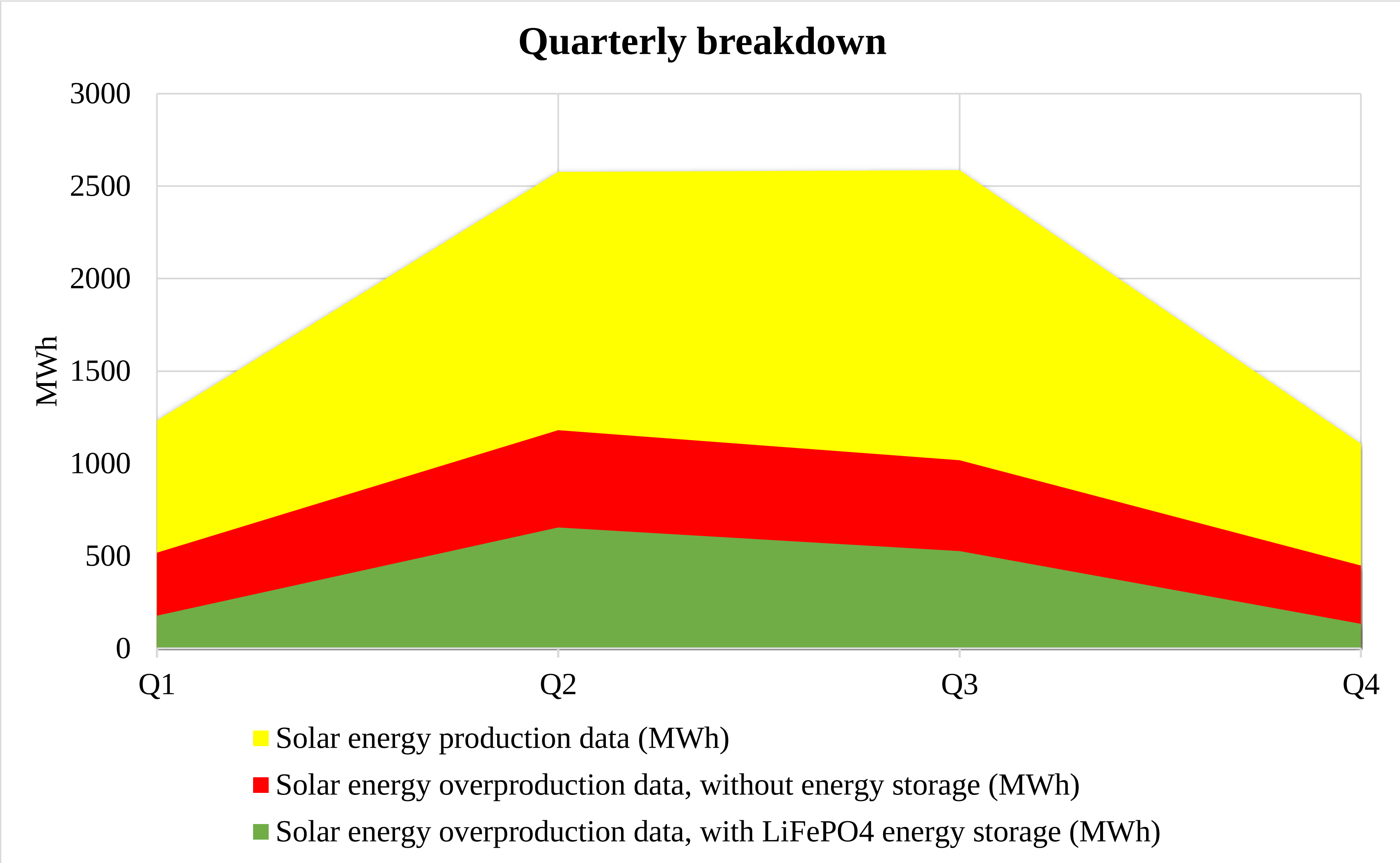

Figure 16. LiFePO4 model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 2

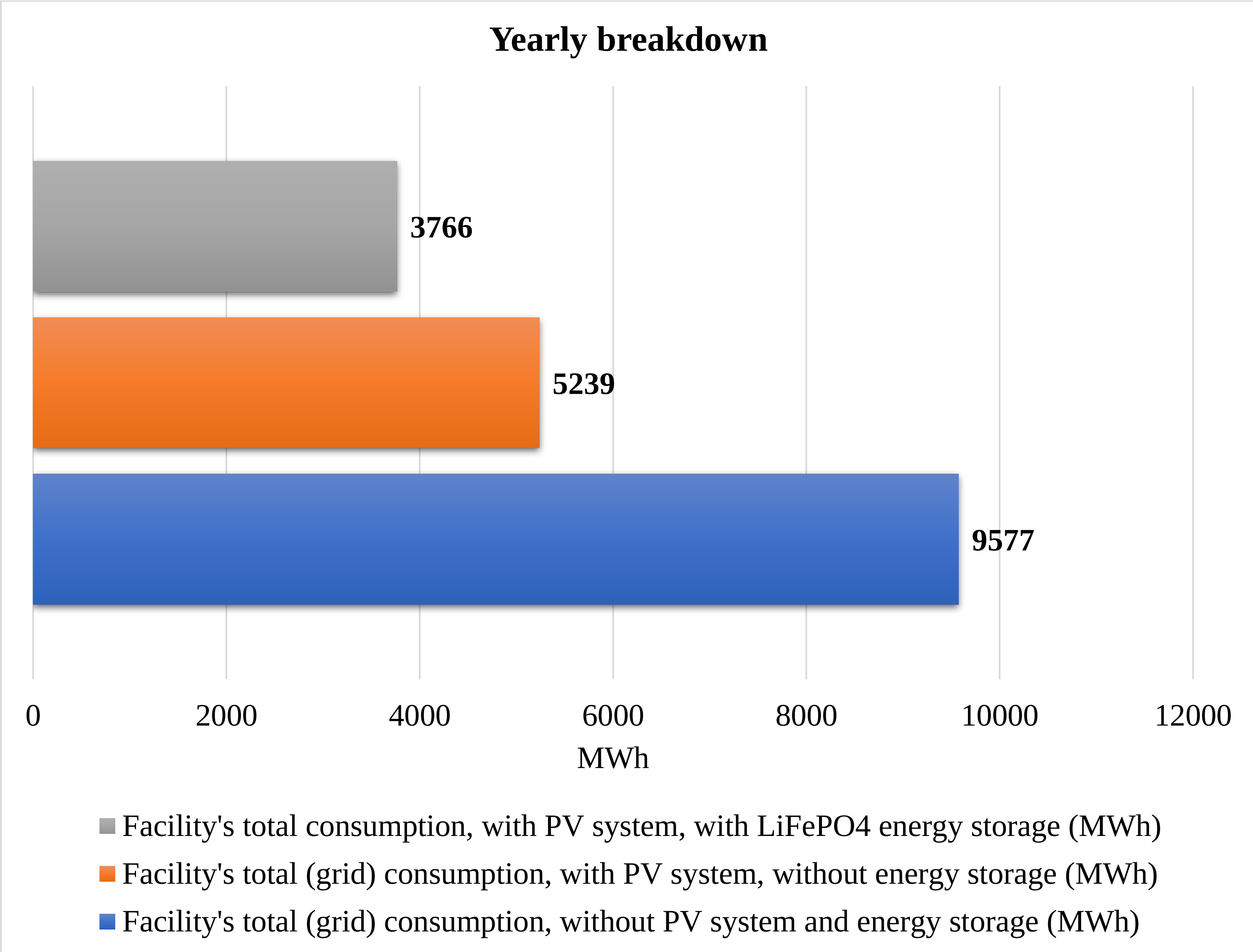

Figure 17. LiFePO4 model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 2

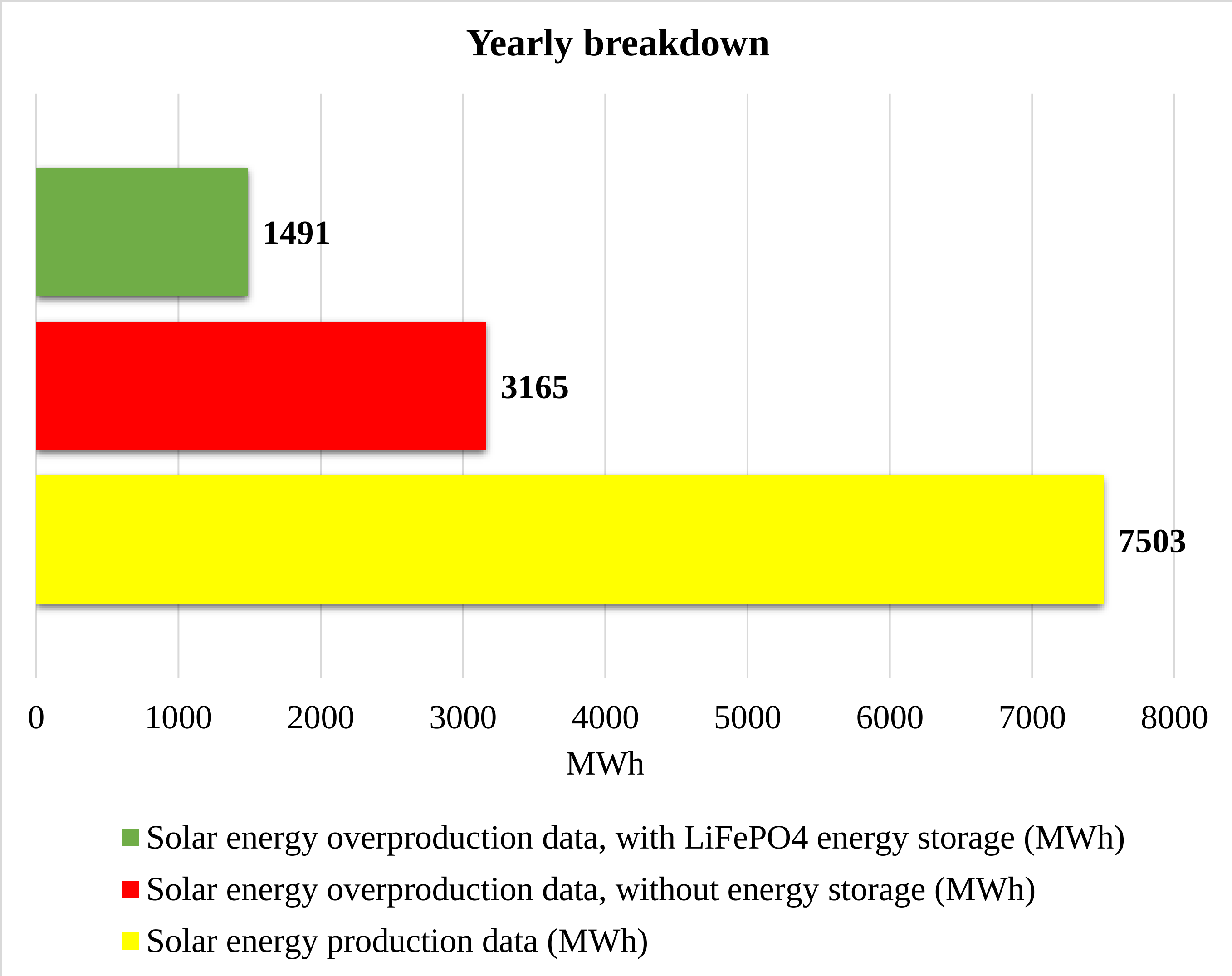

Figure 18. LiFePO4 model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 2

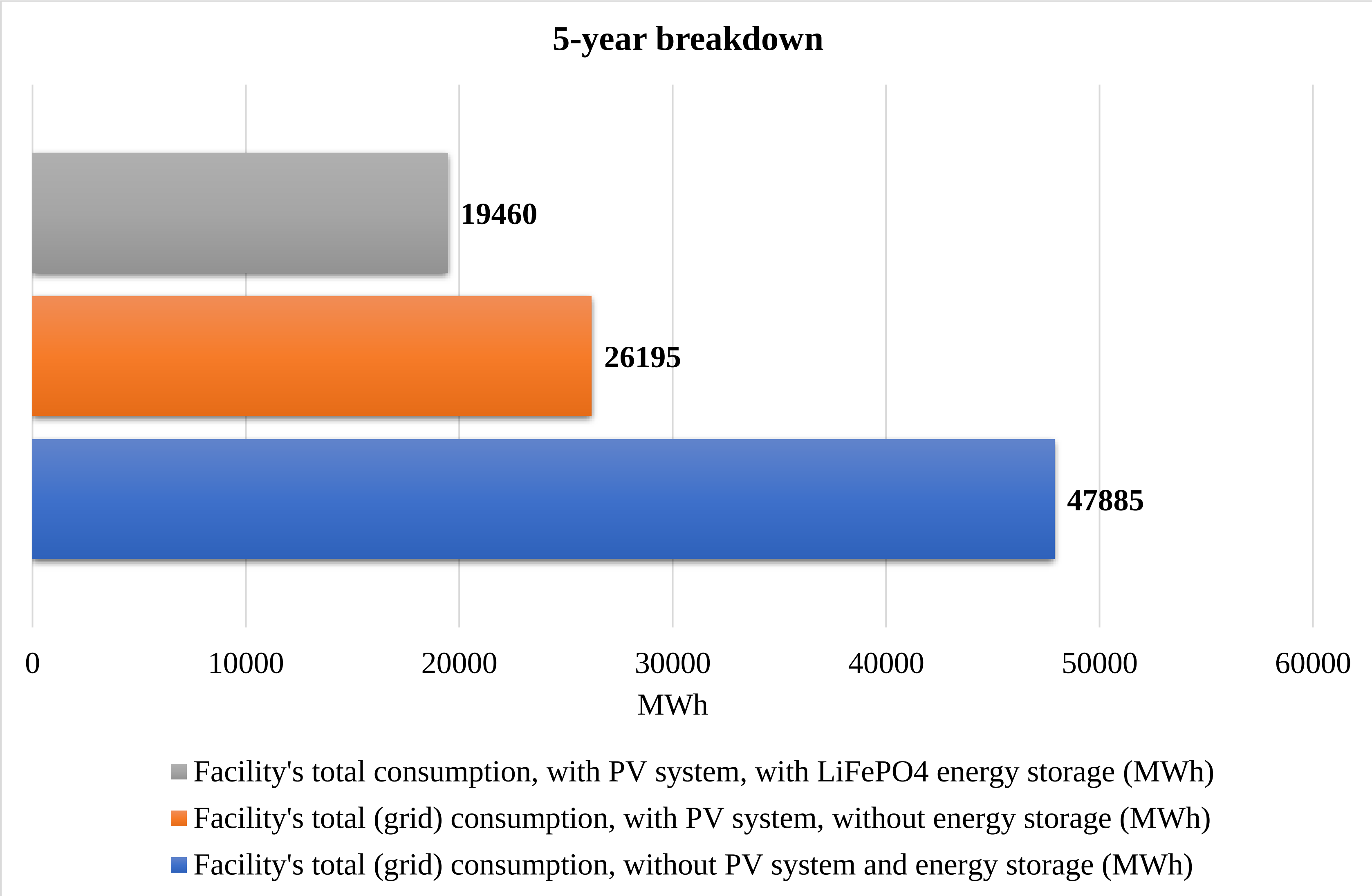

Figure 19. LiFePO4 model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 2

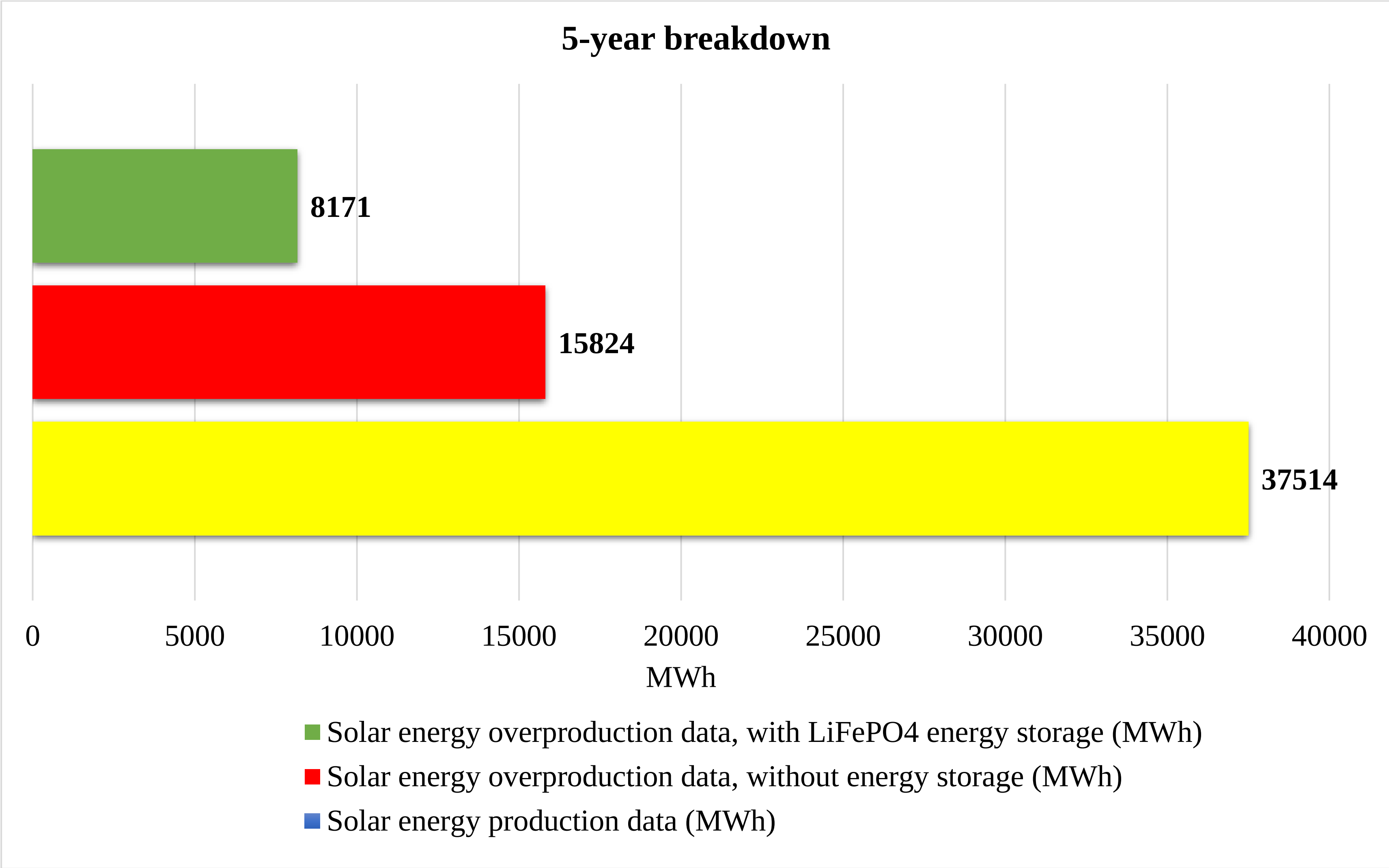

Figure 20. LiFePO4 model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 2

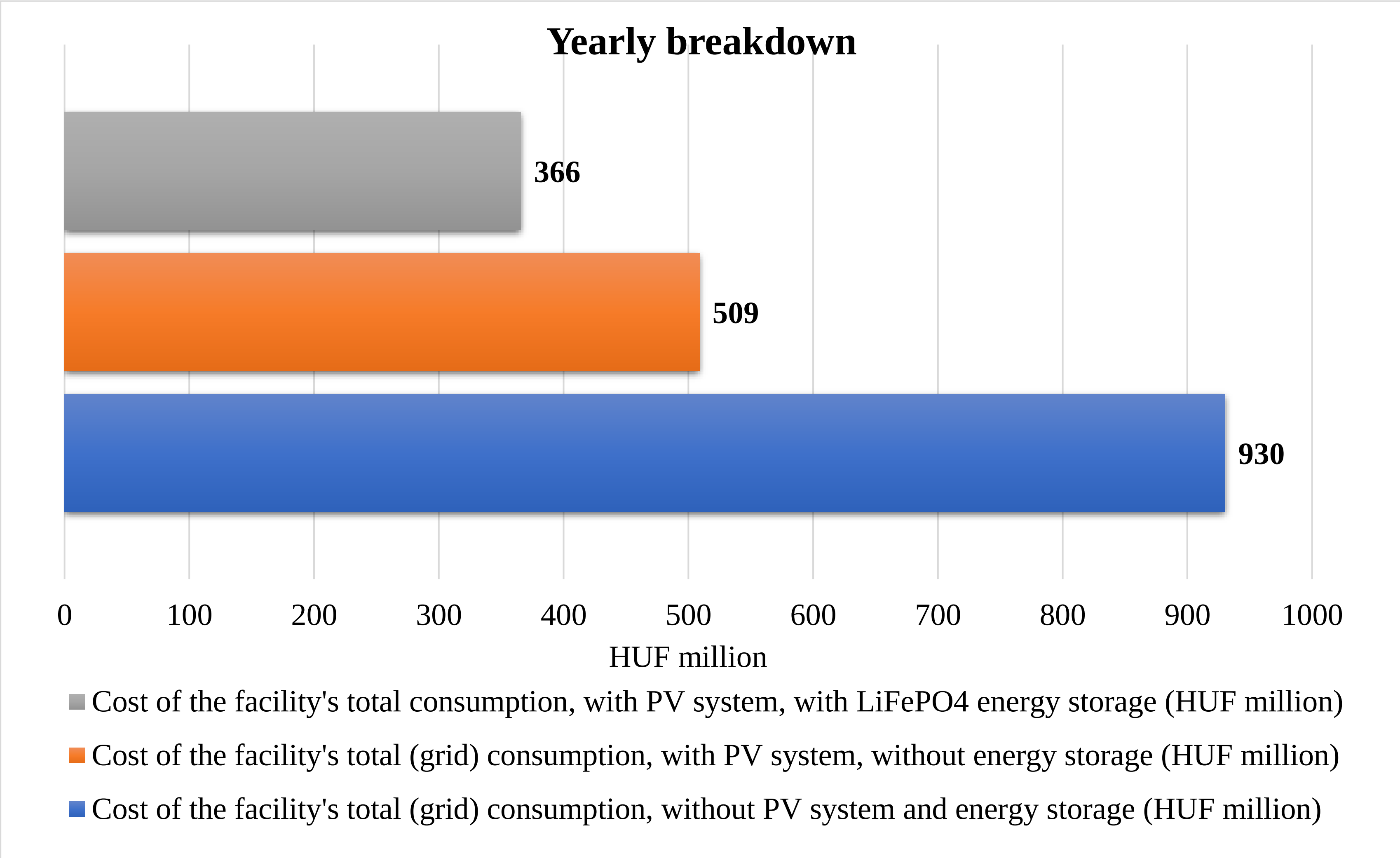

Figure 21. LiFePO4 model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 2

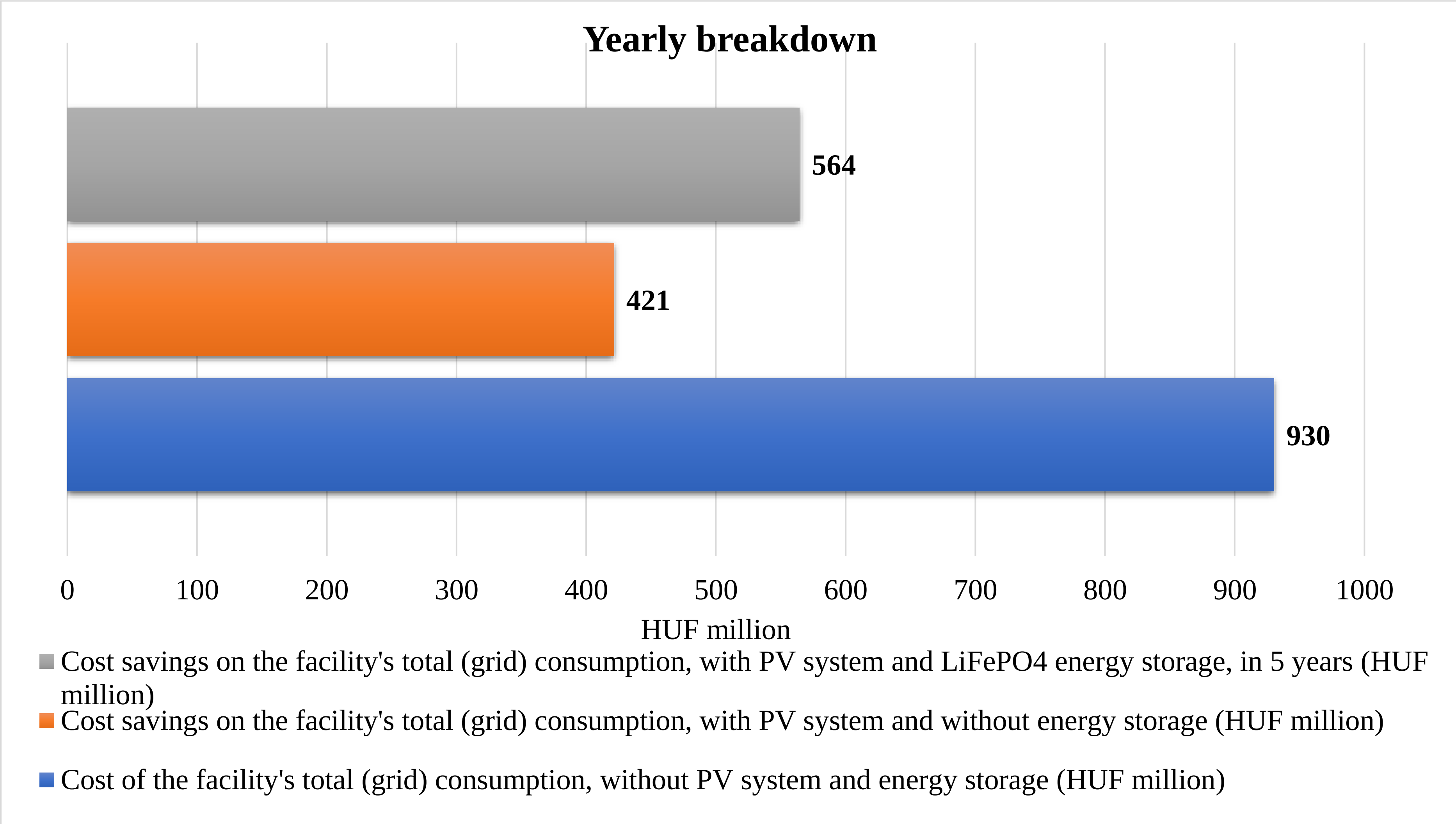

Figure 22. LiFePO4 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 2

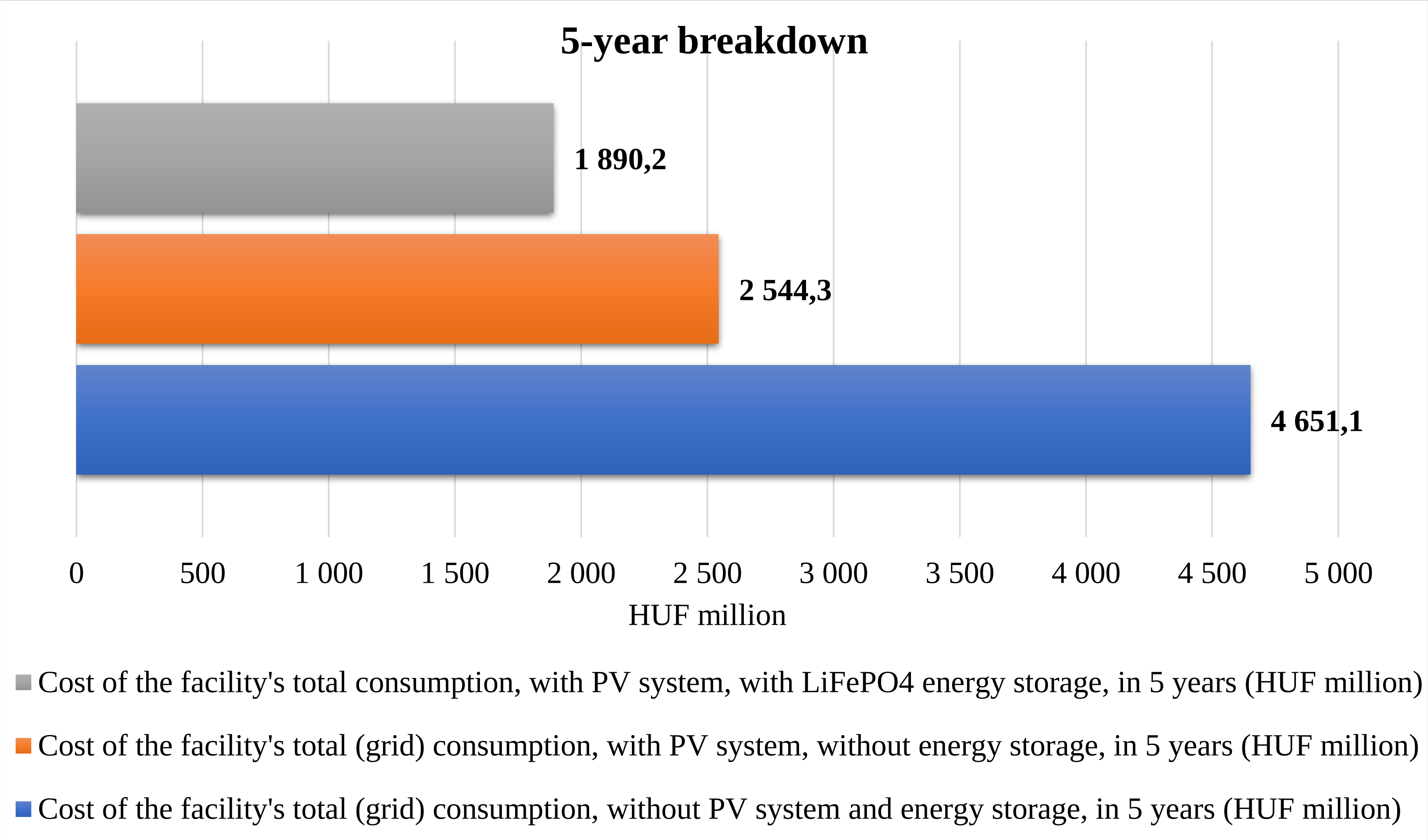

Figure 23. LiFePO4 model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 2

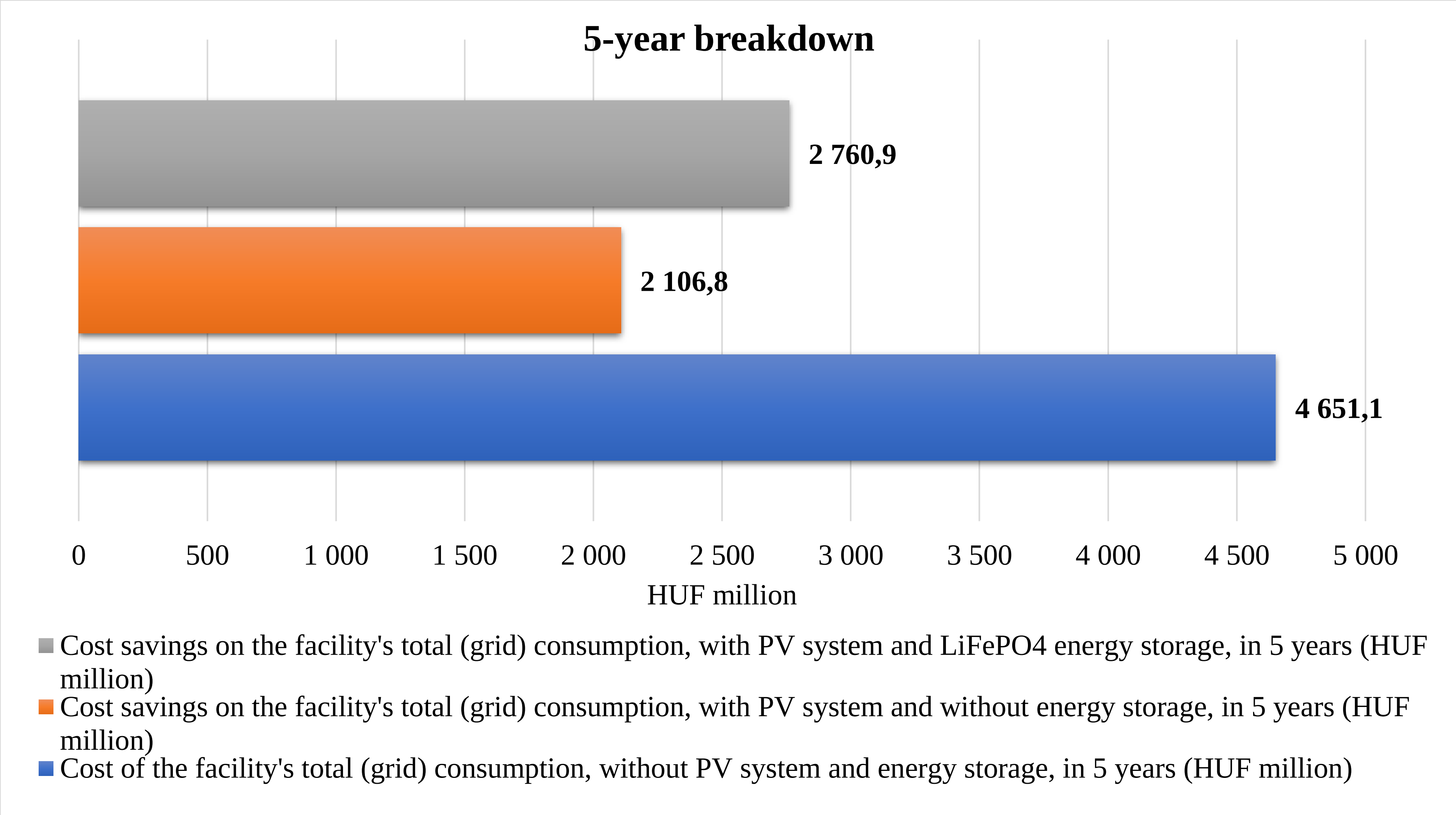

Figure 24. LiFePO4 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 2

3.3. Li-ion, Scenario 1

Table 7. Li-ion model-based energy efficiency analysis, Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with Li-ion energy storage (MWh)	Discharge demand of the Li-ion battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	414	252	68	25	37	17
February	661	438	395	360	138	87	44	20
March	695	388	335	620	313	251	54	24
April	669	330	270	722	383	314	60	27
May	868	394	331	877	404	331	63	29
June	1010	425	370	979	394	330	55	25
July	1118	470	409	1027	380	310	61	28
August	1136	572	518	918	354	291	55	25
September	802	444	391	642	284	224	52	24
October	714	417	355	566	270	198	62	28
November	622	423	384	322	123	77	39	18
December	648	485	455	219	56	22	30	14
Q1	1991	1278	1143	1232	519	364	135	61
Q2	2546	1149	971	2578	1181	976	178	81
Q3	3055	1486	1319	2587	1018	825	168	76
Q4	1984	1325	1194	1107	448	297	132	60
1 year	9577	5239	4626	7503	3165	2461	612	278
5 years	47885	26195	24097	37514	15824	13413	2097	1392

Table 8. Li-ion model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, Li-ion with energy storage (MWh)
January	100%	71%	65%	100%	27%	10%
February	100%	66%	60%	100%	38%	24%
March	100%	56%	48%	100%	50%	41%
April	100%	49%	40%	100%	53%	44%
May	100%	45%	38%	100%	46%	38%
June	100%	42%	37%	100%	40%	34%
July	100%	42%	37%	100%	37%	30%
August	100%	50%	46%	100%	39%	32%
September	100%	55%	49%	100%	44%	35%
October	100%	58%	50%	100%	48%	35%
November	100%	68%	62%	100%	38%	24%
December	100%	75%	70%	100%	26%	10%
Q1	100%	64%	57%	100%	42%	30%
Q2	100%	45%	38%	100%	46%	38%
Q3	100%	49%	43%	100%	39%	32%
Q4	100%	67%	60%	100%	40%	27%
1 year	100%	55%	48%	100%	42%	33%
5 years	100%	55%	50%	100%	42%	36%

Table 9. Li-ion model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 1

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system and Li-ion energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost saving with the Li-ion energy storage system (HUF million)
January	62	44	40	18	22	4
February	64	43	38	22	26	4
March	68	38	33	30	35	5
April	65	32	26	33	39	6
May	84	38	32	46	52	6
June	98	41	36	57	62	5
July	109	46	40	63	69	6
August	110	56	50	55	60	5
September	78	43	38	35	40	5
October	69	41	34	29	35	6
November	60	41	37	19	23	4
December	63	47	44	16	19	3
Q1	193	124	111	69	82	13
Q2	247	112	94	136	153	17
Q3	297	144	128	152	169	16
Q4	193	129	116	64	77	13
1 year	930	509	449	421	481	60
5 years	4651	2544	2341	2107	2310	204

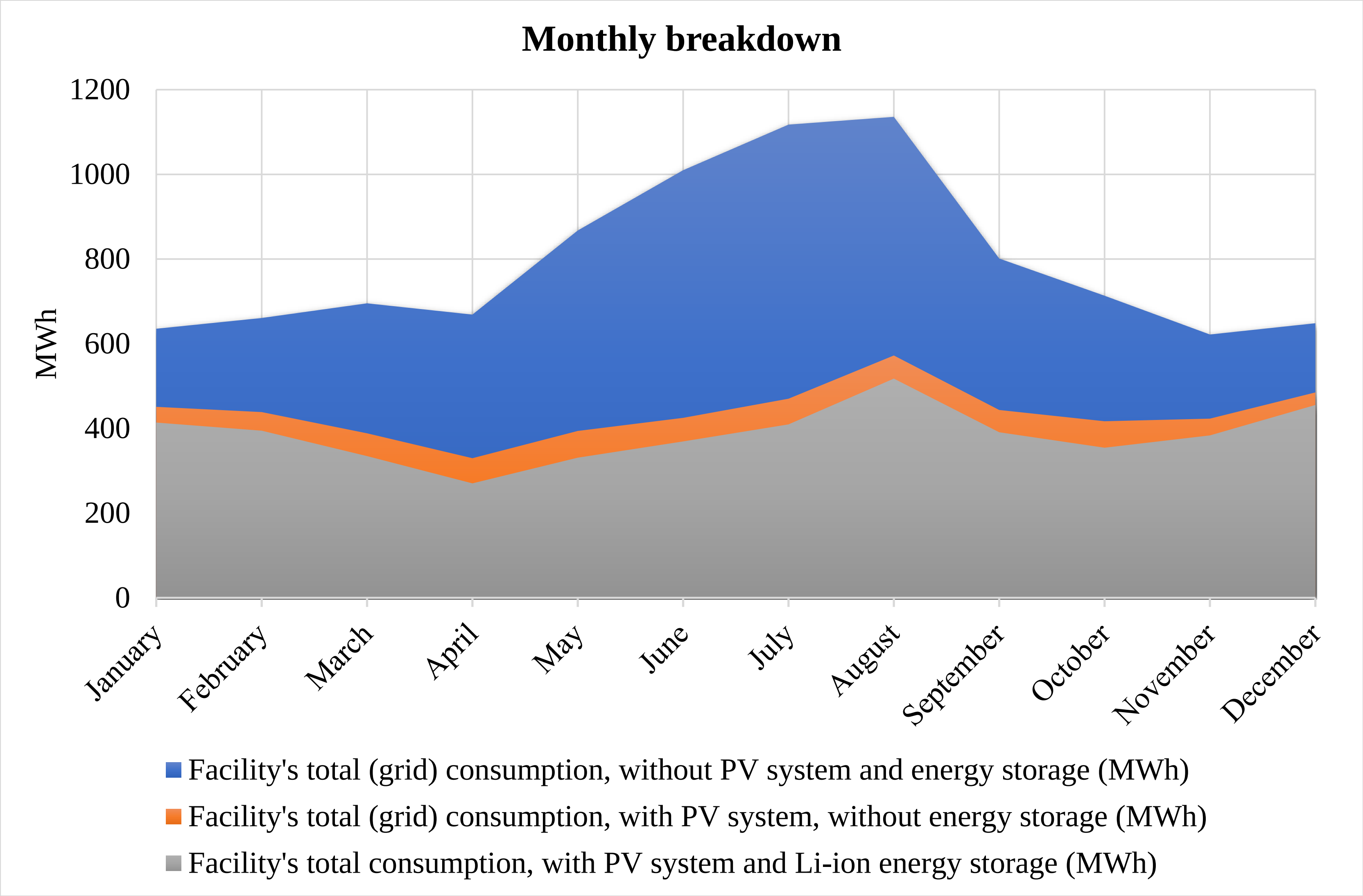

Figure 25. Li-ion model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 1

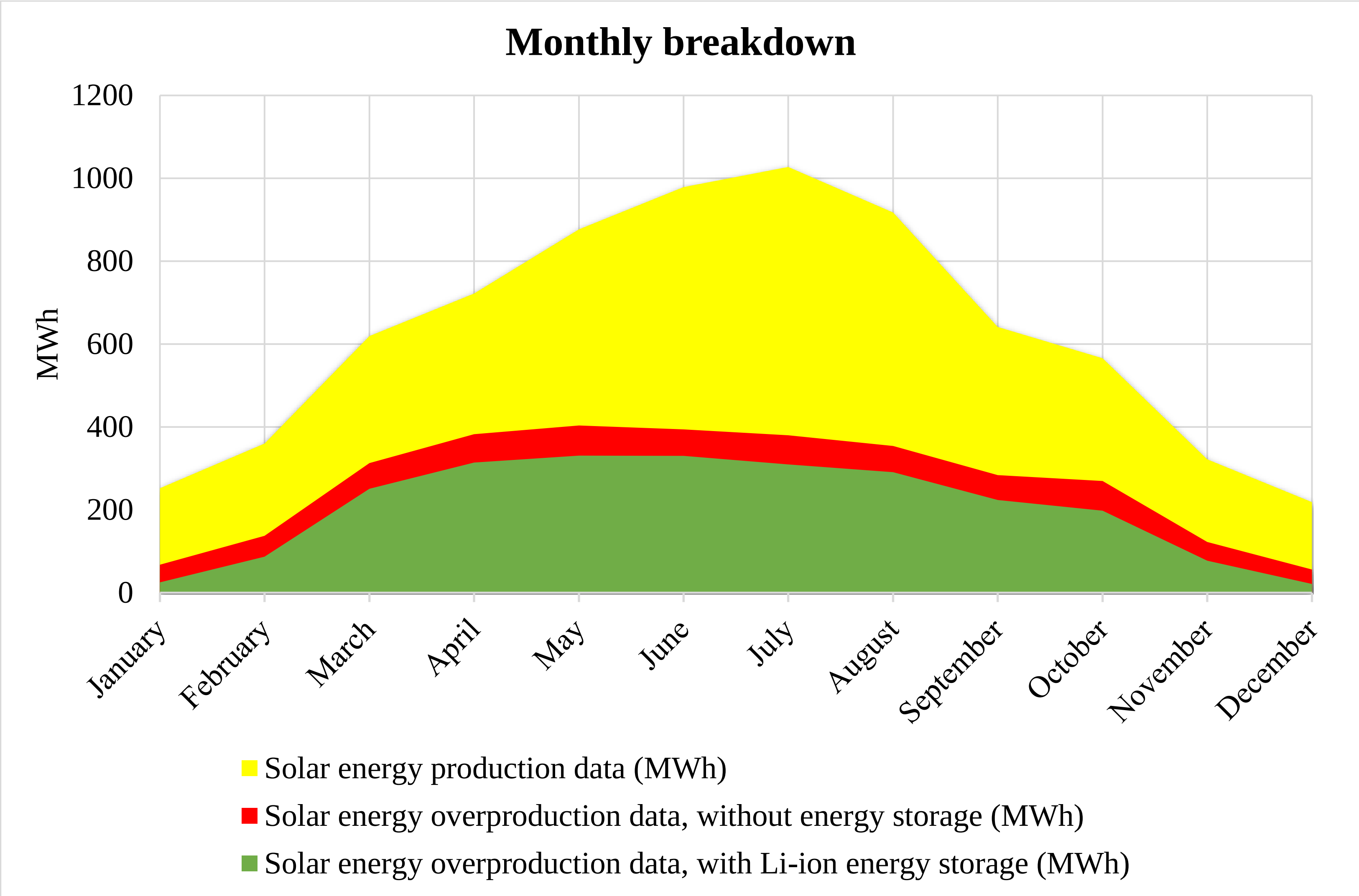

Figure 26. Li-ion model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 1

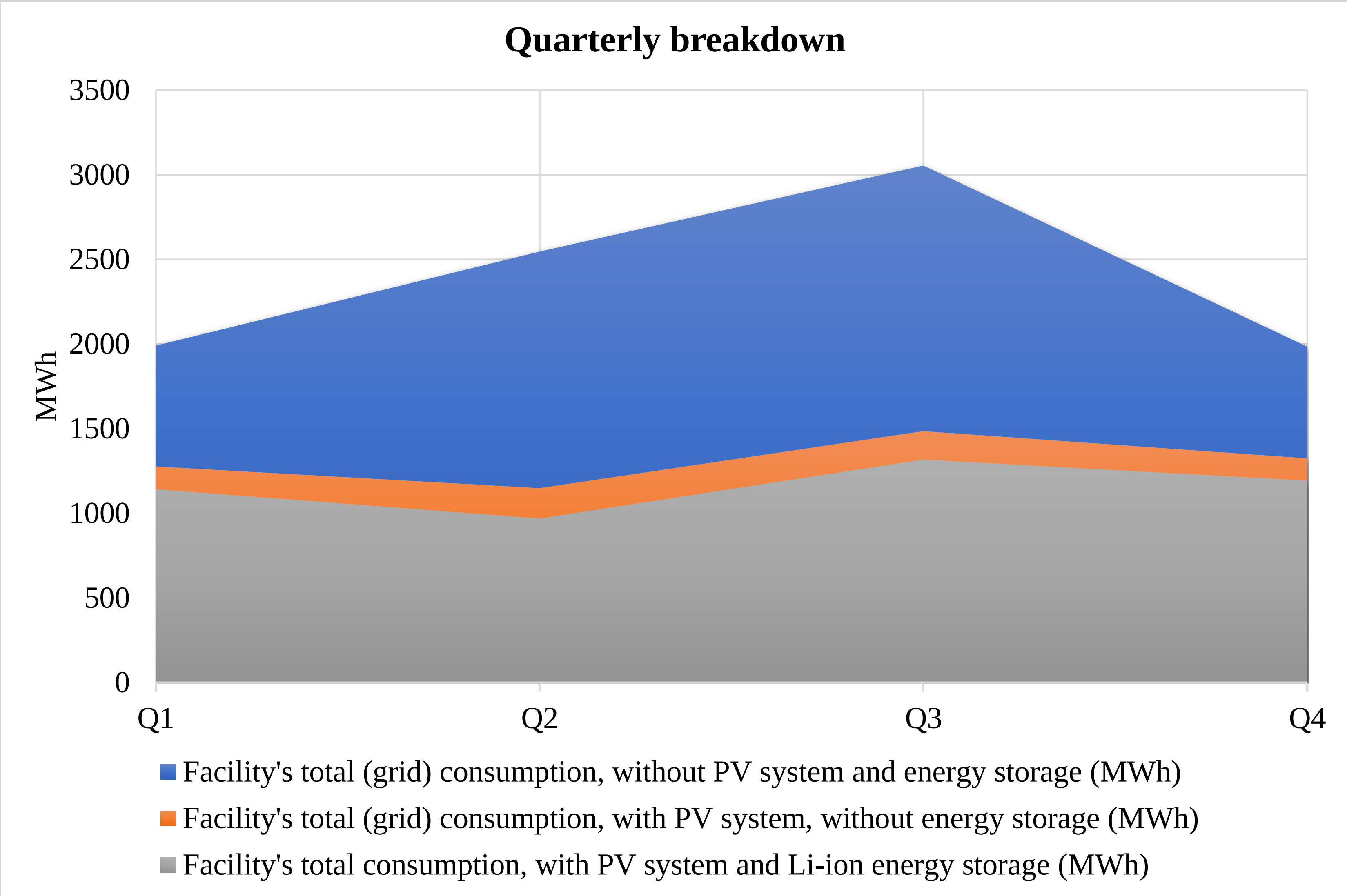

Figure 27. Li-ion model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 1

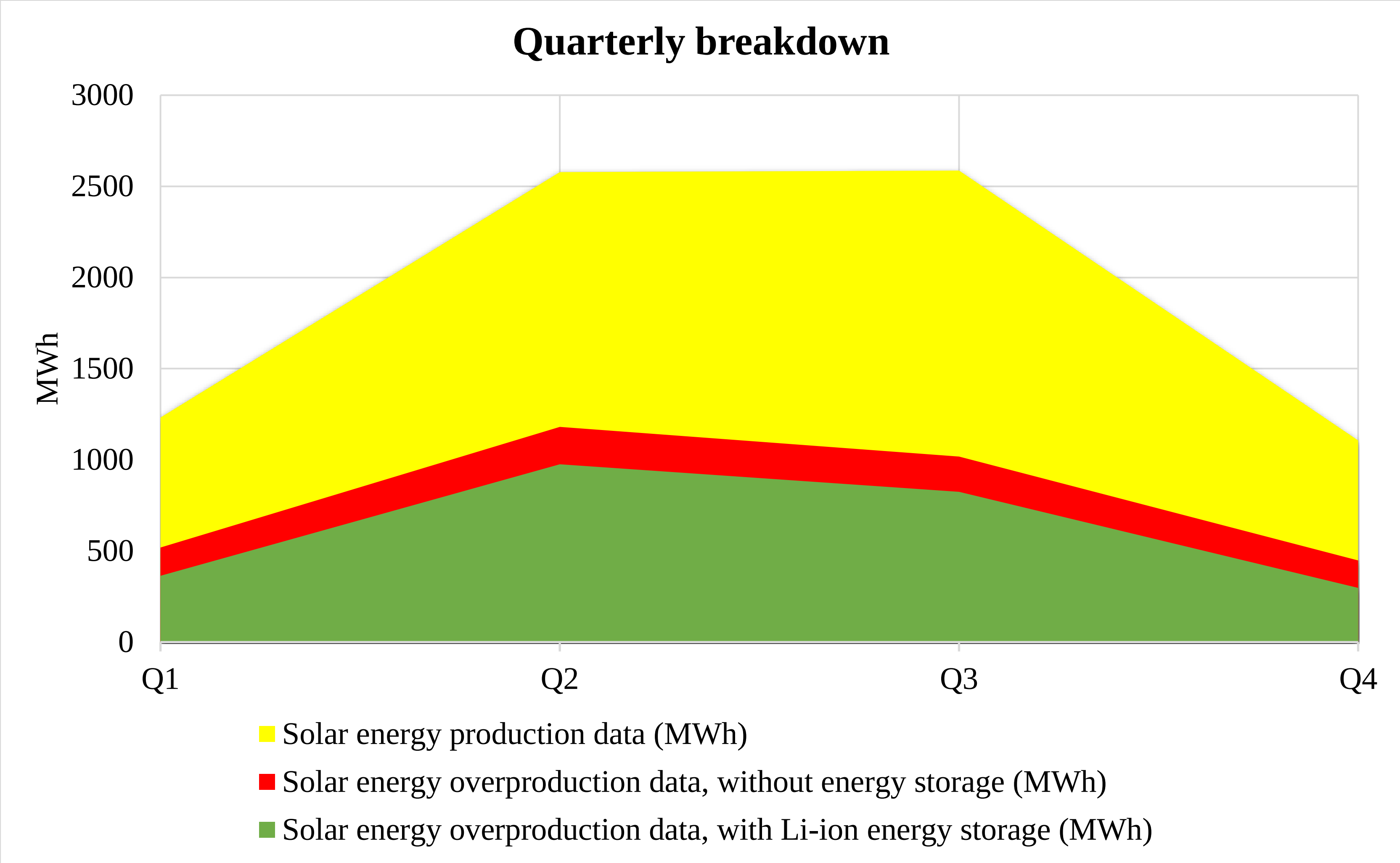

Figure 28. Li-ion model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 1

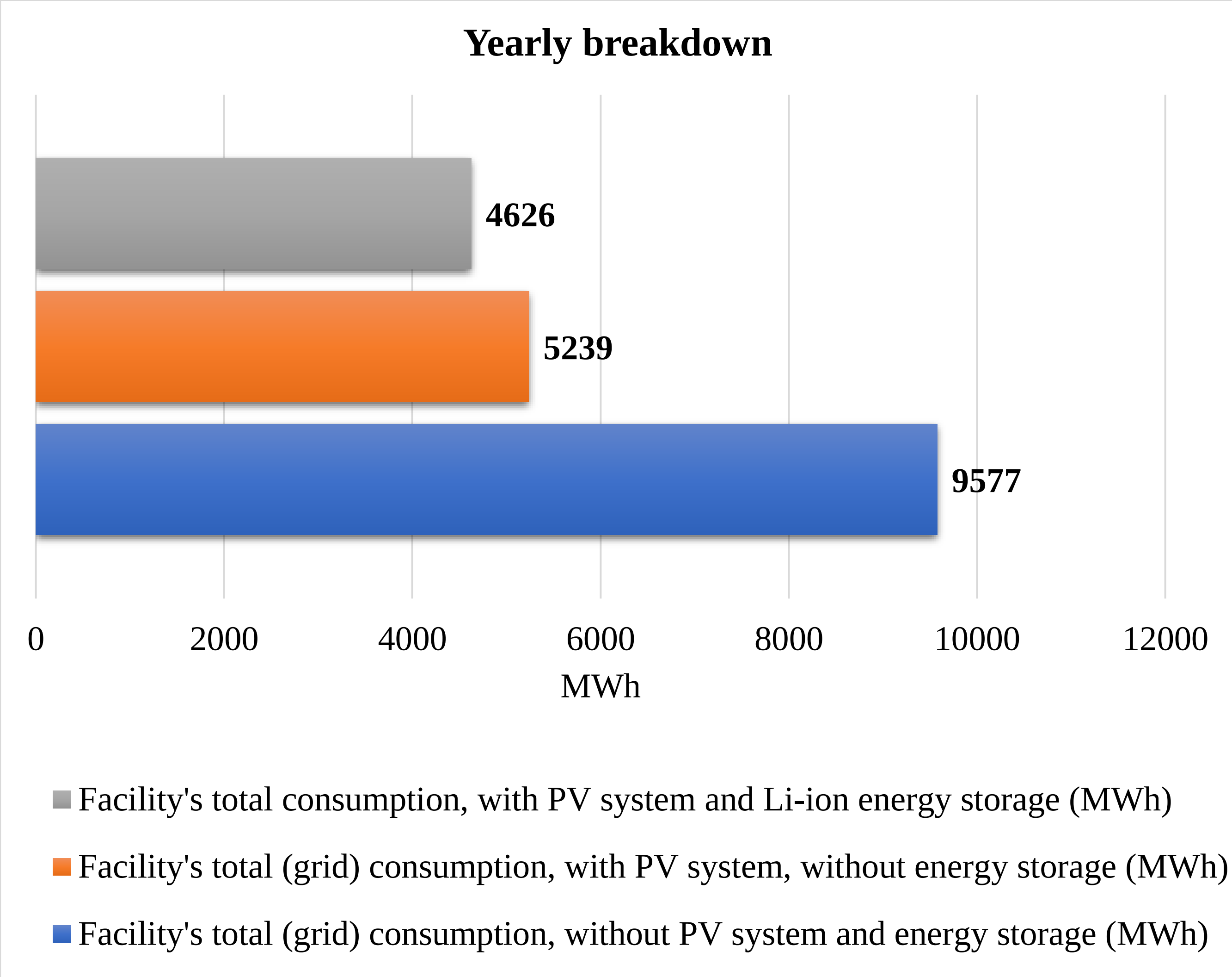

Figure 29. Li-ion model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 1

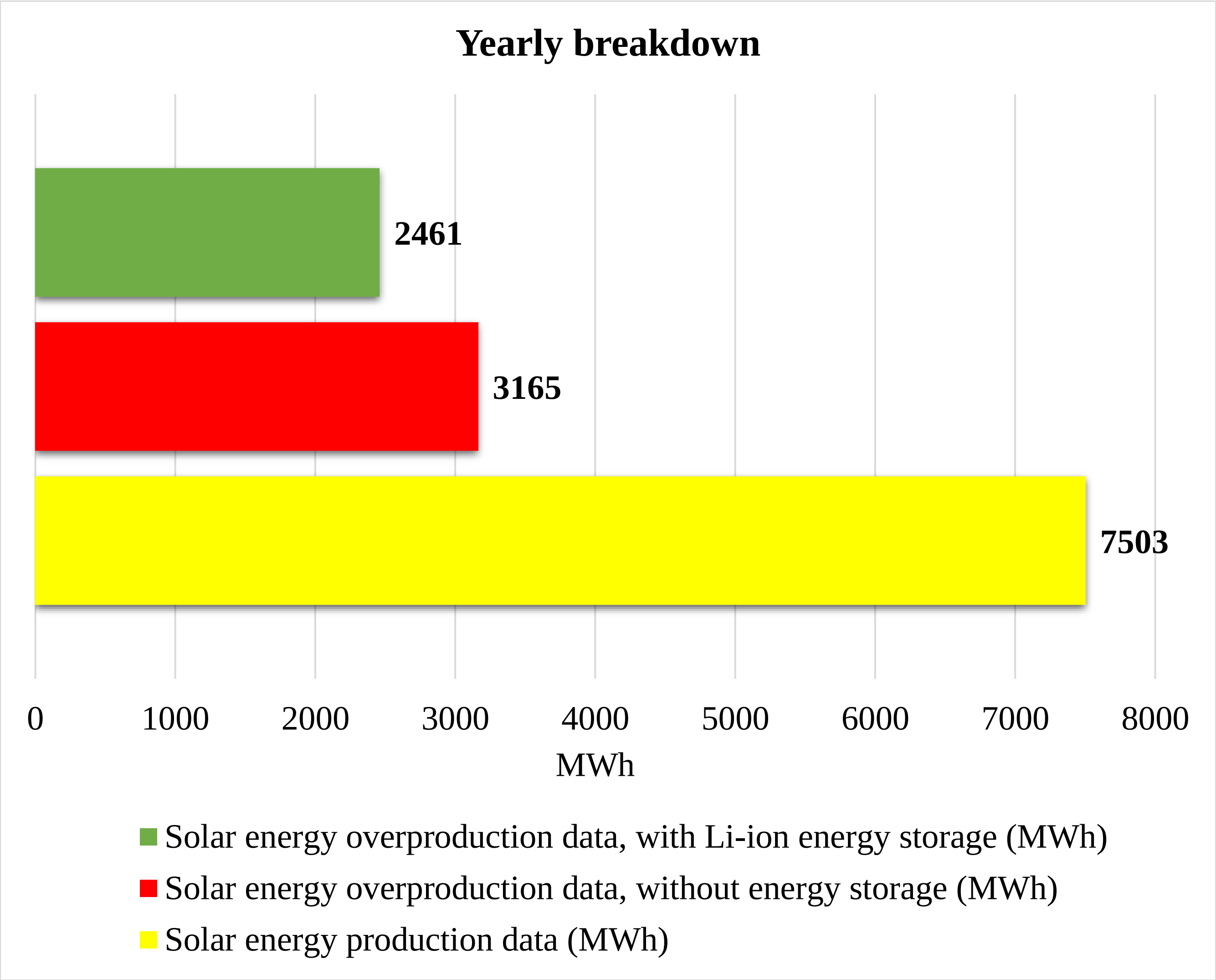

Figure 30. Li-ion model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 1

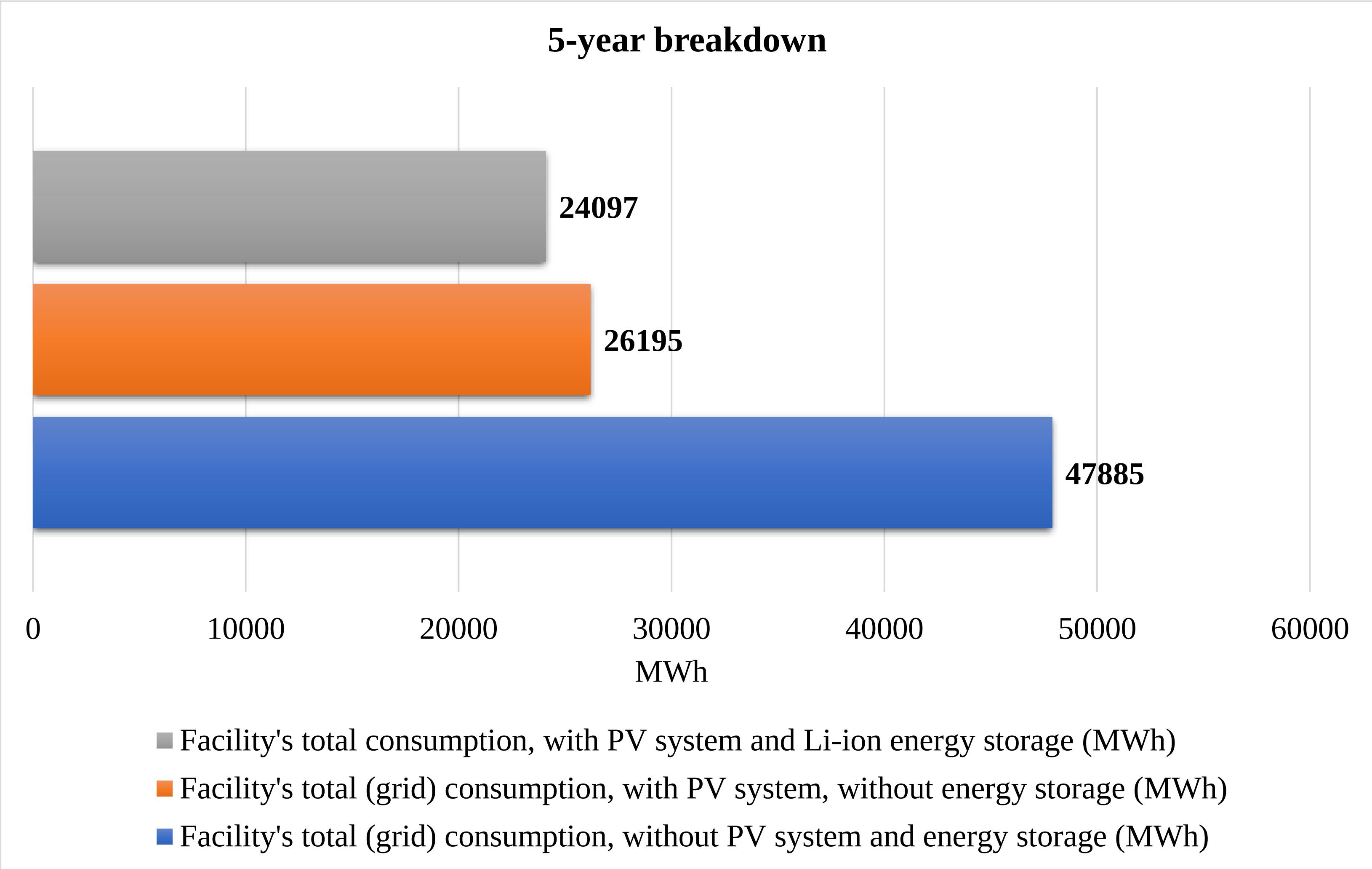

Figure 31. Li-ion model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 1

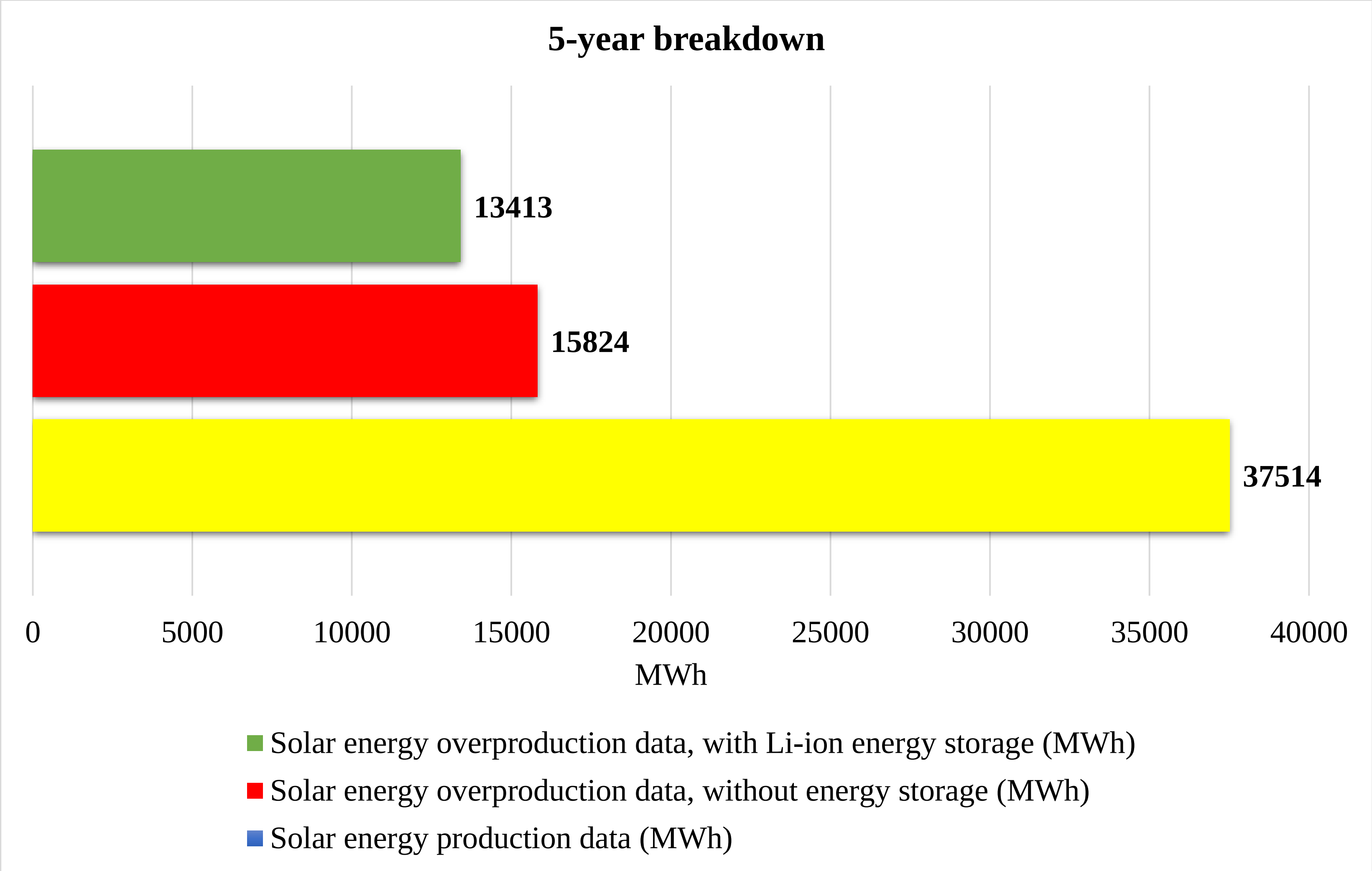

Figure 32. Li-ion model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 1

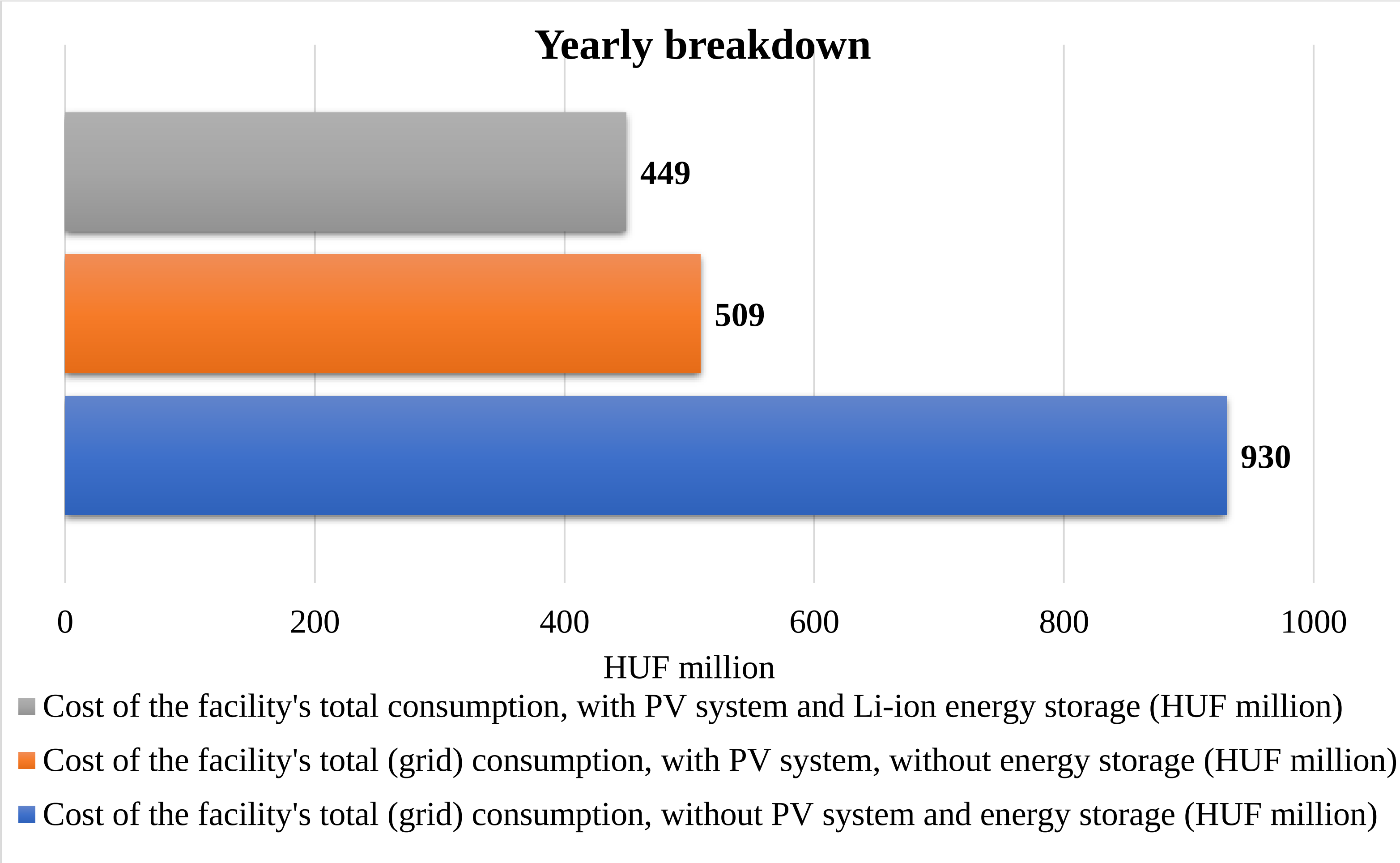

Figure 33. Li-ion model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 1

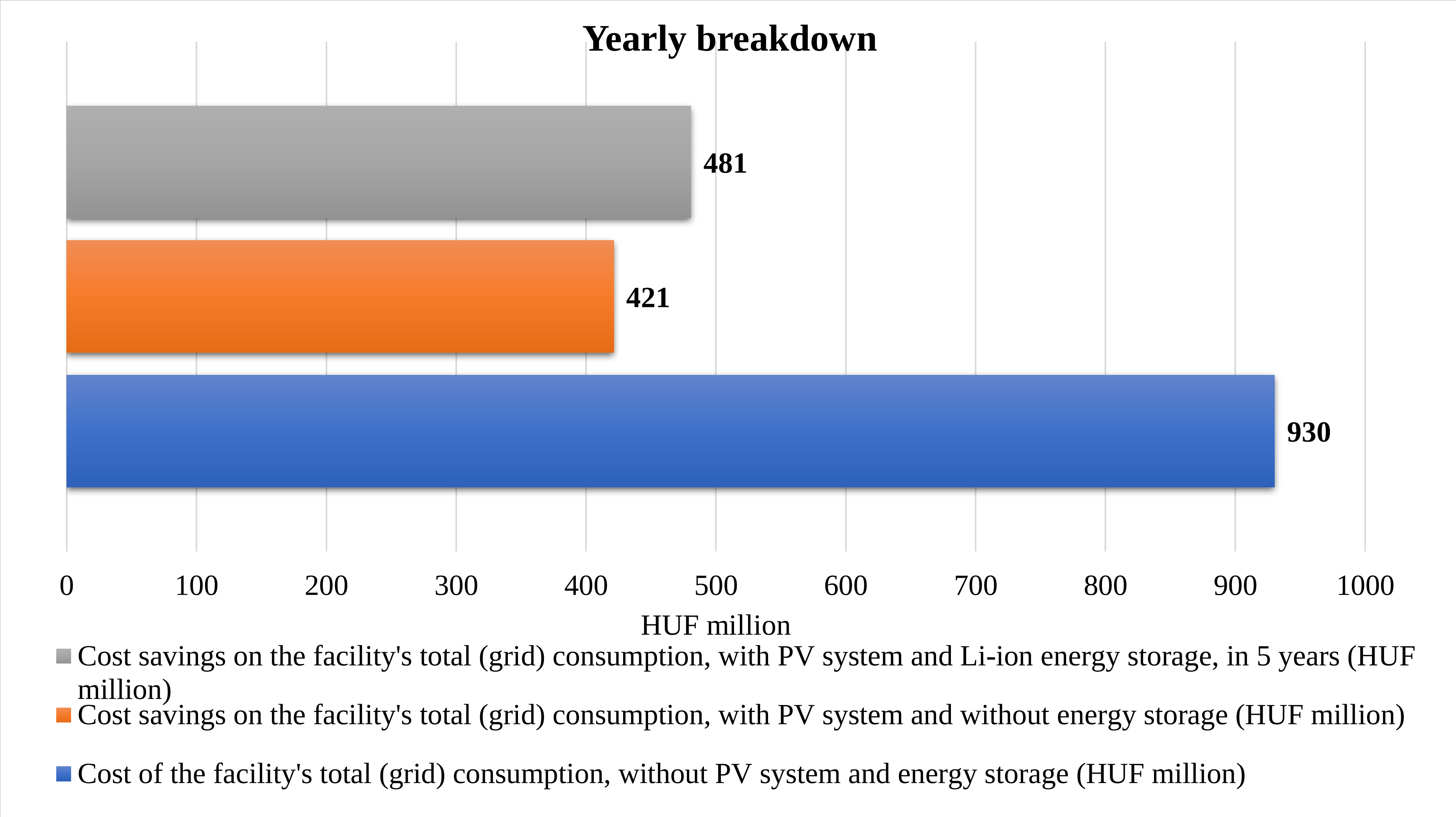

Figure 34. Li-ion model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 1

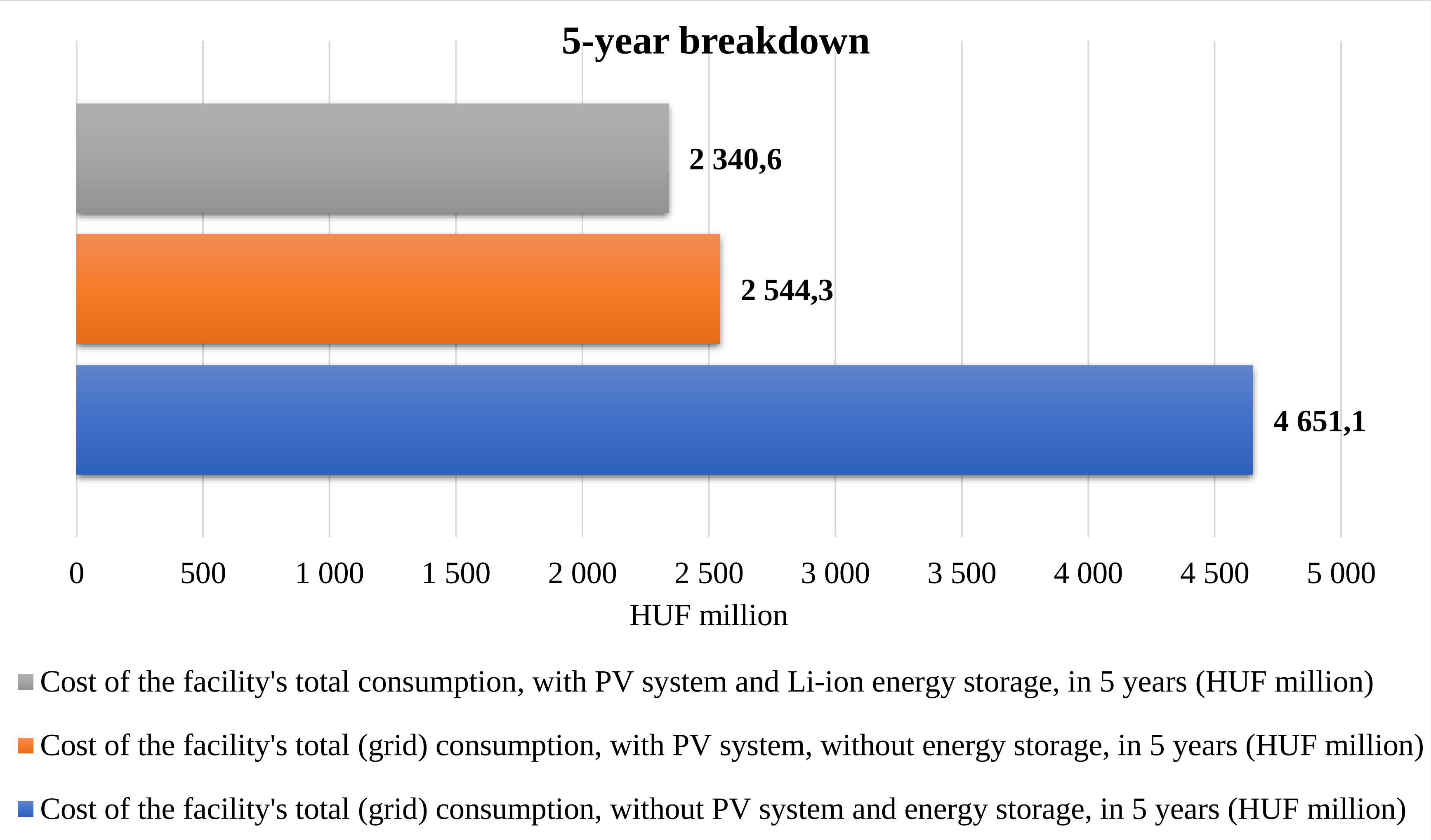

Figure 35. Li-ion model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 1

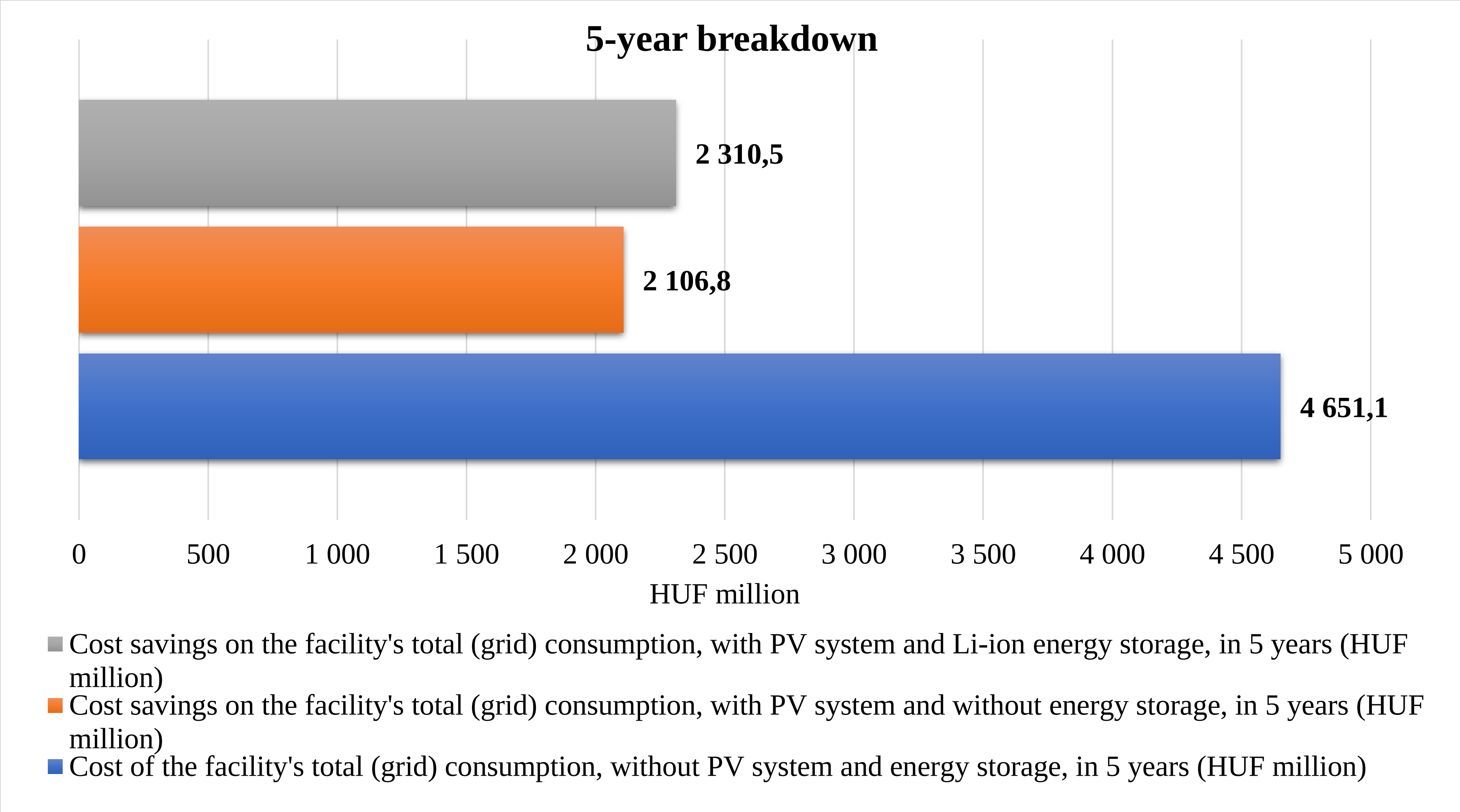

Figure 36. Li-ion model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 1

3.4. Li-ion, Scenario 2

Table 10. Li-ion model-based energy efficiency analysis, Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with Li-ion energy storage (MWh)	Discharge demand of the Li-ion battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	392	252	68	0	59	9
February	661	438	345	360	138	30	93	14
March	695	388	240	620	313	142	148	22
April	669	330	174	722	383	204	156	24
May	868	394	233	877	404	218	161	24
June	1010	425	279	979	394	226	146	22
July	1118	470	308	1027	380	194	162	25
August	1136	572	435	918	354	196	137	21
September	802	444	311	642	284	131	133	20
October	714	417	278	566	270	110	139	21
November	622	423	332	322	123	18	91	14
December	648	485	439	219	56	2	47	7
Q1	1991	1278	977	1232	519	173	301	46
Q2	2546	1149	686	2578	1181	648	463	70
Q3	3055	1486	1054	2587	1018	521	432	65
Q4	1984	1325	1048	1107	448	130	277	42
1 year	9577	5239	3766	7503	3165	1472	1473	223
5 years	47885	26195	19460	37514	15824	8083	6734	1116

Table 11. Li-ion model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with Li-ion energy storage (MWh)
January	100%	71%	62%	100%	27%	0%
February	100%	66%	52%	100%	38%	8%
March	100%	56%	35%	100%	50%	23%
April	100%	49%	26%	100%	53%	28%
May	100%	45%	27%	100%	46%	25%
June	100%	42%	28%	100%	40%	23%
July	100%	42%	28%	100%	37%	19%
August	100%	50%	38%	100%	39%	21%
September	100%	55%	39%	100%	44%	20%
October	100%	58%	39%	100%	48%	19%
November	100%	68%	53%	100%	38%	5%
December	100%	75%	68%	100%	26%	1%
Q1	100%	64%	49%	100%	42%	14%
Q2	100%	45%	27%	100%	46%	25%
Q3	100%	49%	35%	100%	39%	20%
Q4	100%	67%	53%	100%	40%	12%
1 year	100%	55%	39%	100%	42%	20%
5 years	100%	55%	41%	100%	42%	22%

Table 12. Li-ion model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 2

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system and Li-ion energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost saving with the Li-ion energy storage system(HUF million)
January	62	44	38	18	24	6
February	64	43	34	22	31	9
March	68	38	23	30	44	14
April	65	32	17	33	48	15
May	84	38	23	46	62	16
June	98	41	27	57	71	14
July	109	46	30	63	79	16
August	110	56	42	55	68	13
September	78	43	30	35	48	13
October	69	41	27	29	42	14
November	60	41	32	19	28	9
December	63	47	43	16	20	5
Q1	193	124	95	69	98	29
Q2	247	112	67	136	181	45
Q3	297	144	102	152	194	42
Q4	193	129	102	64	91	27
1 year	930	509	366	421	564	143
5 years	4651	2544	1890	2107	2761	654

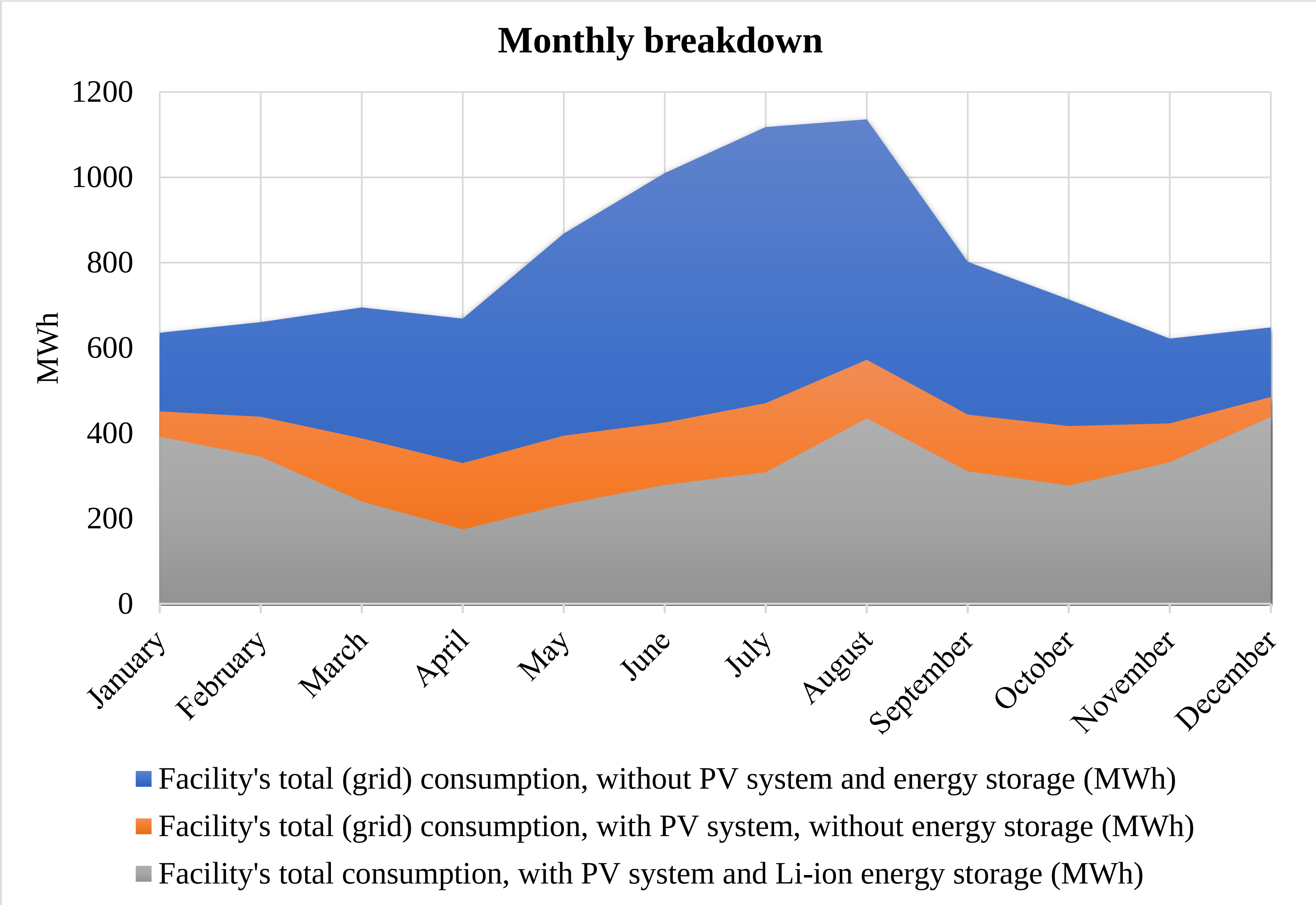

Figure 37. Li-ion model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 2

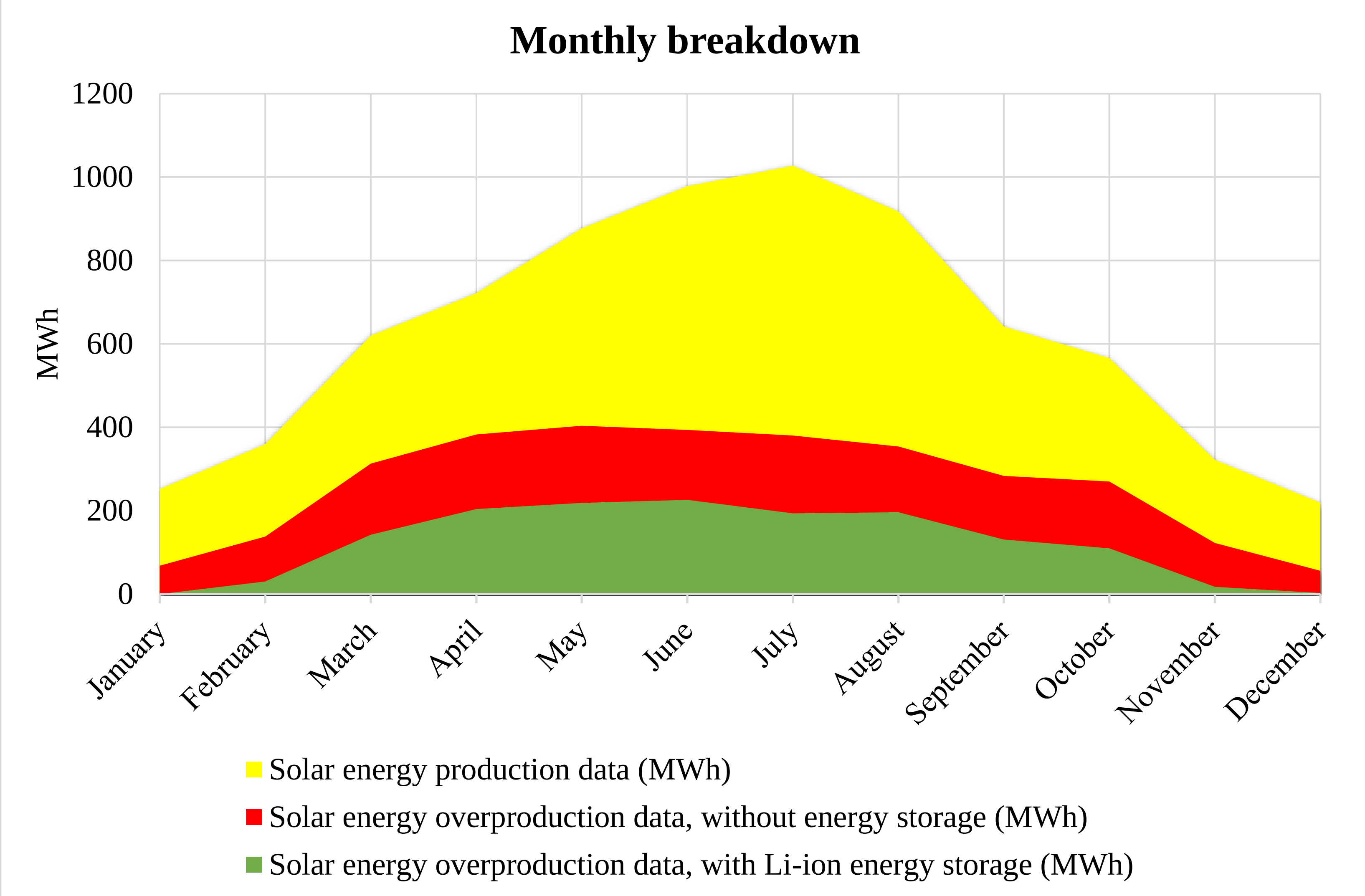

Figure 38. Li-ion model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 2

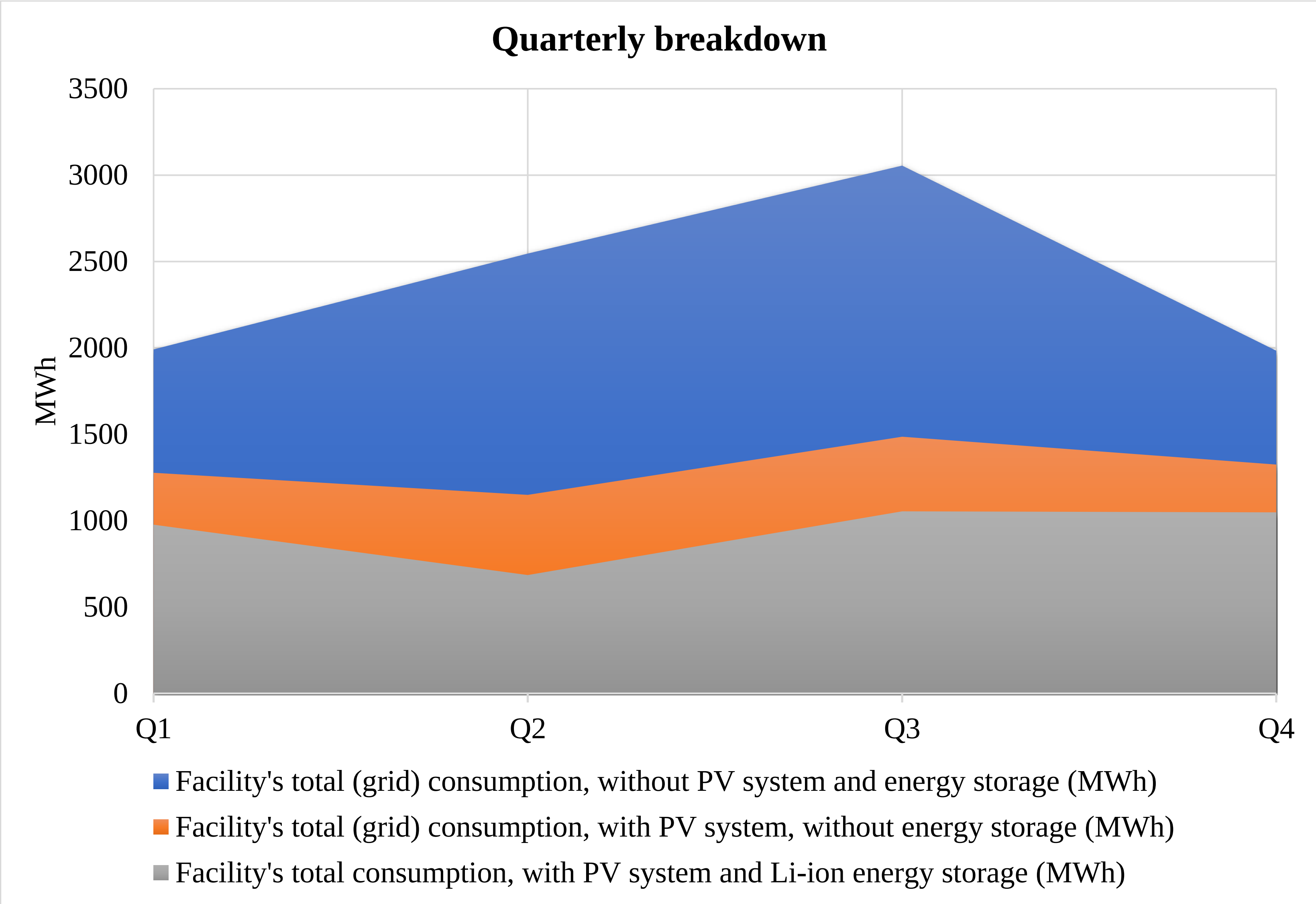

Figure 39. Li-ion model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 2

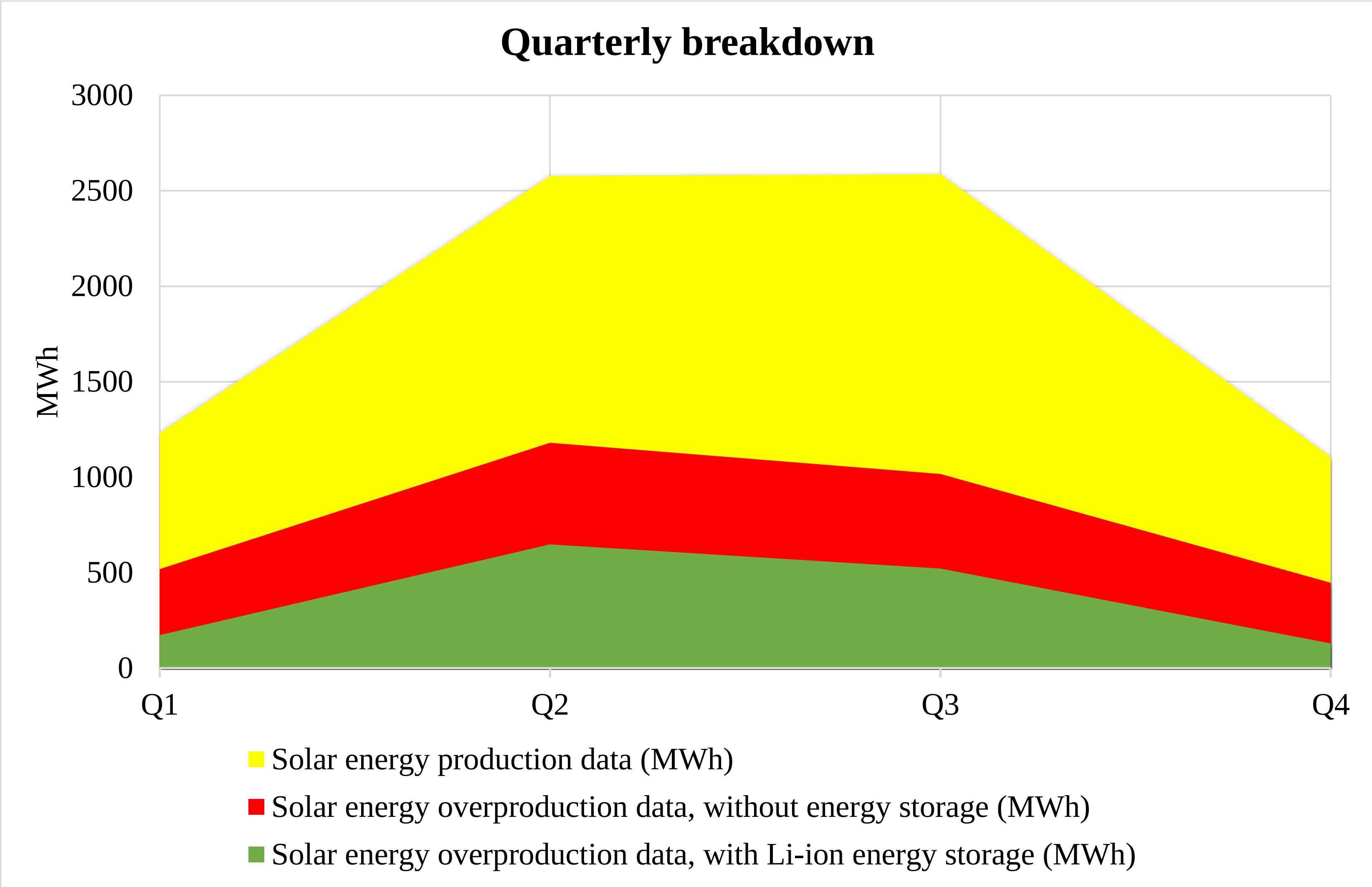

Figure 40. Li-ion model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 2

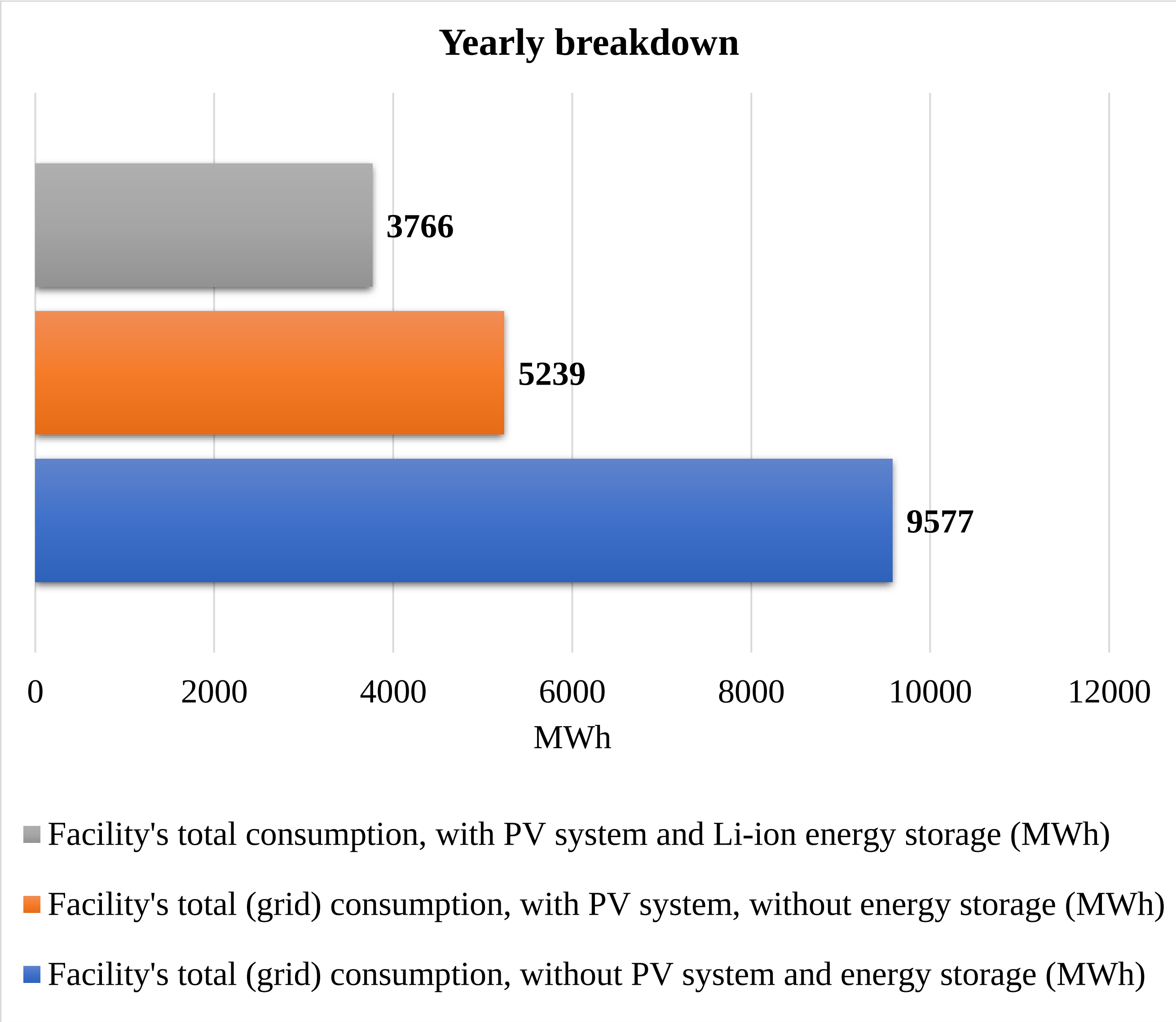

Figure 41. Li-ion model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 2

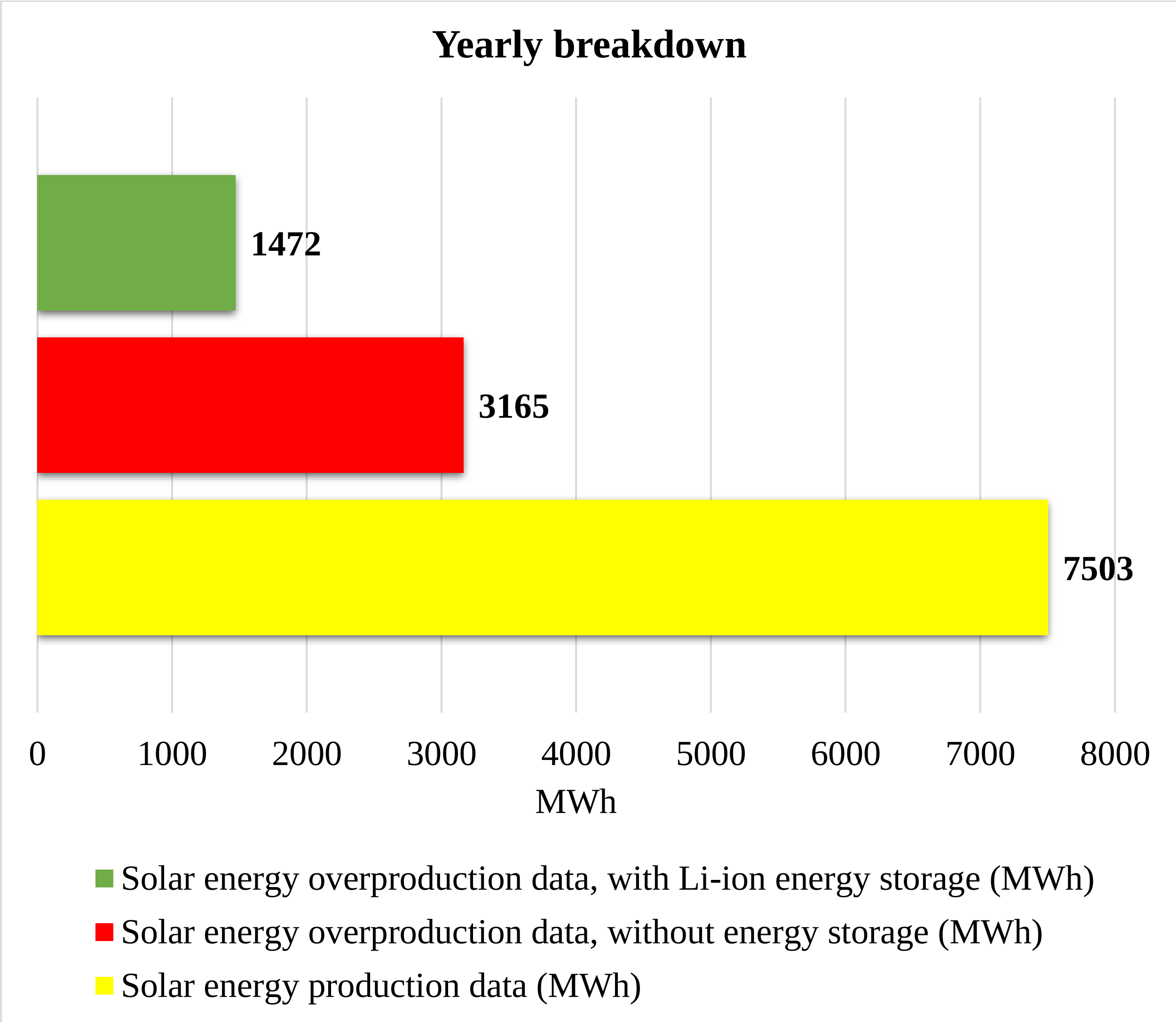

Figure 42. Li-ion model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 2

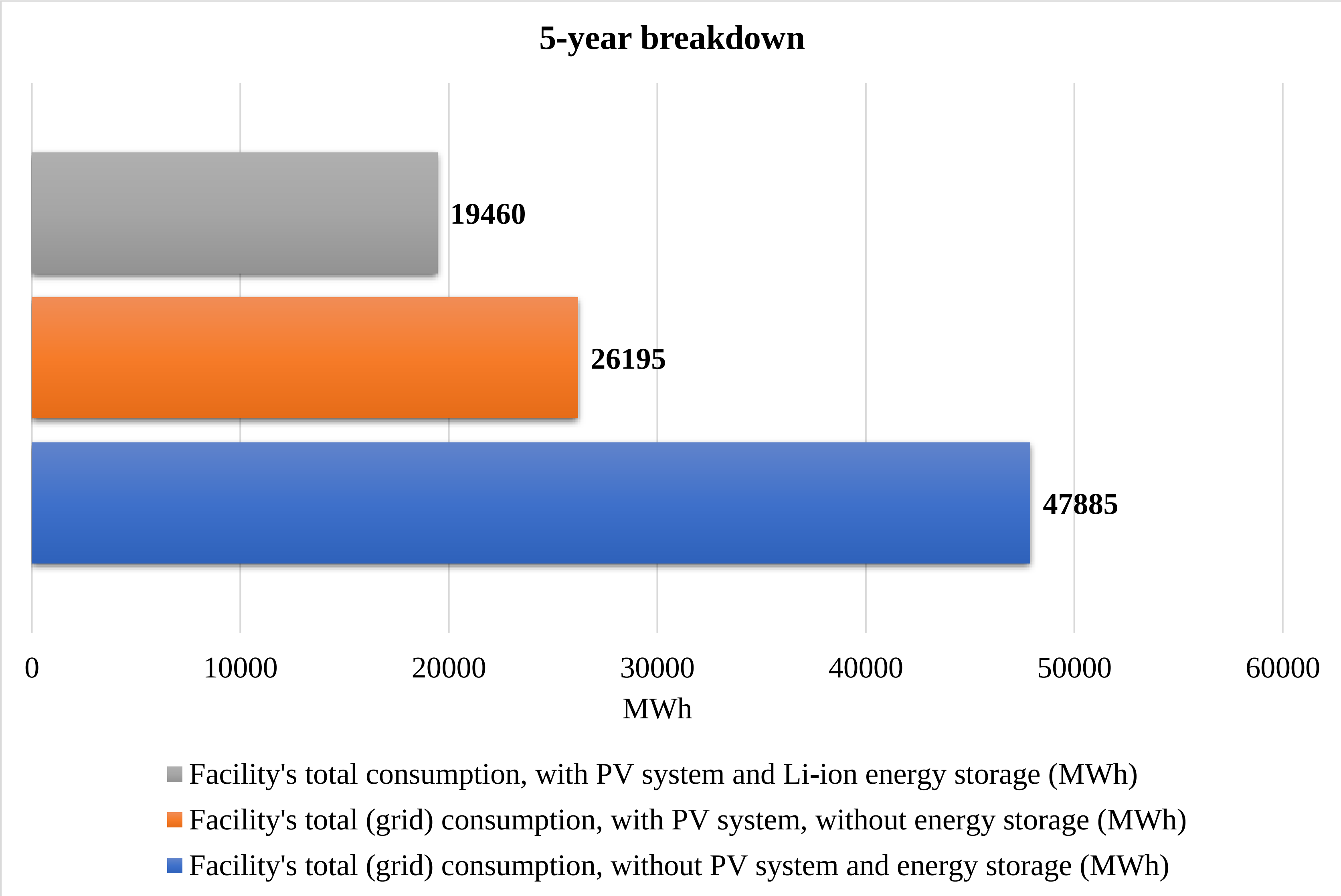

Figure 43. Li-ion model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 2

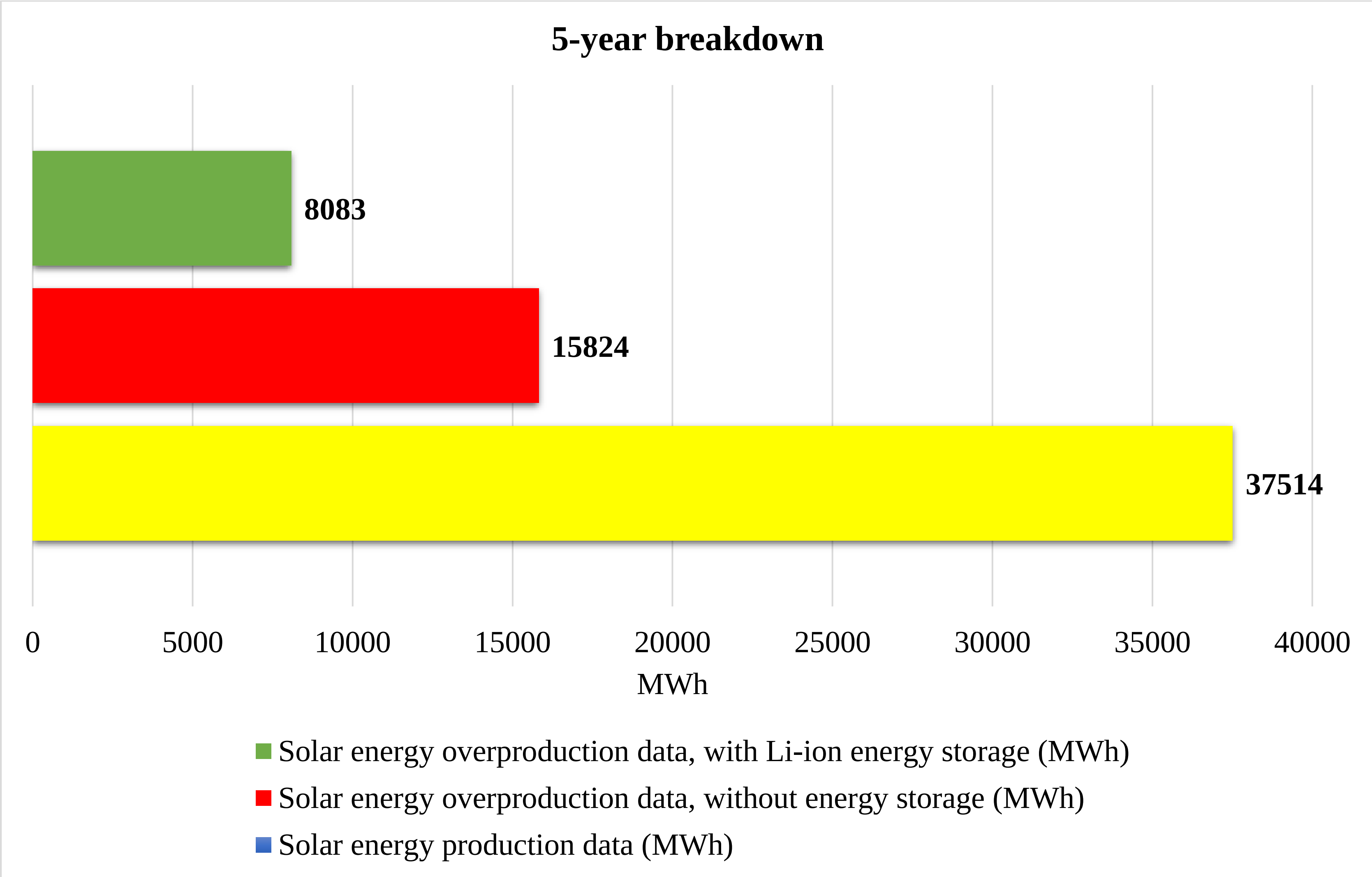

Figure 44. Li-ion model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 2

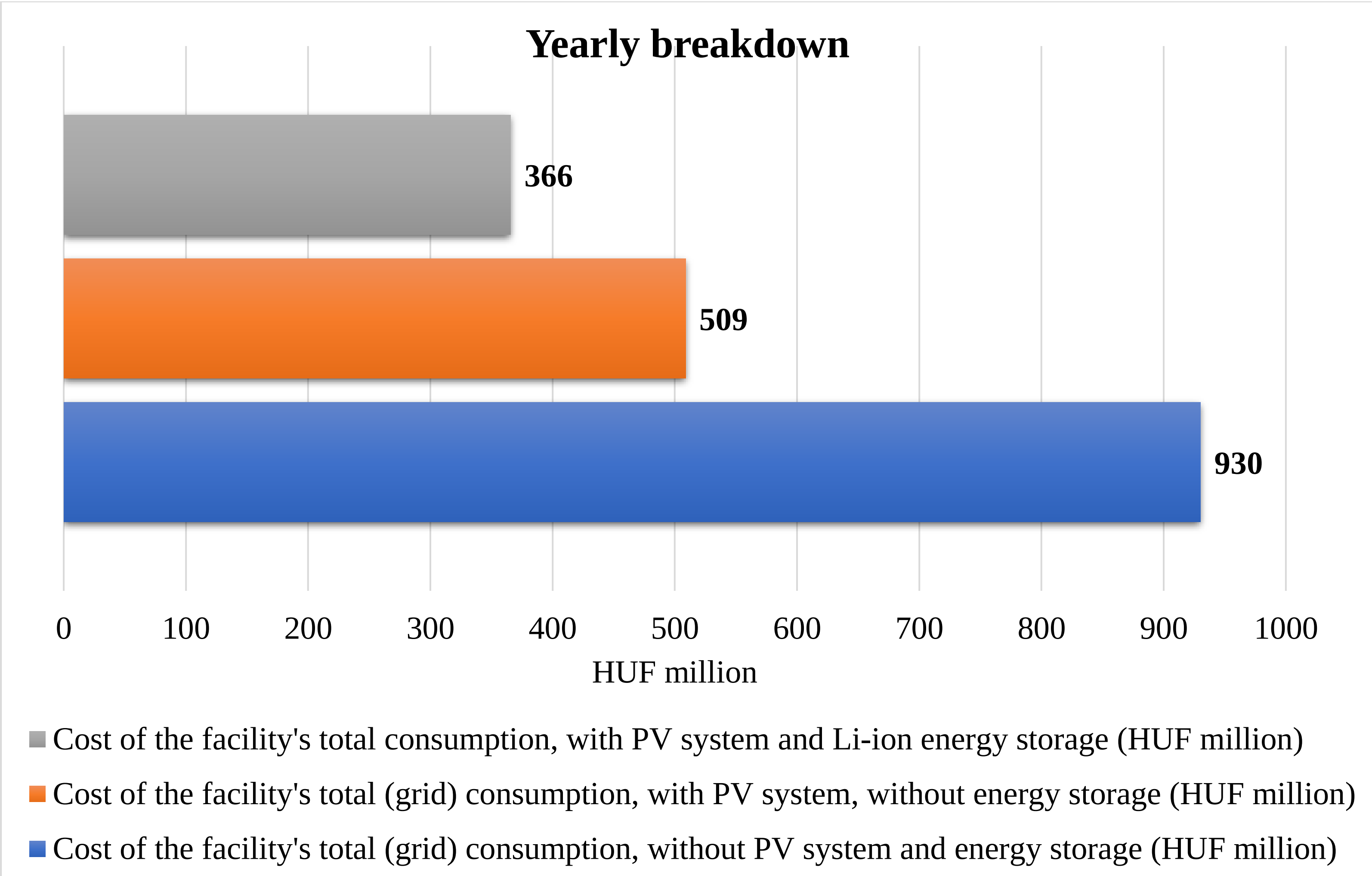

Figure 45. Li-ion model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 2

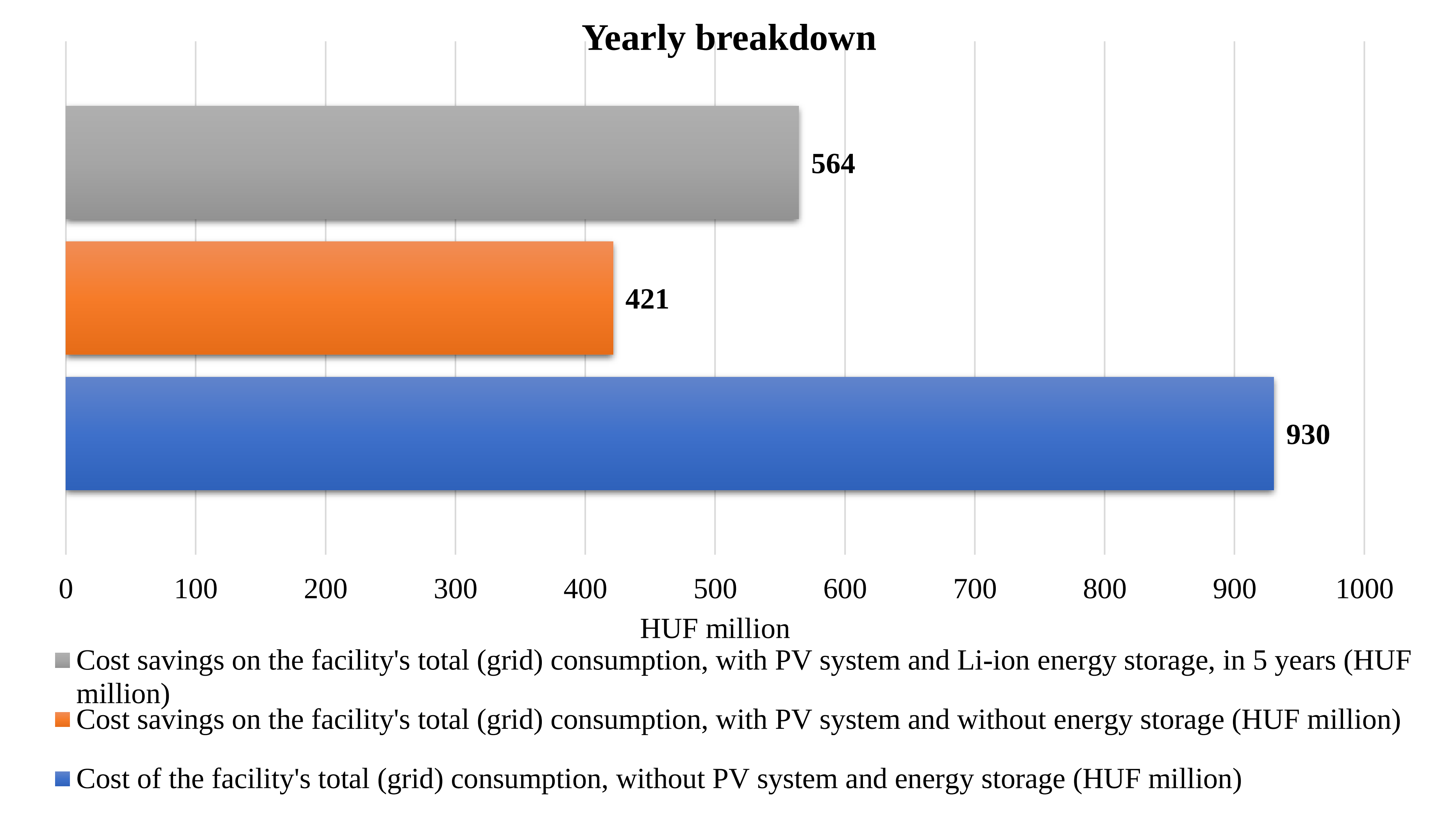

Figure 46. Li-ion model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 2

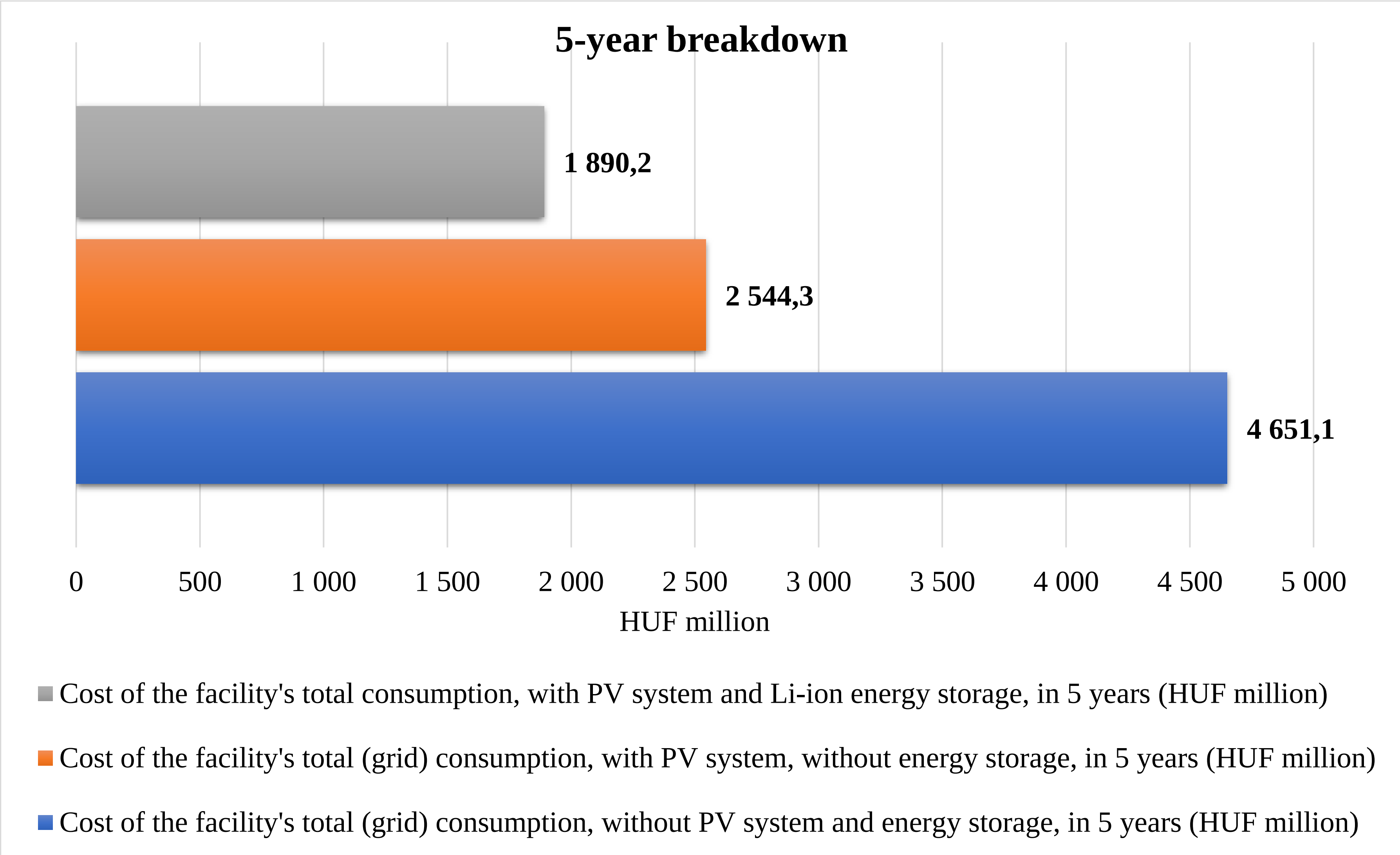

Figure 47. Li-ion model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 2

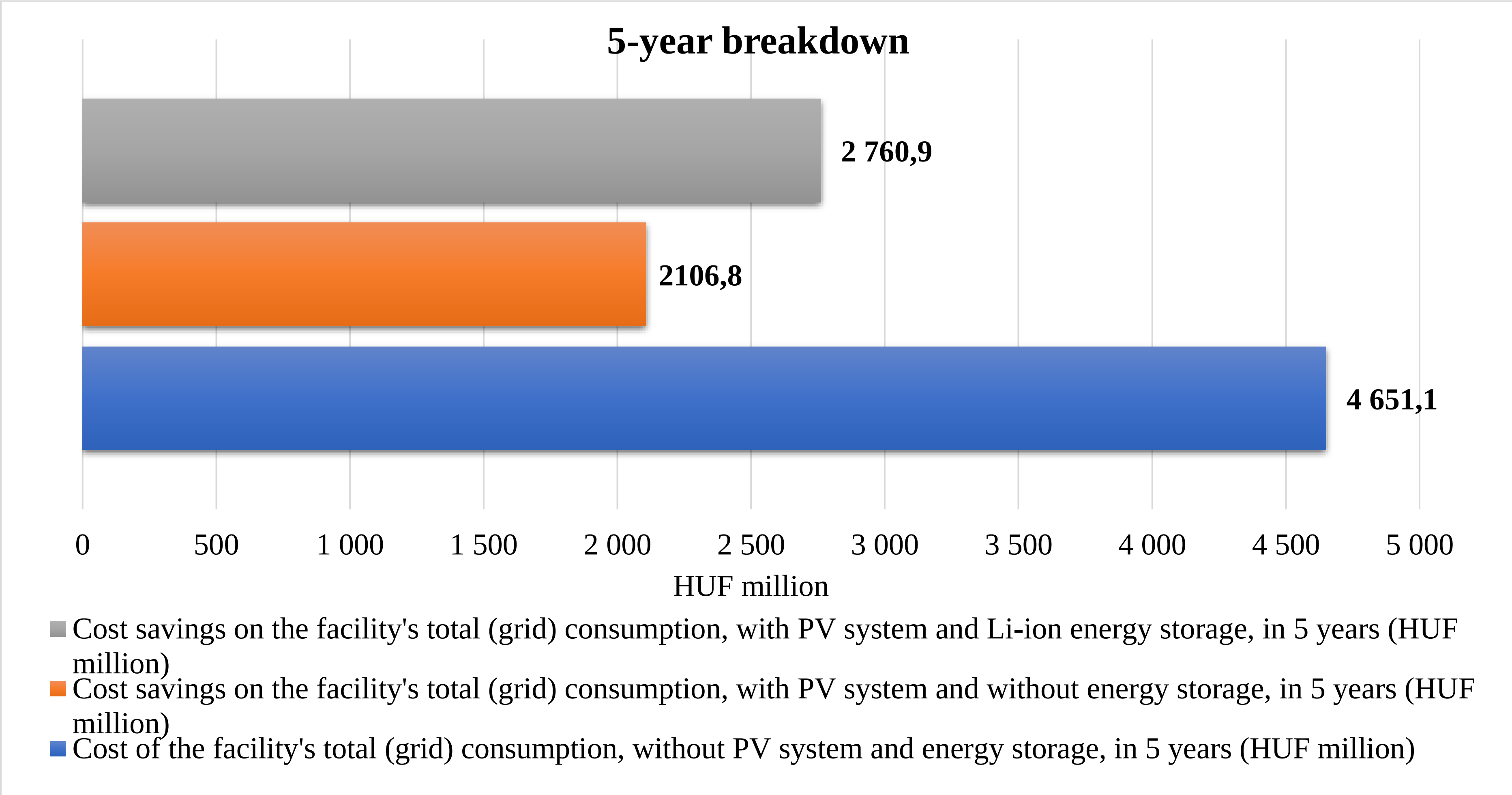

Figure 48. Li-ion model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 2

3.5. NaS, Scenario 1

At rated output, this technology is not suitable for short discharge durations. Therefore, Scenario 1 is not applicable for this technology.

3.6. NaS, Scenario 2

Table 13. NaS model-based energy efficiency analysis, Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Solar power plant production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, NaS with energy storage (MWh)	Discharge demand of the NaS battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	395	252	68	0	57	9
February	661	438	348	360	138	13	91	14
March	695	388	241	620	313	111	147	22
April	669	330	175	722	383	170	155	23
May	868	394	235	877	404	184	159	24
June	1010	425	280	979	394	194	145	22
July	1118	470	310	1027	380	159	161	24
August	1136	572	436	918	354	167	136	21
September	802	444	313	642	284	104	131	20
October	714	417	280	566	270	81	137	21
November	622	423	334	322	123	0	89	14
December	648	485	440	219	56	0	45	7
Q1	1991	1278	984	1232	519	124	294	45
Q2	2546	1149	690	2578	1181	548	460	70
Q3	3055	1486	1059	2587	1018	429	428	65
Q4	1984	1325	1054	1107	448	81	271	41
1 year	9577	5239	3786	7503	3165	1182	1453	220
5 years	47885	26195	18930	37514	15824	5872	7265	1101

Table 14. NaS model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Solar power plant production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, NaS with energy storage (MWh)
January	100%	71%	62%	100%	27%	0%
February	100%	66%	53%	100%	38%	4%
March	100%	56%	35%	100%	50%	18%
April	100%	49%	26%	100%	53%	24%
May	100%	45%	27%	100%	46%	21%
June	100%	42%	28%	100%	40%	20%
July	100%	42%	28%	100%	37%	15%
August	100%	50%	38%	100%	39%	18%
September	100%	55%	39%	100%	44%	16%
October	100%	58%	39%	100%	48%	14%
November	100%	68%	54%	100%	38%	0%
December	100%	75%	68%	100%	26%	0%
Q1	100%	64%	49%	100%	42%	10%
Q2	100%	45%	27%	100%	46%	21%
Q3	100%	49%	35%	100%	39%	17%
Q4	100%	67%	53%	100%	40%	7%
1 year	100%	55%	40%	100%	42%	16%
5 years	100%	55%	40%	100%	42%	16%

Table 15. NaS model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 2

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system and NaS energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system and NaS energy storage, in 5 years (HUF million)	Cost saving on the NaS energy storage system (HUF million)
January	62	44	38	18	23	5
February	64	43	34	22	30	9
March	68	38	23	30	44	14
April	65	32	17	33	48	15
May	84	38	23	46	61	15
June	98	41	27	57	71	14
July	109	46	30	63	78	16
August	110	56	42	55	68	13
September	78	43	30	35	47	13
October	69	41	27	29	42	13
November	60	41	32	19	28	9
December	63	47	43	16	20	4
Q1	193	124	96	69	98	29
Q2	247	112	67	136	180	45
Q3	297	144	103	152	194	42
Q4	193	129	102	64	90	26
1 year	930	509	368	421	562	141
5 years	4651	2544	1839	2107	2812	706

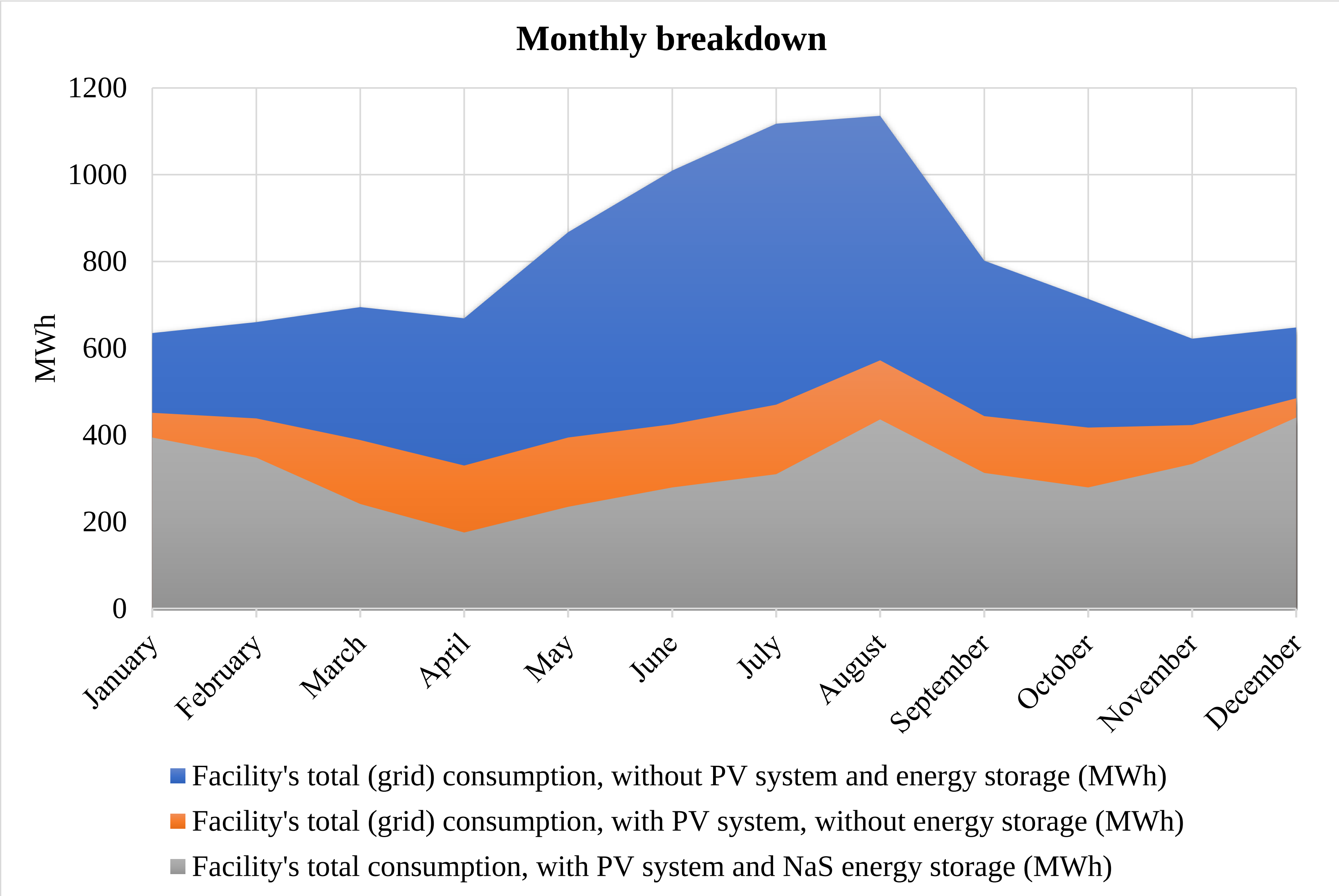

Figure 49. NaS model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 2

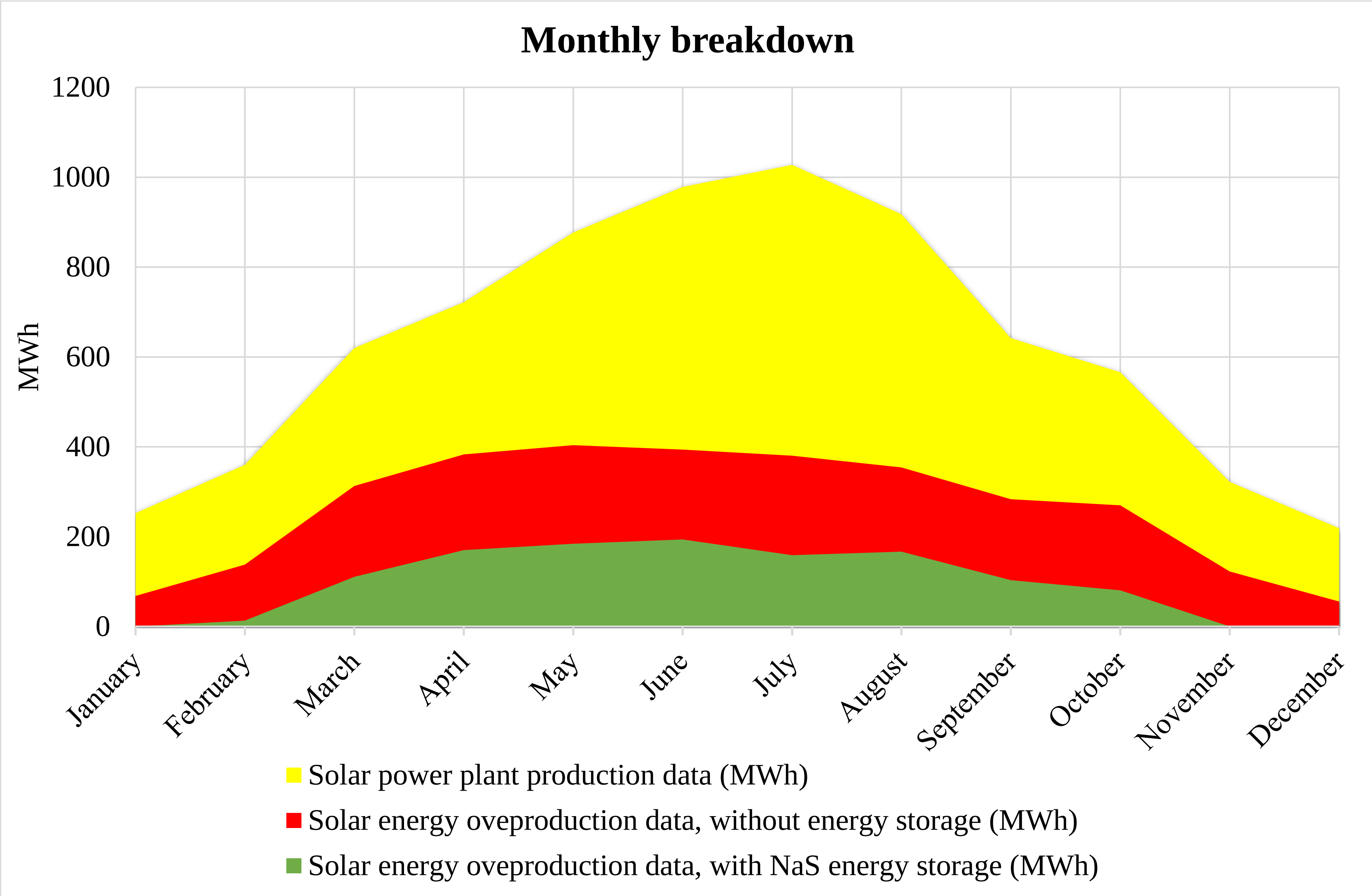

Figure 50. NaS model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 2

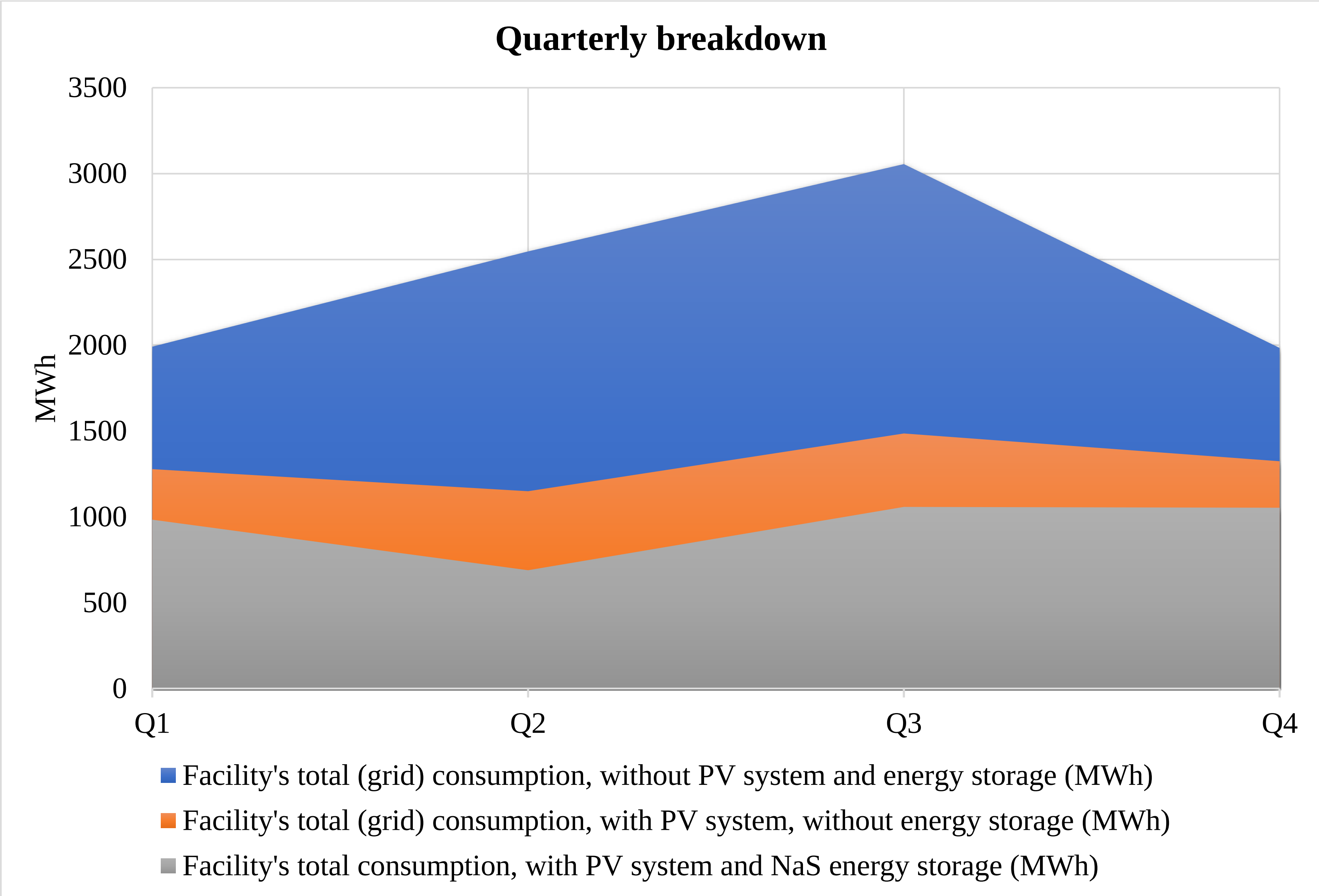

Figure 51. NaS model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 2

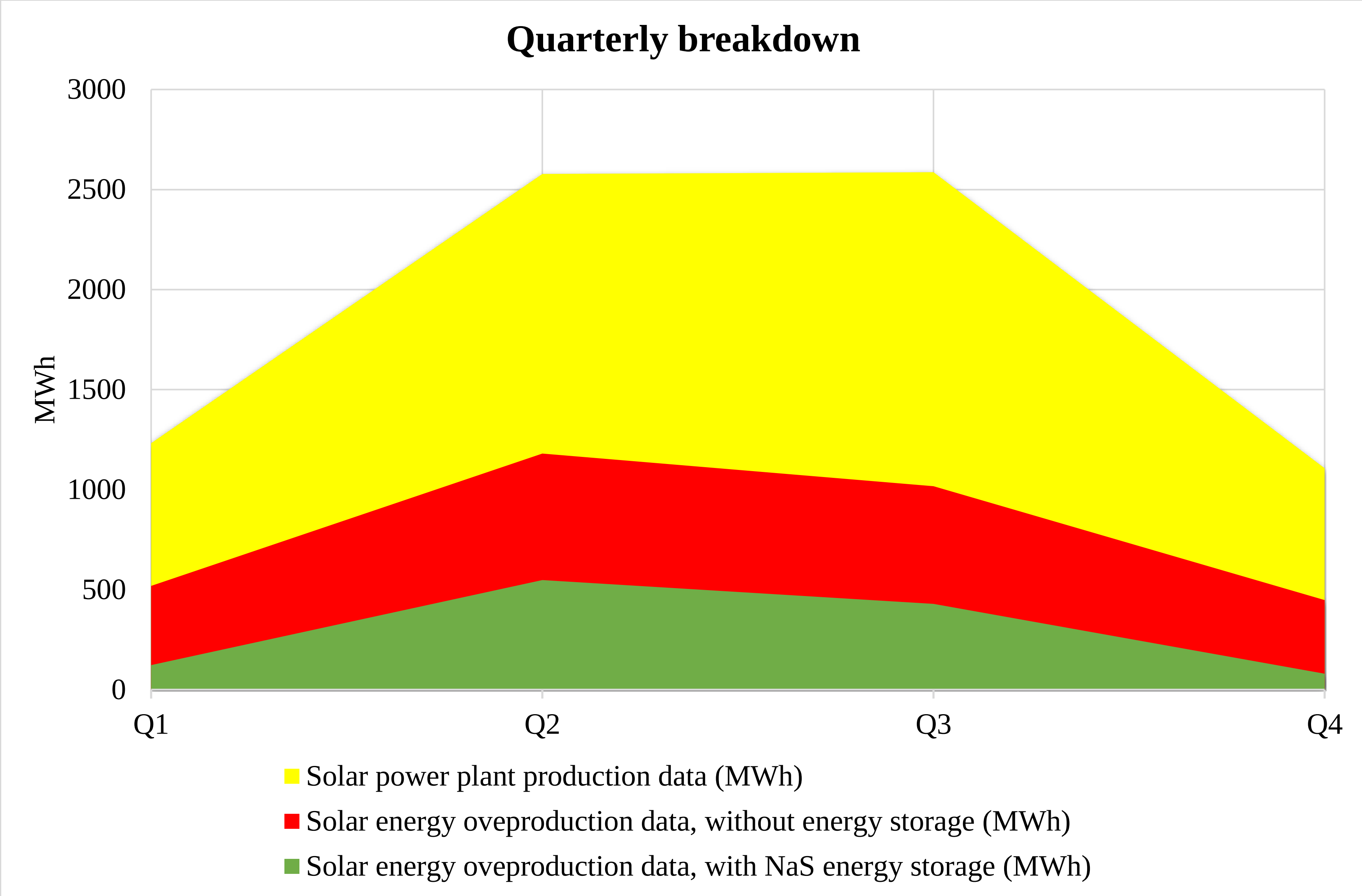

Figure 52. NaS model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 2

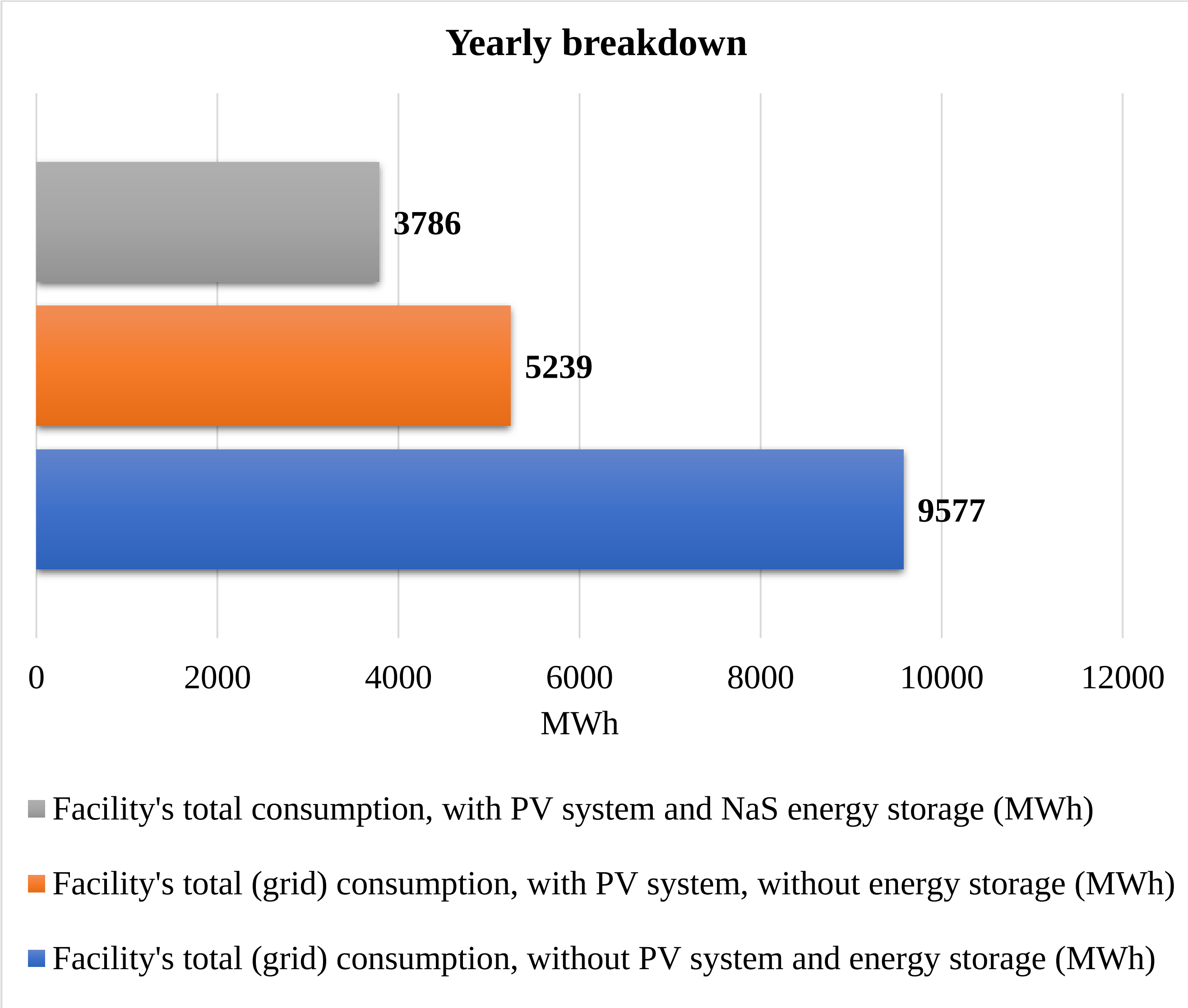

Figure 53. NaS model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 2

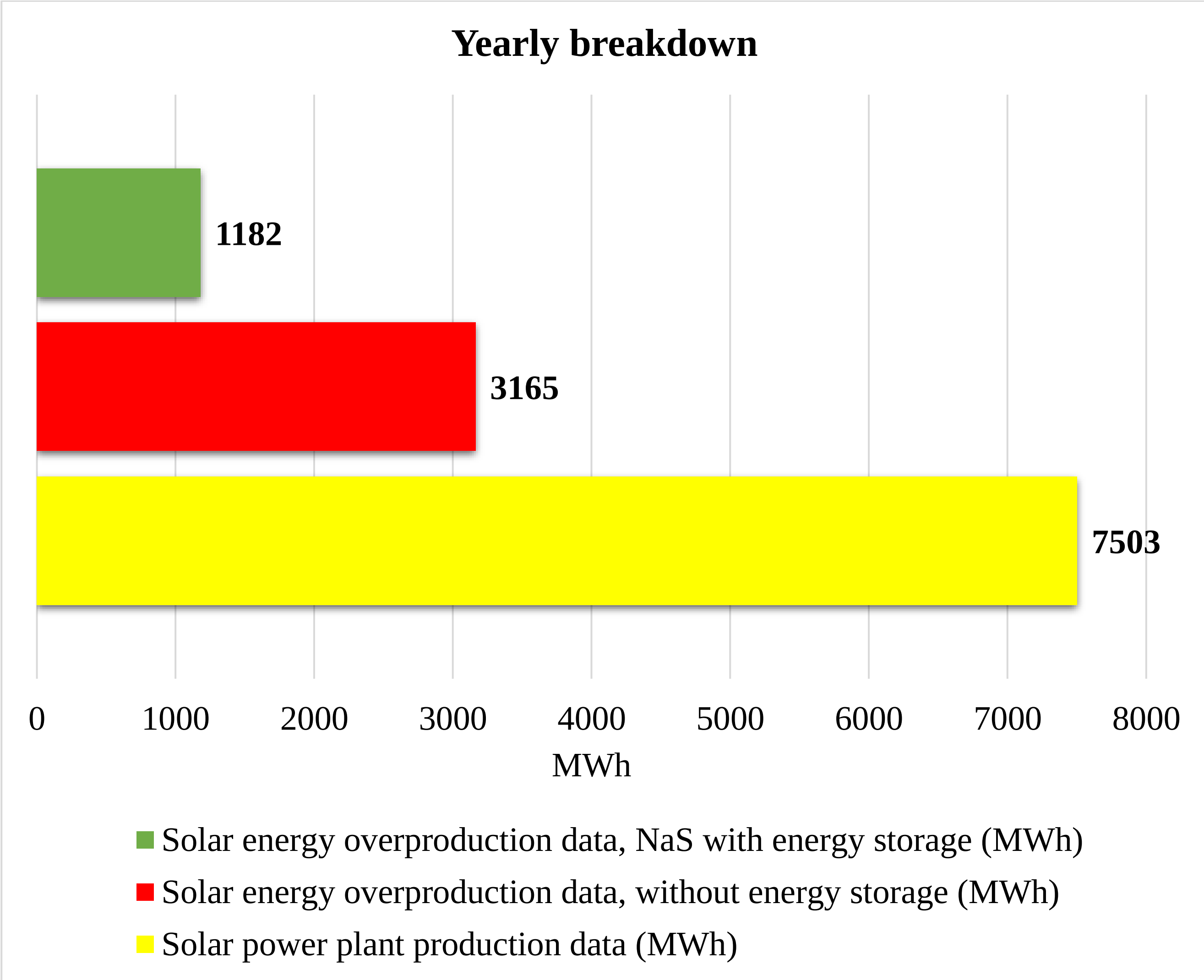

Figure 54. NaS model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 2

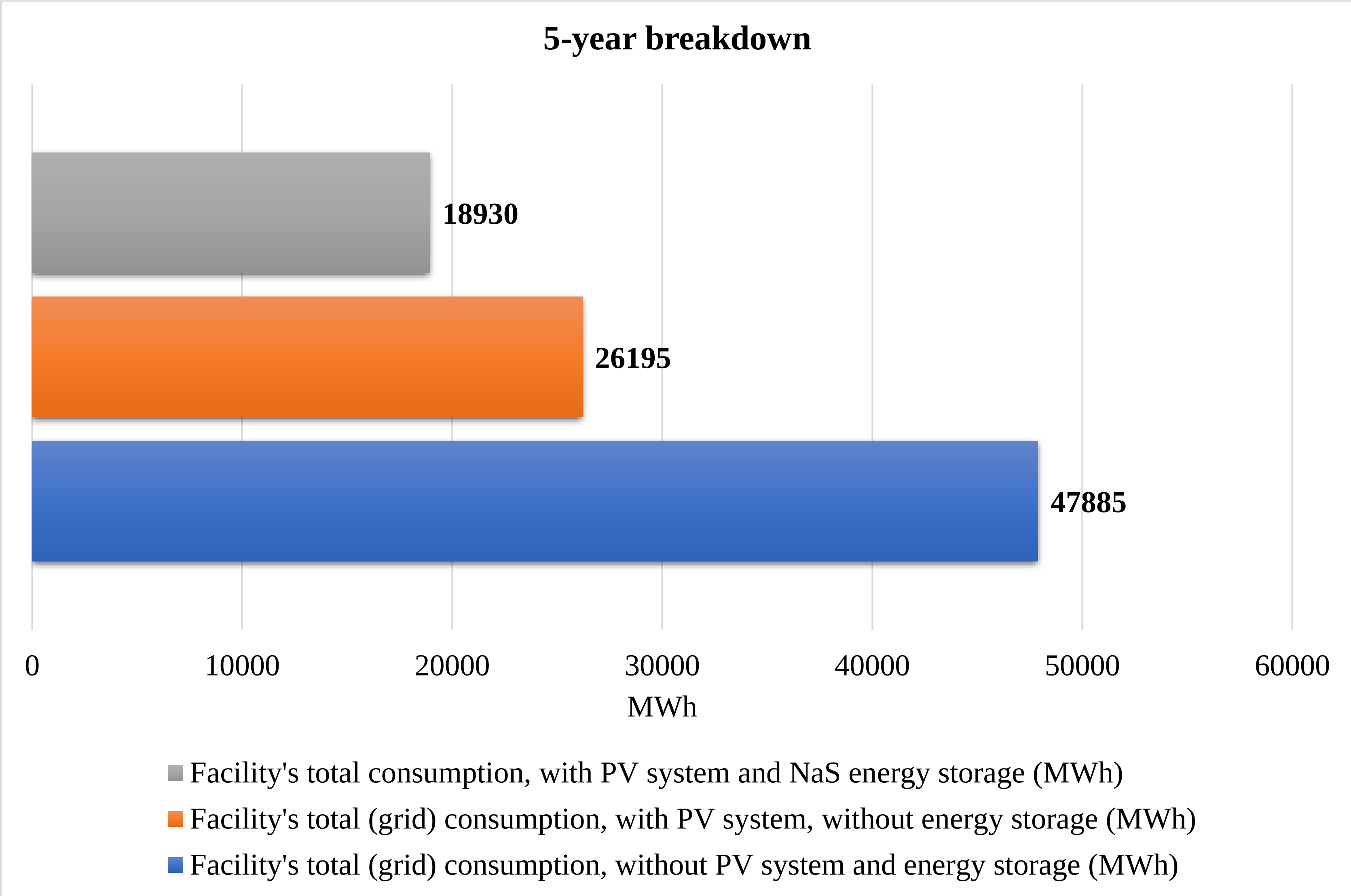

Figure 55. NaS model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 2

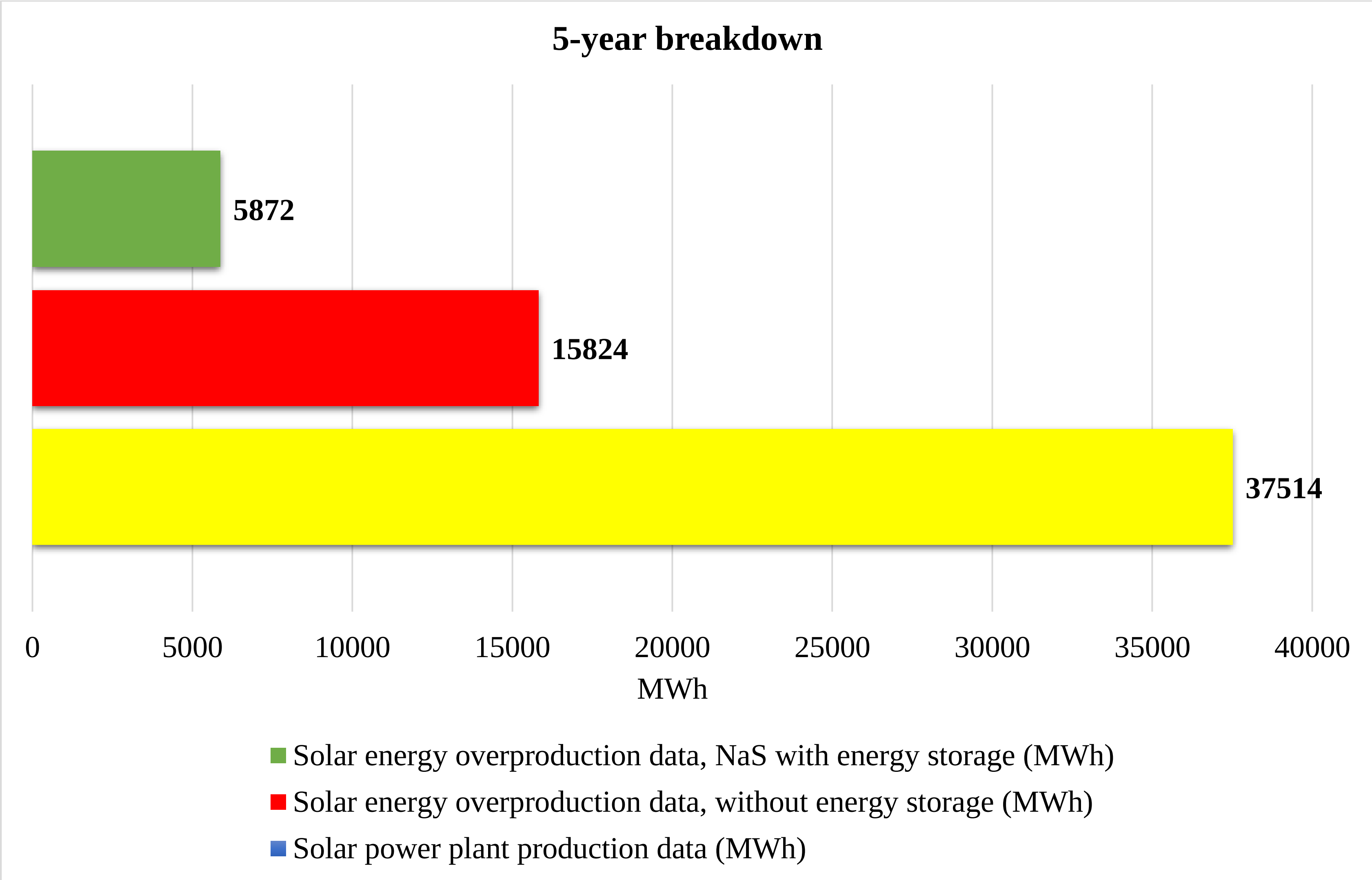

Figure 56. NaS model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 2

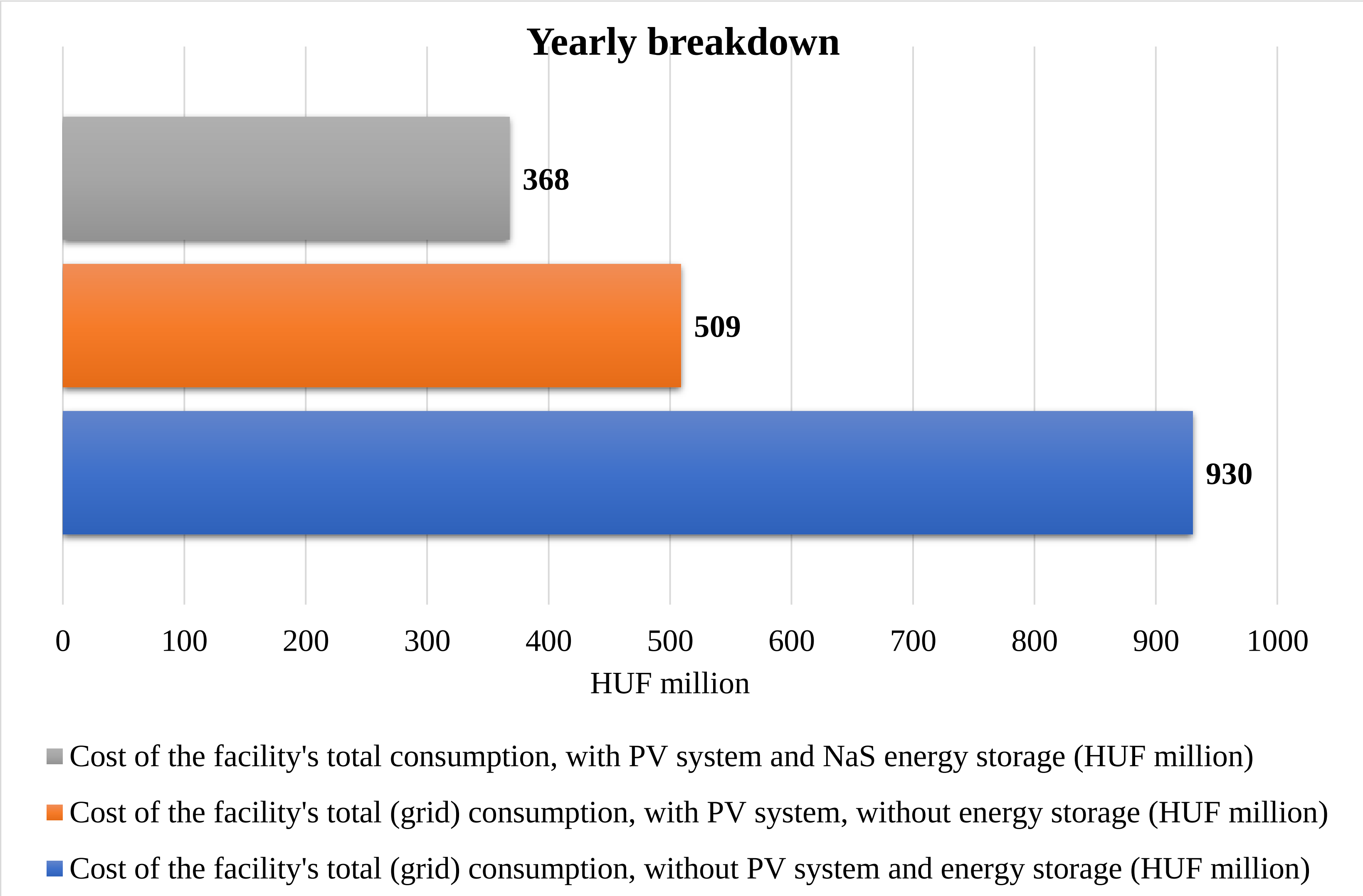

Figure 57. NaS model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 2

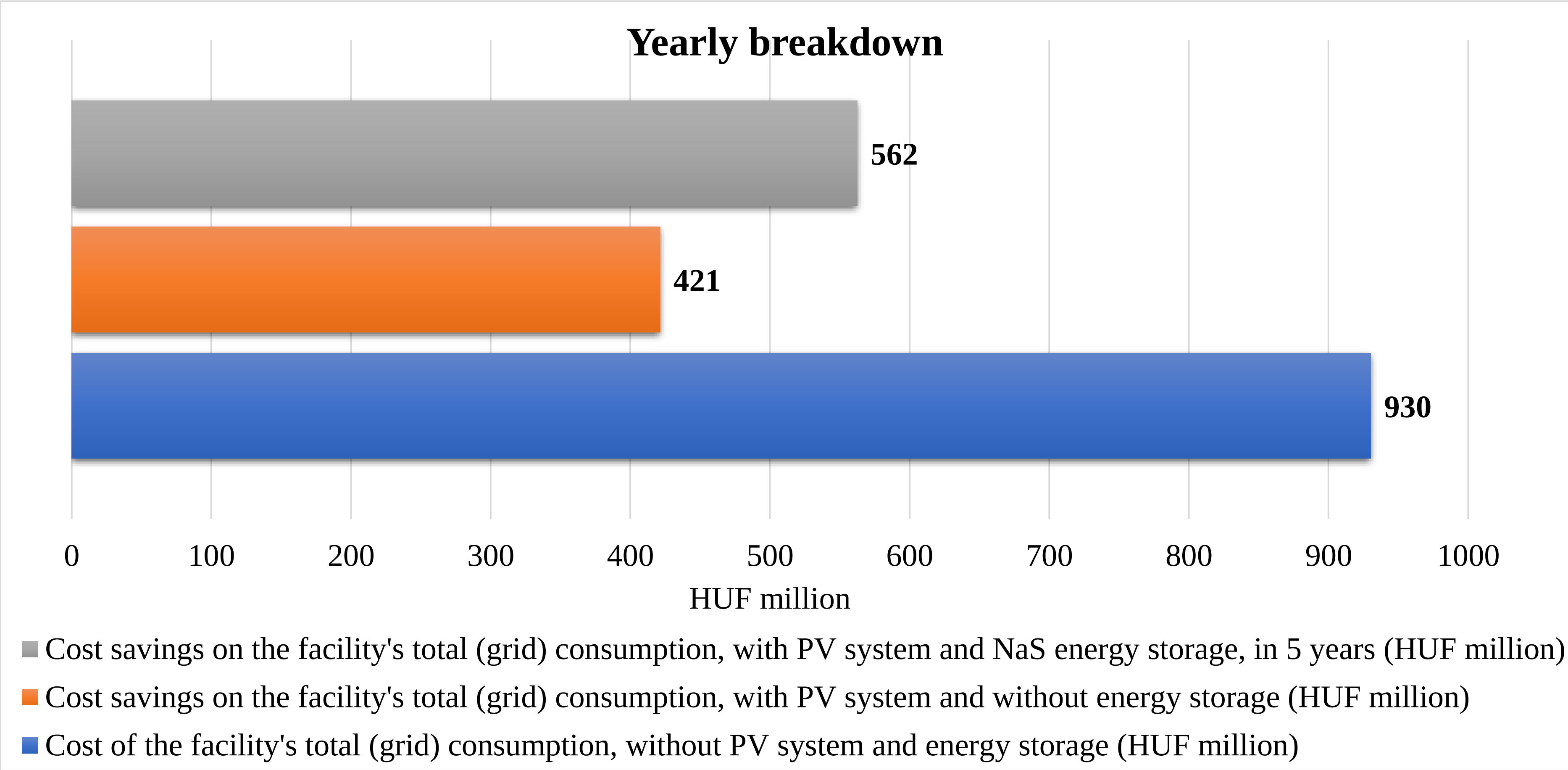

Figure 58. NaS model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 2

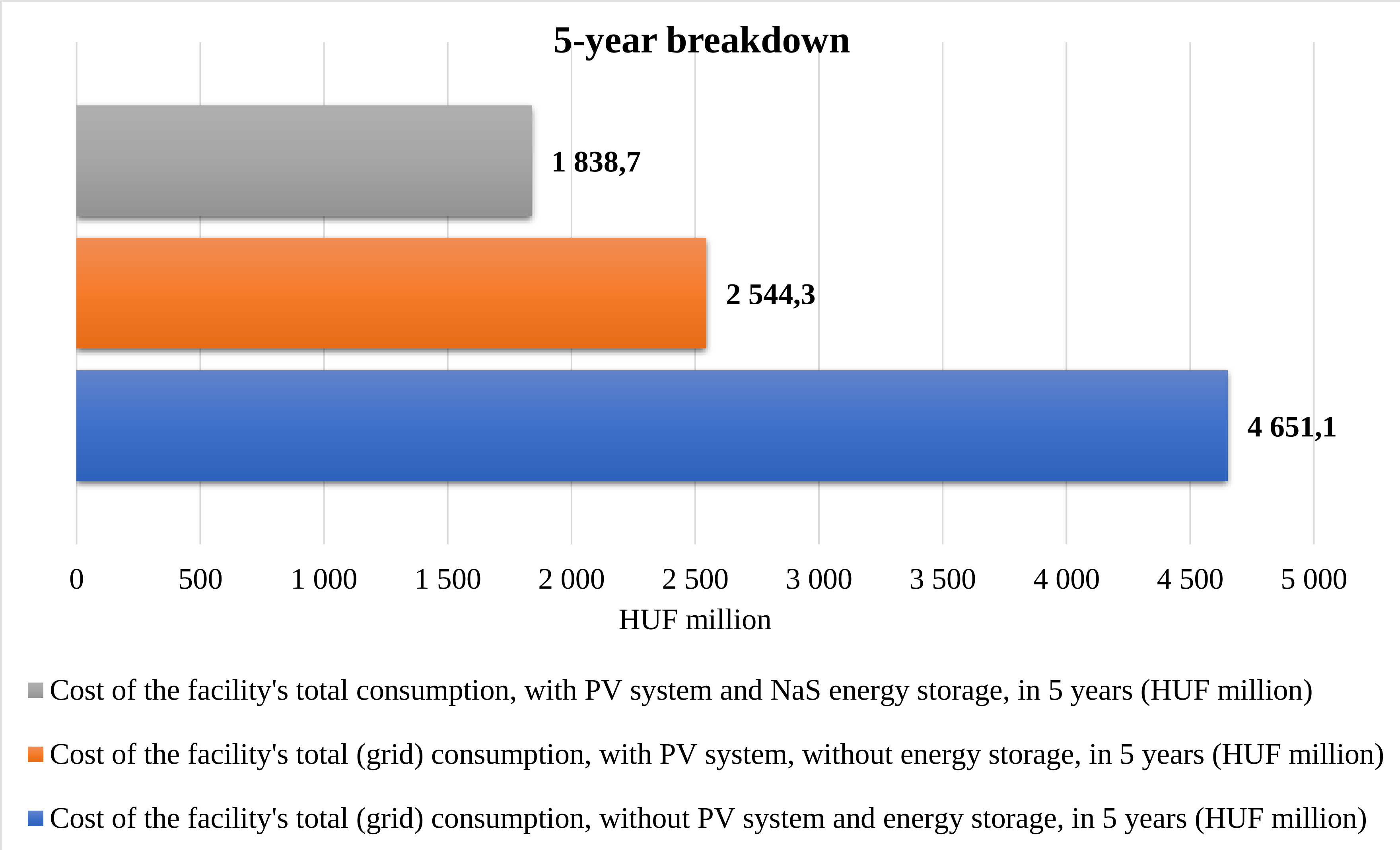

Figure 59. NaS model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 2

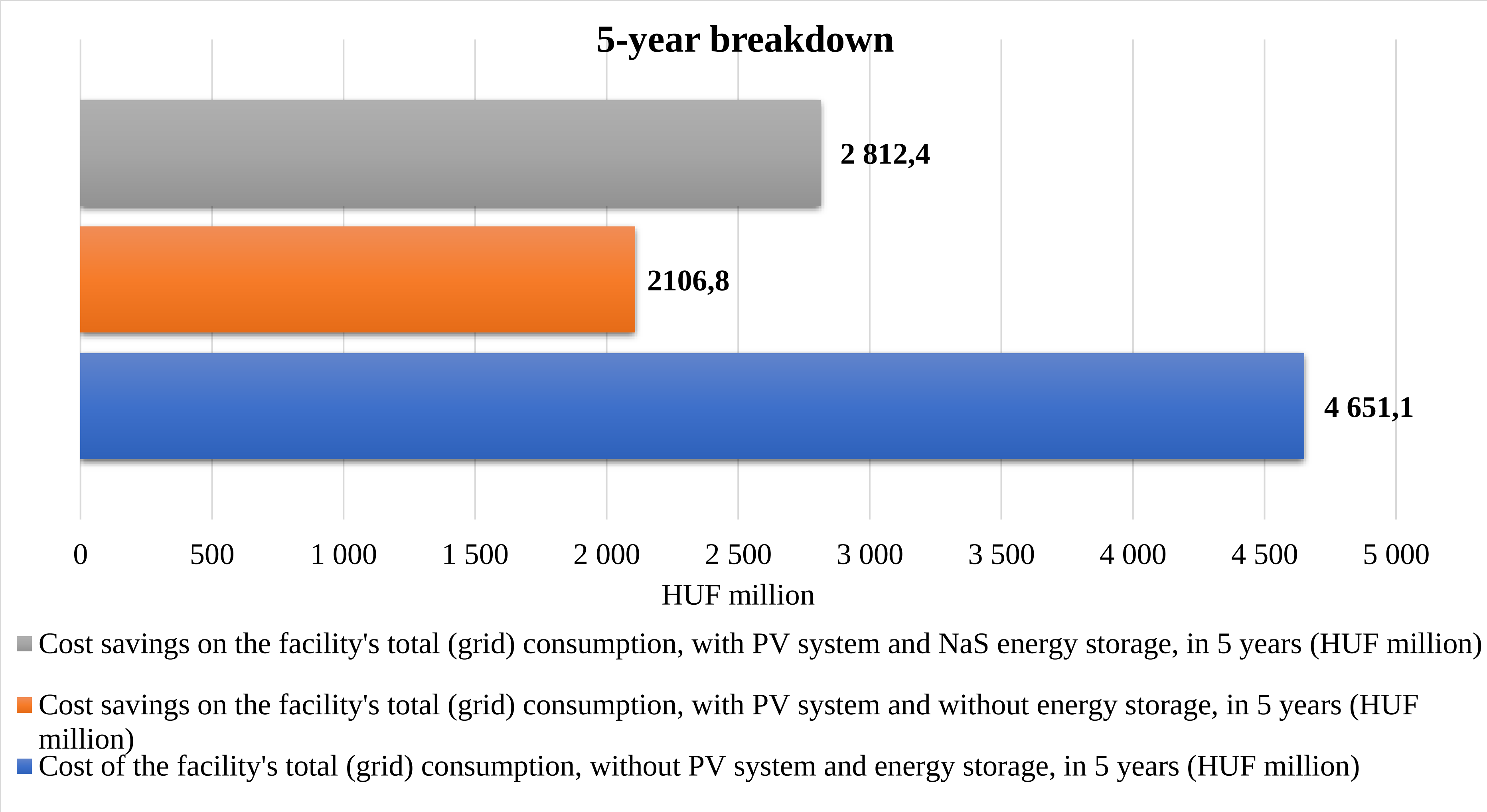

Figure 60. NaS model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 2

3.7. VRFB, Scenario 1

Table 16. VRFB model-based energy efficiency analysis, Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with VRFB energy storage (MWh)	Discharge demand of the VRFB battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	415	252	68	17	36	16
February	661	438	395	360	138	76	43	20
March	695	388	335	620	313	237	53	24
April	669	330	271	722	383	298	59	27
May	868	394	332	877	404	314	63	29
June	1010	425	370	979	394	315	55	25
July	1118	470	410	1027	380	294	60	27
August	1136	572	518	918	354	277	54	25
September	802	444	392	642	284	210	52	24
October	714	417	356	566	270	182	62	28
November	622	423	384	322	123	67	39	18
December	648	485	456	219	56	15	29	13
Q1	1991	1278	1145	1232	519	329	132	60
Q2	2546	1149	972	2578	1181	927	177	81
Q3	3055	1486	1320	2587	1018	780	166	75
Q4	1984	1325	1196	1107	448	263	129	59
1 year	9577	5239	4634	7503	3165	2300	605	275
5 years	47885	26195	23168	37514	15824	11501	3026	1375

Table 17. VRFB model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 1

Time interval	Facility's total (grid) consumption, without PV syst[illegible] and energy storage (MWh)	Facility's total (grid) consumption, with PV [illegible]ut energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with VRFB energy storage (MWh)
January	100%	71%	65%	100%	27%	7%
February	100%	66%	60%	100%	38%	21%
March	100%	56%	48%	100%	50%	38%
April	100%	49%	40%	100%	53%	41%
May	100%	45%	38%	100%	46%	36%
June	100%	42%	37%	100%	40%	32%
July	100%	42%	37%	100%	37%	29%
August	100%	50%	46%	100%	39%	30%
September	100%	55%	49%	100%	44%	33%
October	100%	58%	50%	100%	48%	32%
November	100%	68%	62%	100%	38%	21%
December	100%	75%	70%	100%	26%	7%
Q1	100%	64%	58%	100%	42%	27%
Q2	100%	45%	38%	100%	46%	36%
Q3	100%	49%	43%	100%	39%	30%
Q4	100%	67%	60%	100%	40%	24%
1 year	100%	55%	48%	100%	42%	31%
5 years	100%	55%	48%	100%	42%	31%

Table 18. VRFB model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 1

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system and VRFB energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost saving on the VRFB energy storage system (HUF million)
January	62	44	40	18	21	3
February	64	43	38	22	26	4
March	68	38	33	30	35	5
April	65	32	26	33	39	6
May	84	38	32	46	52	6
June	98	41	36	57	62	5
July	109	46	40	63	69	6
August	110	56	50	55	60	5
September	78	43	38	35	40	5
October	69	41	35	29	35	6
November	60	41	37	19	23	4
December	63	47	44	16	19	3
Q1	193	124	111	69	82	13
Q2	247	112	94	136	153	17
Q3	297	144	128	152	169	16
Q4	193	129	116	64	77	13
1 year	930	509	450	421	480	59
5 years	4651	2544	2250	2107	2401	294

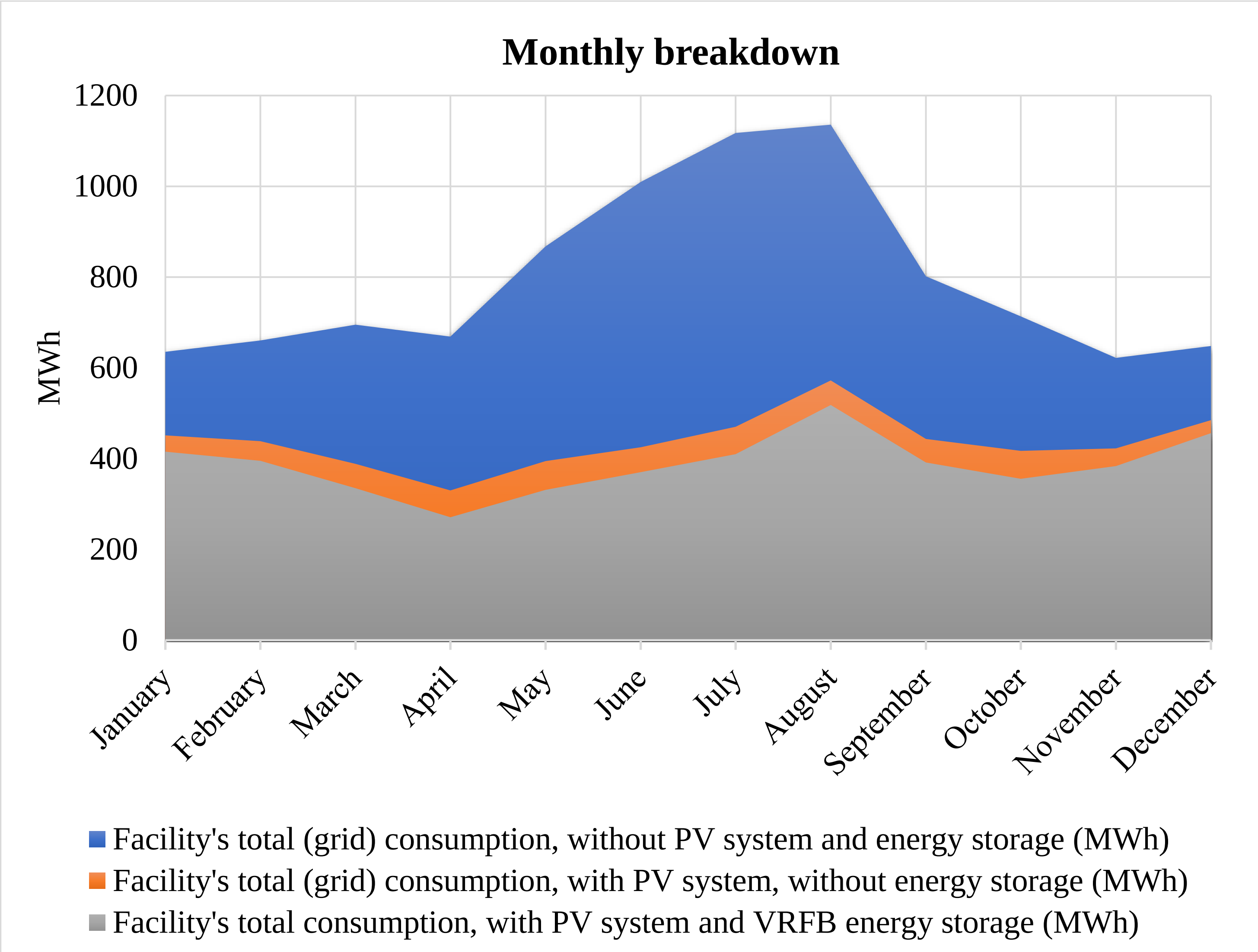

Figure 61. VRFB model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 1

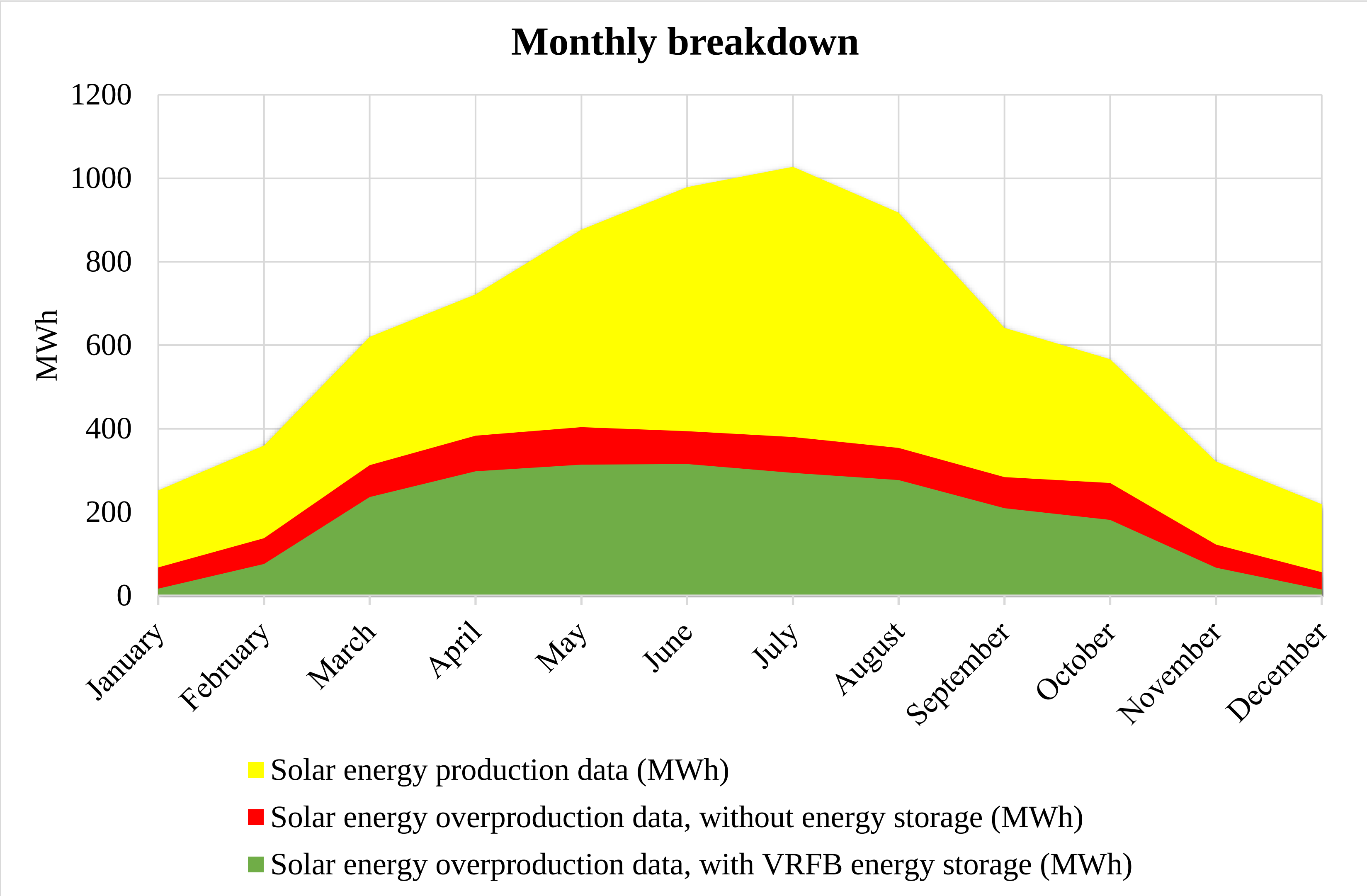

Figure 62. VRFB model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 1

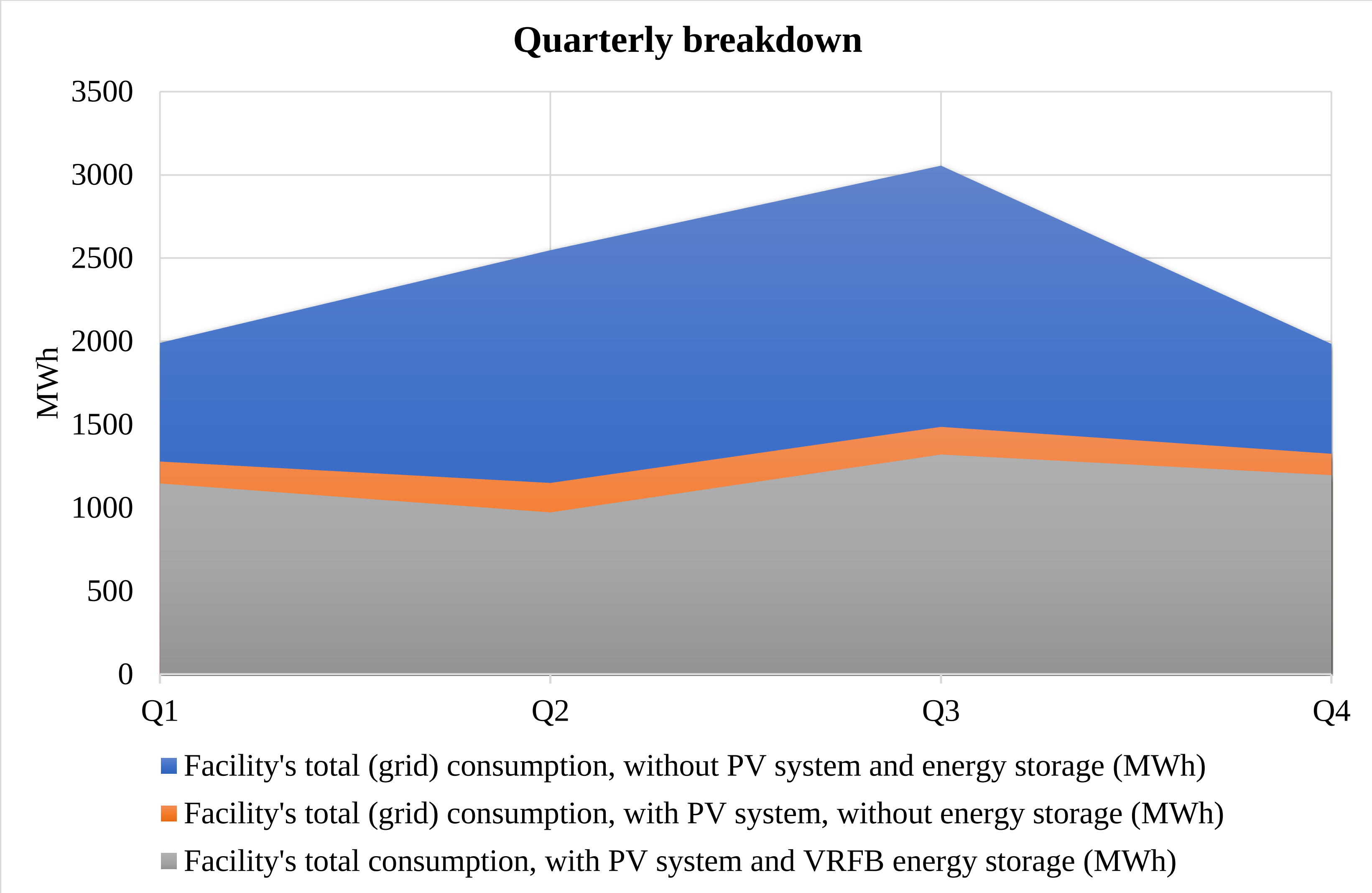

Figure 63. VRFB model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 1

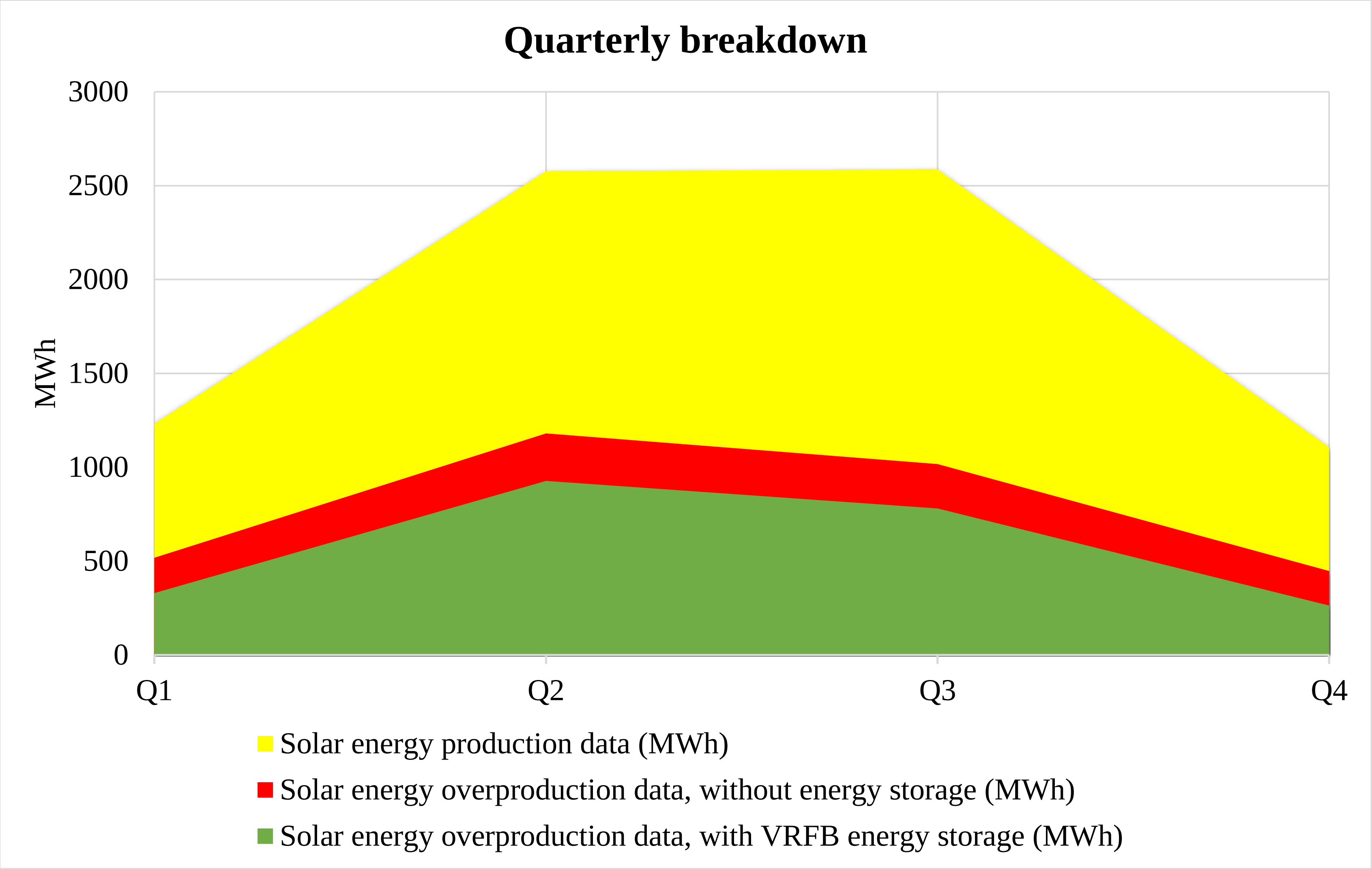

Figure 64. VRFB model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 1

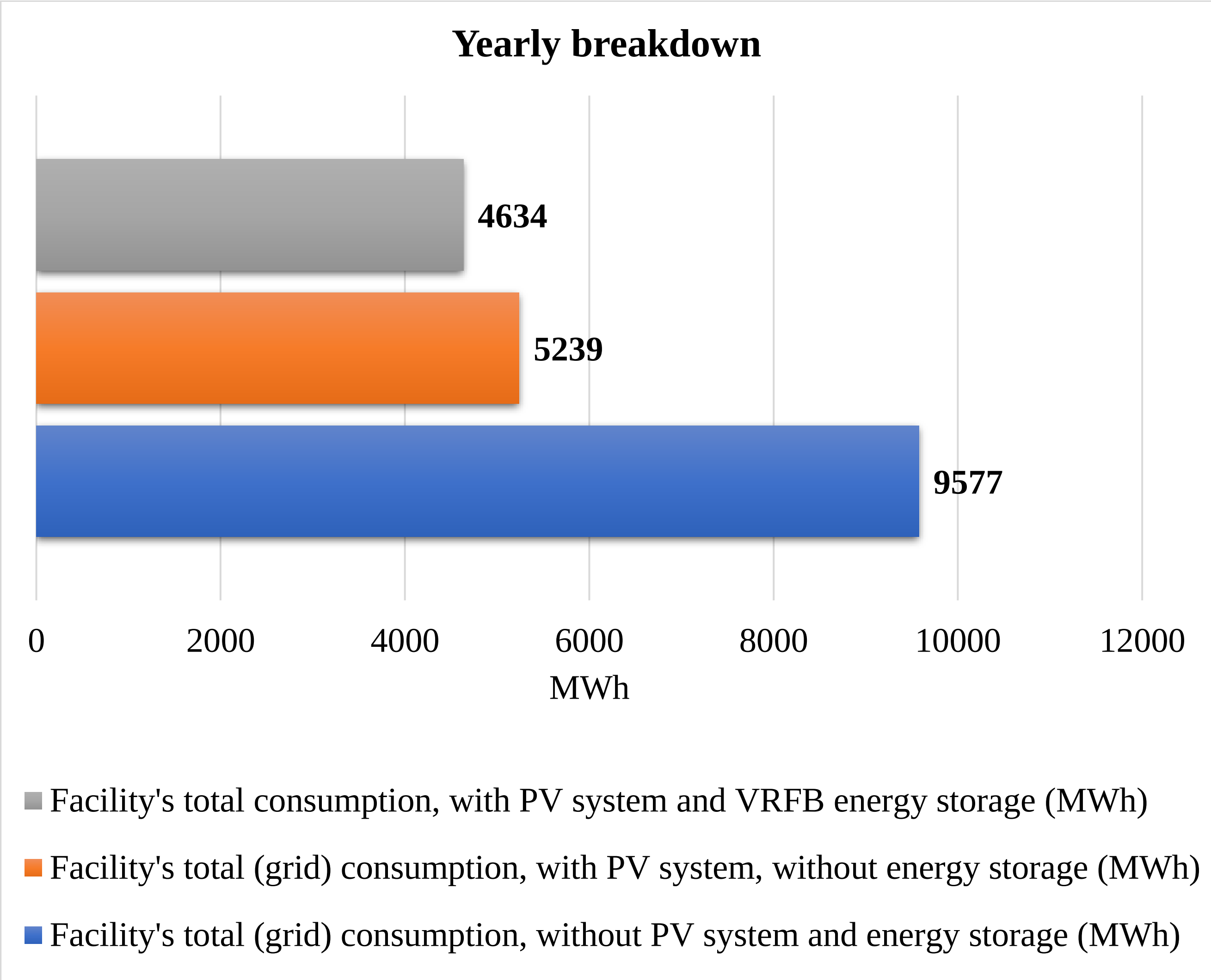

Figure 65. VRFB model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 1

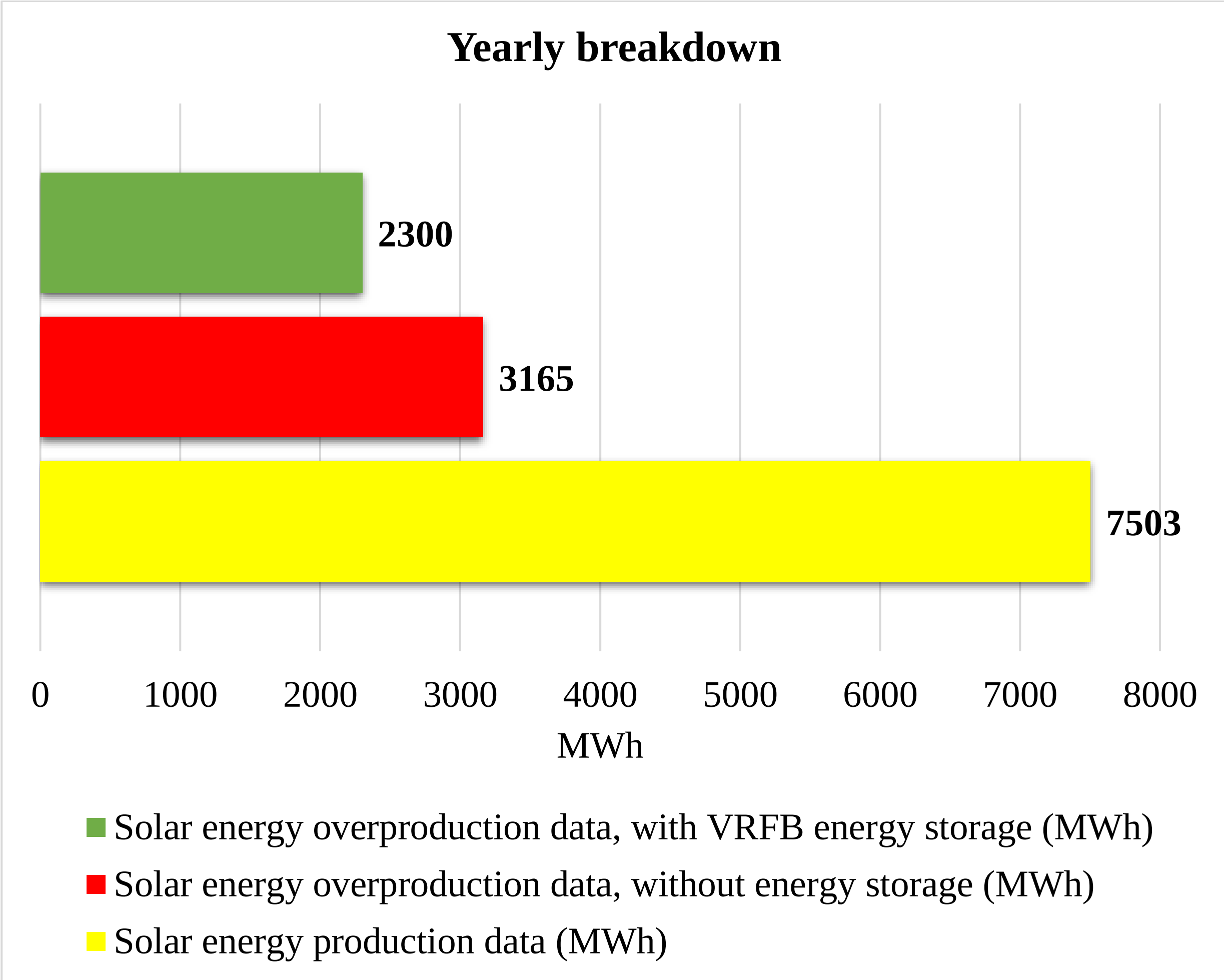

Figure 66. VRFB model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 1

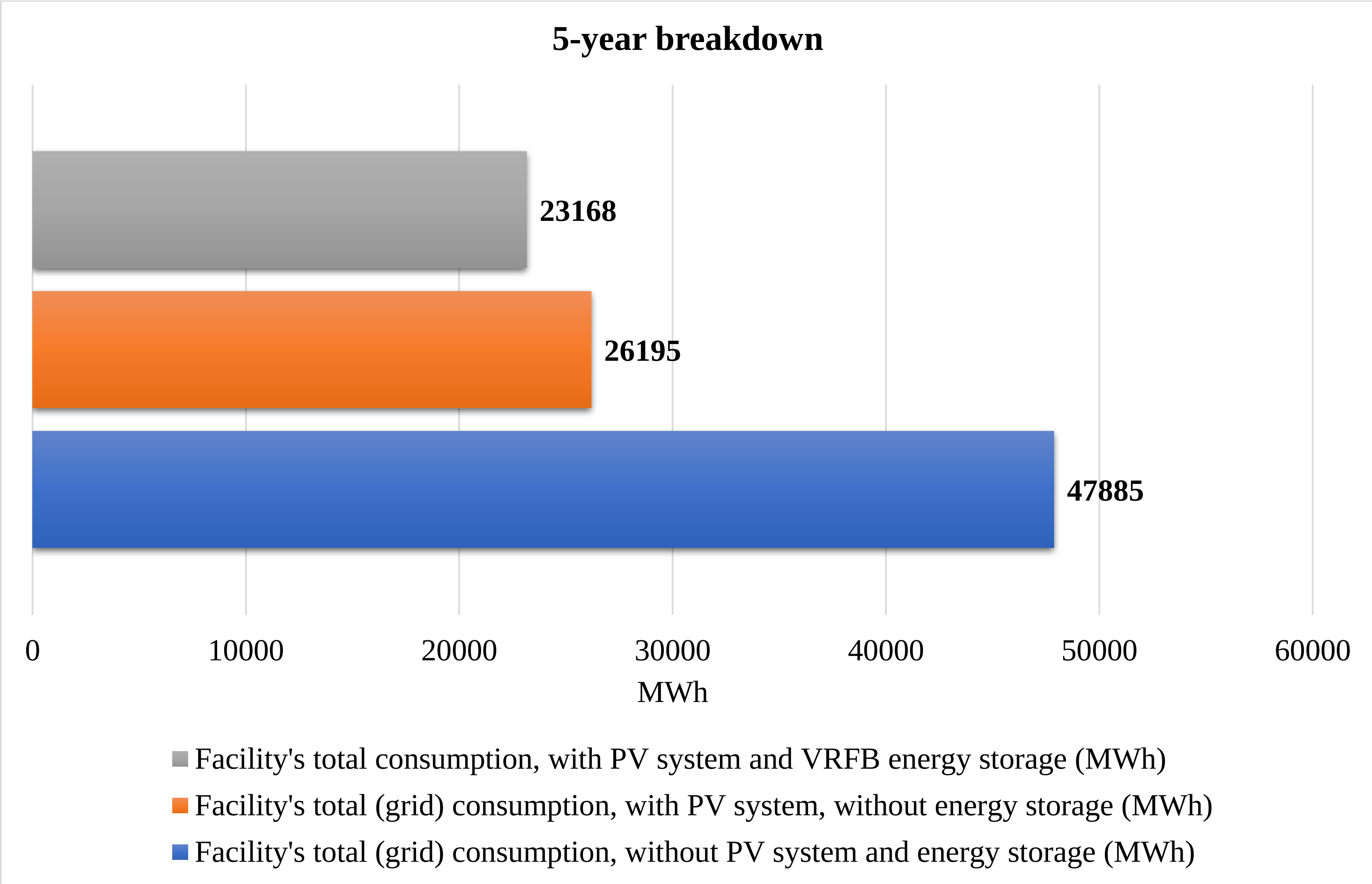

Figure 67. VRFB model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 1

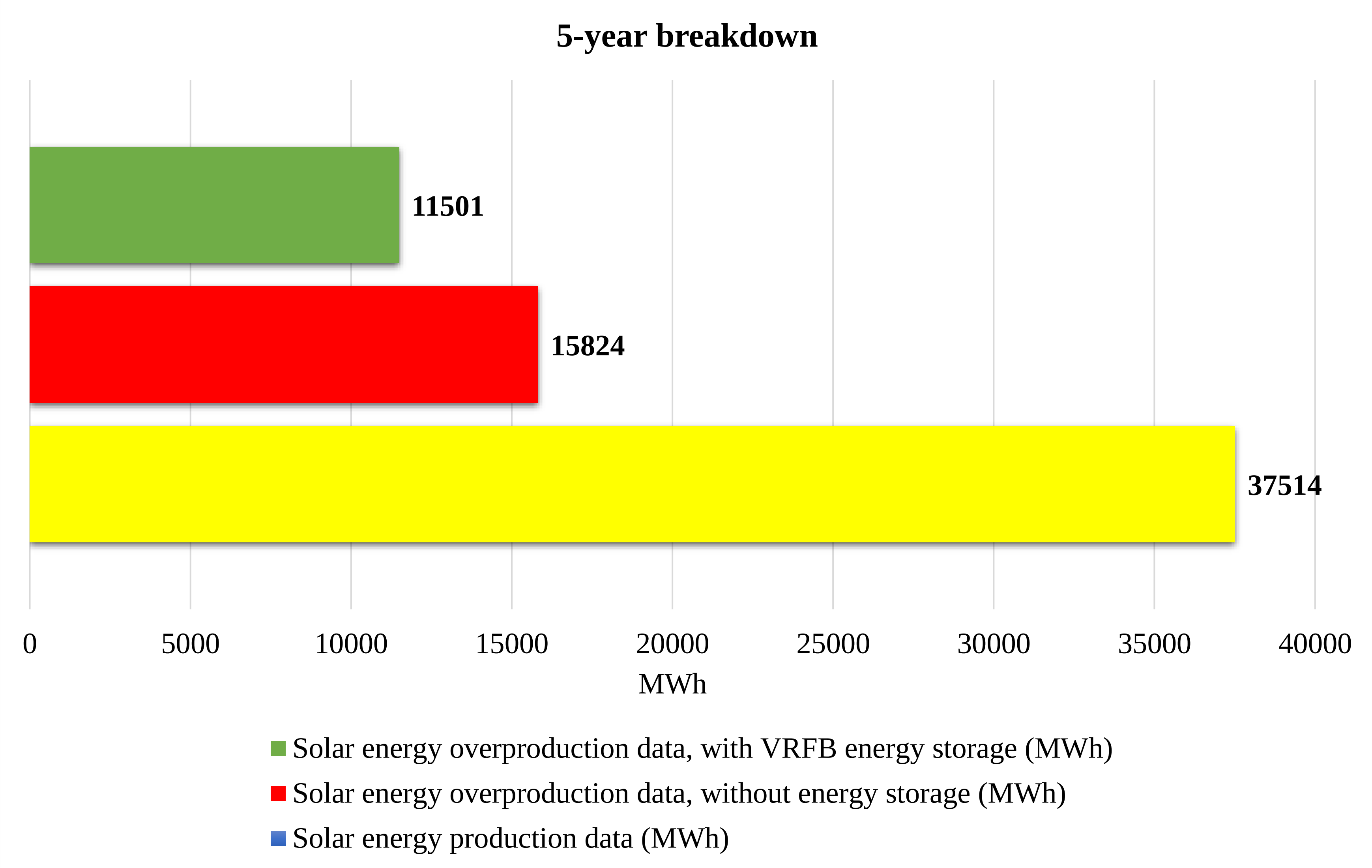

Figure 68. VRFB model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 1

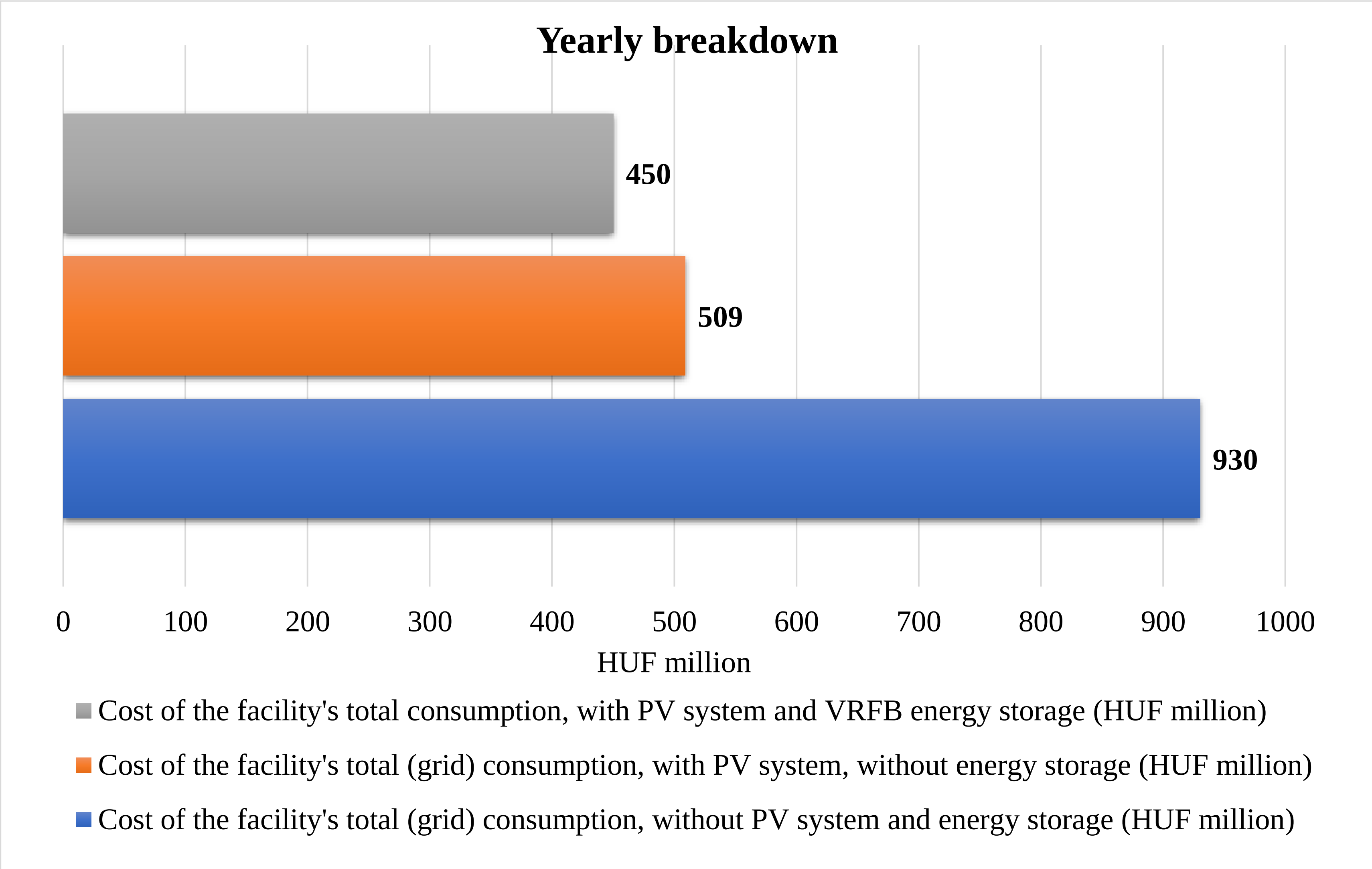

Figure 69. VRFB model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 1

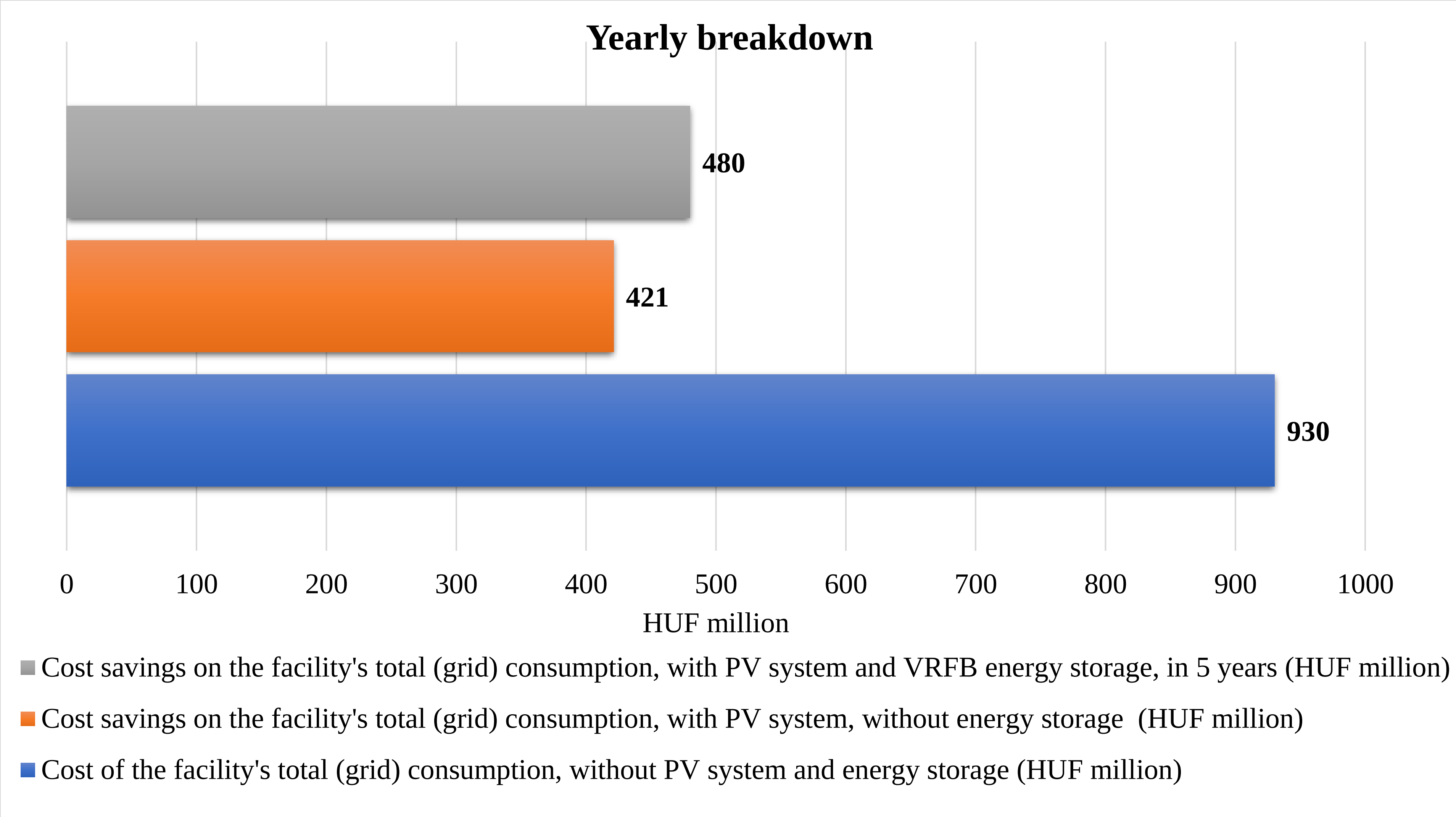

Figure 70. VRFB model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 1

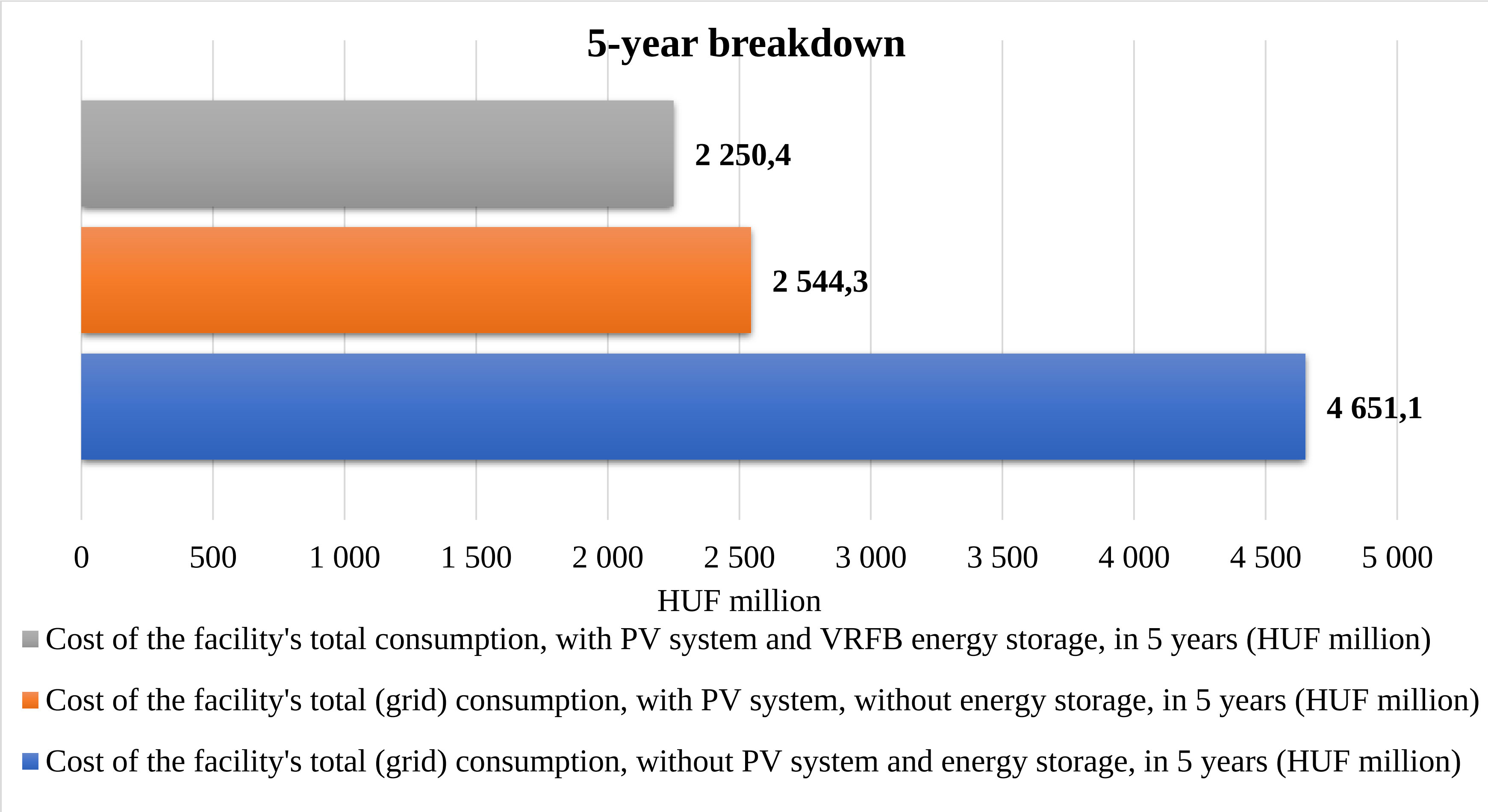

Figure 71. VRFB model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 1

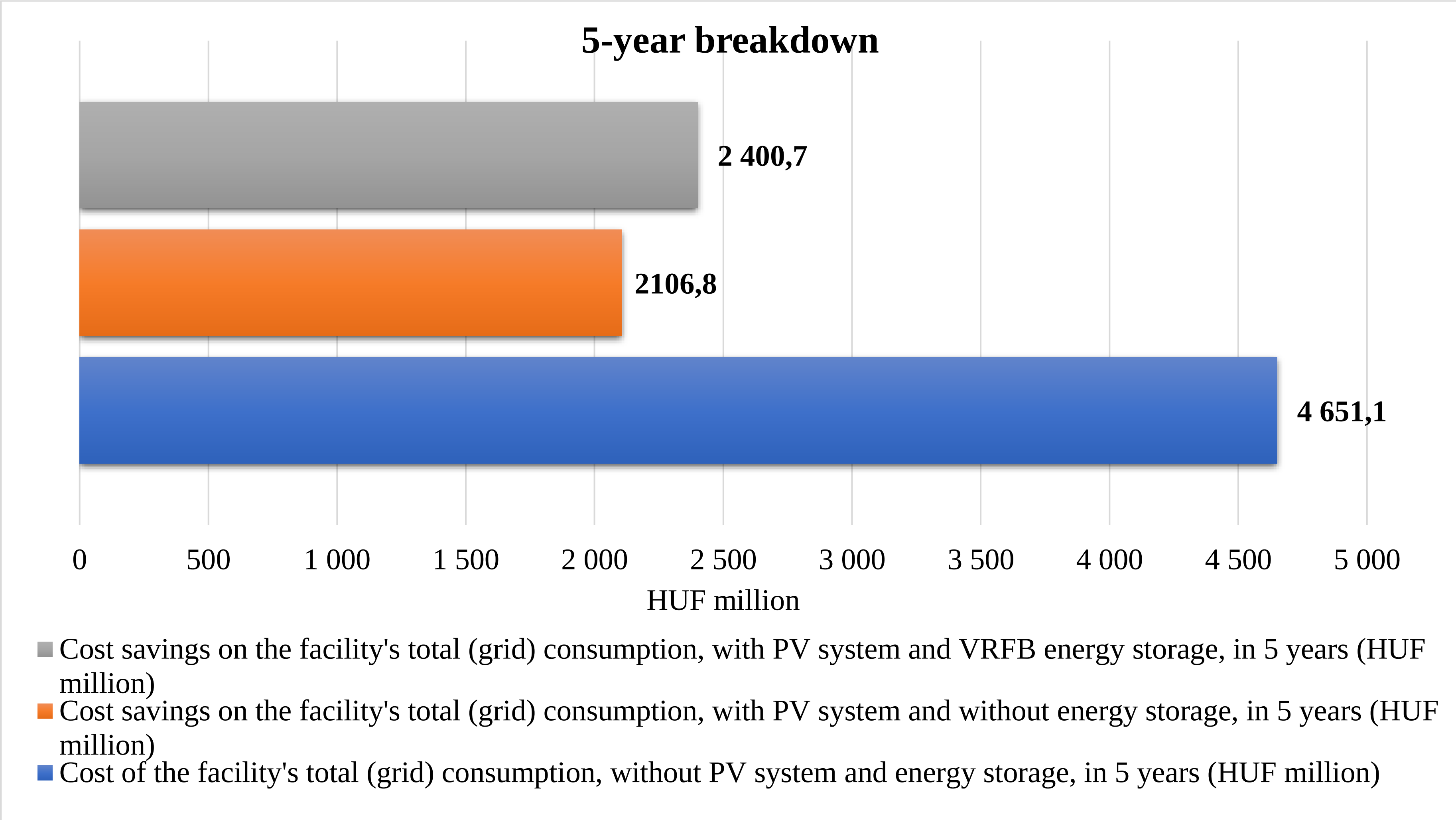

Figure 72. VRFB model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 1

3.8. VRFB, Scenario 2

Table 19. VRFB model-based energy efficiency analysis, Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with VRFB energy storage (MWh)	Discharge demand of the VRFB battery, with regard to the electricity to electricity efficiency (MWh)	Battery cycle count
January	635	451	395	252	68	0	57	9
February	661	438	348	360	138	7	91	14
March	695	388	241	620	313	101	147	22
April	669	330	175	722	383	160	155	23
May	868	394	235	877	404	174	159	24
June	1010	425	280	979	394	185	145	22
July	1118	470	310	1027	380	149	161	24
August	1136	572	436	918	354	158	136	21
September	802	444	313	642	284	95	131	20
October	714	417	280	566	270	72	138	21
November	622	423	334	322	123	0	89	14
December	648	485	440	219	56	0	45	7
Q1	1991	1278	984	1232	519	109	294	45
Q2	2546	1149	690	2578	1181	519	460	70
Q3	3055	1486	1059	2587	1018	402	428	65
Q4	1984	1325	1054	1107	448	72	271	41
1 year	9577	5239	3786	7503	3165	1102	1453	220
5 years	47885	26195	18930	37514	15824	5446	7264	1101

Table 20. VRFB model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system, without energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without energy storage (MWh)	Solar energy oveproduction data, with VRFB energy storage (MWh)
January	100%	71%	62%	100%	27%	0%
February	100%	66%	53%	100%	38%	2%
March	100%	56%	35%	100%	50%	16%
April	100%	49%	26%	100%	53%	22%
May	100%	45%	27%	100%	46%	20%
June	100%	42%	28%	100%	40%	19%
July	100%	42%	28%	100%	37%	14%
August	100%	50%	38%	100%	39%	17%
September	100%	55%	39%	100%	44%	15%
October	100%	58%	39%	100%	48%	13%
November	100%	68%	54%	100%	38%	0%
December	100%	75%	68%	100%	26%	0%
Q1	100%	64%	49%	100%	42%	9%
Q2	100%	45%	27%	100%	46%	20%
Q3	100%	49%	35%	100%	39%	16%
Q4	100%	67%	53%	100%	40%	6%
1 year	100%	55%	40%	100%	42%	15%
5 years	100%	55%	40%	100%	42%	15%

Table 21. VRFB model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 2

Time interval	Cost of the facility's total (grid) consumption, without PV system and energy storage (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost of the facility's total consumption, with PV system and VRFB energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system, without energy storage (HUF million)	Cost saving on the facility's total (grid) consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost saving on the VRFB energy storage system (HUF million)
January	62	44	38	18	23	5
February	64	43	34	22	30	9
March	68	38	23	30	44	14
April	65	32	17	33	48	15
May	84	38	23	46	61	15
June	98	41	27	57	71	14
July	109	46	30	63	78	16
August	110	56	42	55	68	13
September	78	43	30	35	47	13
October	69	41	27	29	42	13
November	60	41	32	19	28	9
December	63	47	43	16	20	4
Q1	193	124	96	69	98	29
Q2	247	112	67	136	180	45
Q3	297	144	103	152	194	42
Q4	193	129	102	64	90	26
1 year	930	509	368	421	562	141
5 years	4651	2544	1839	2107	2812	706

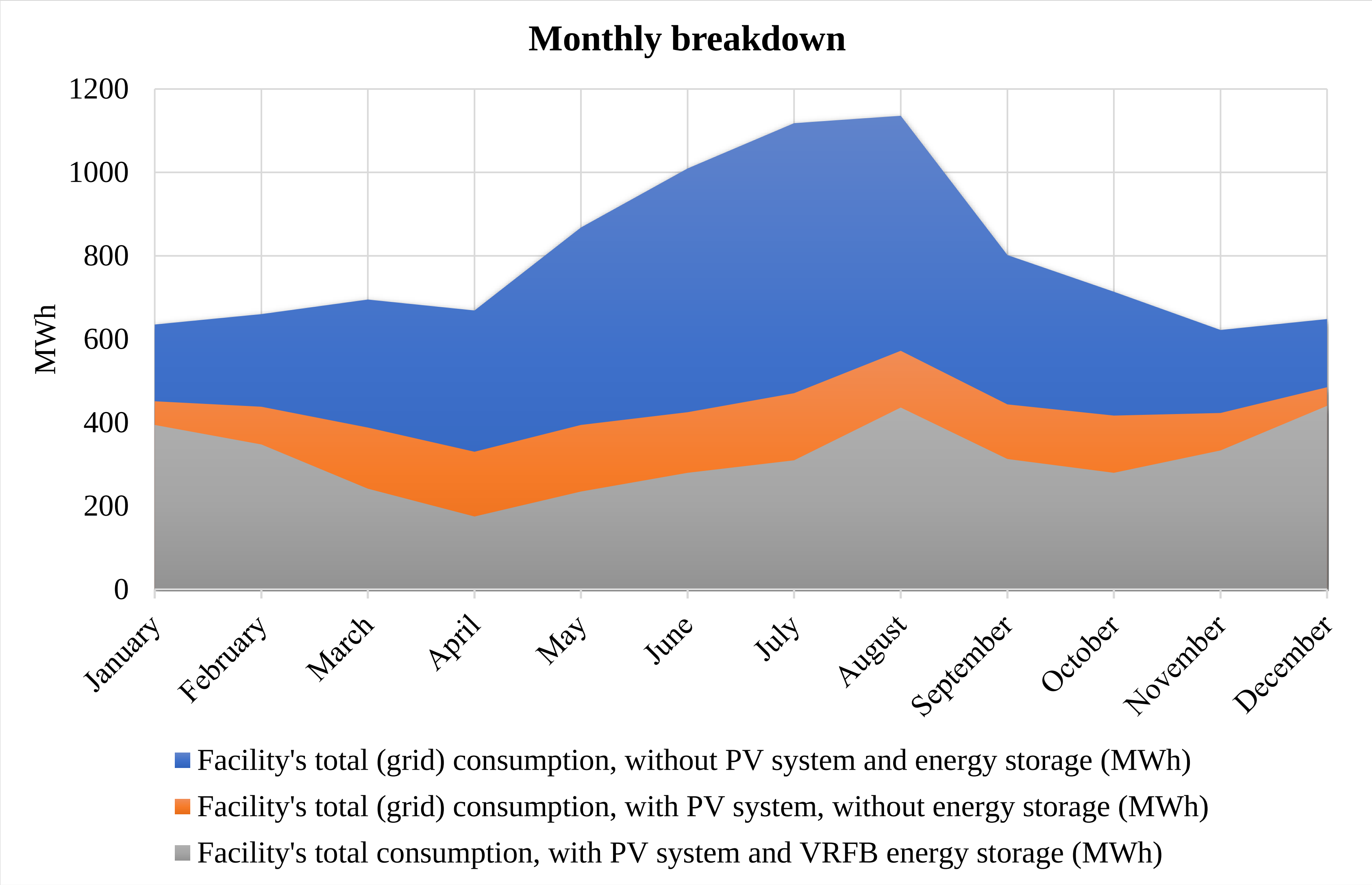

Figure 73. VRFB model-based energy efficiency analysis for total consumption, monthly breakdown, Scenario 2

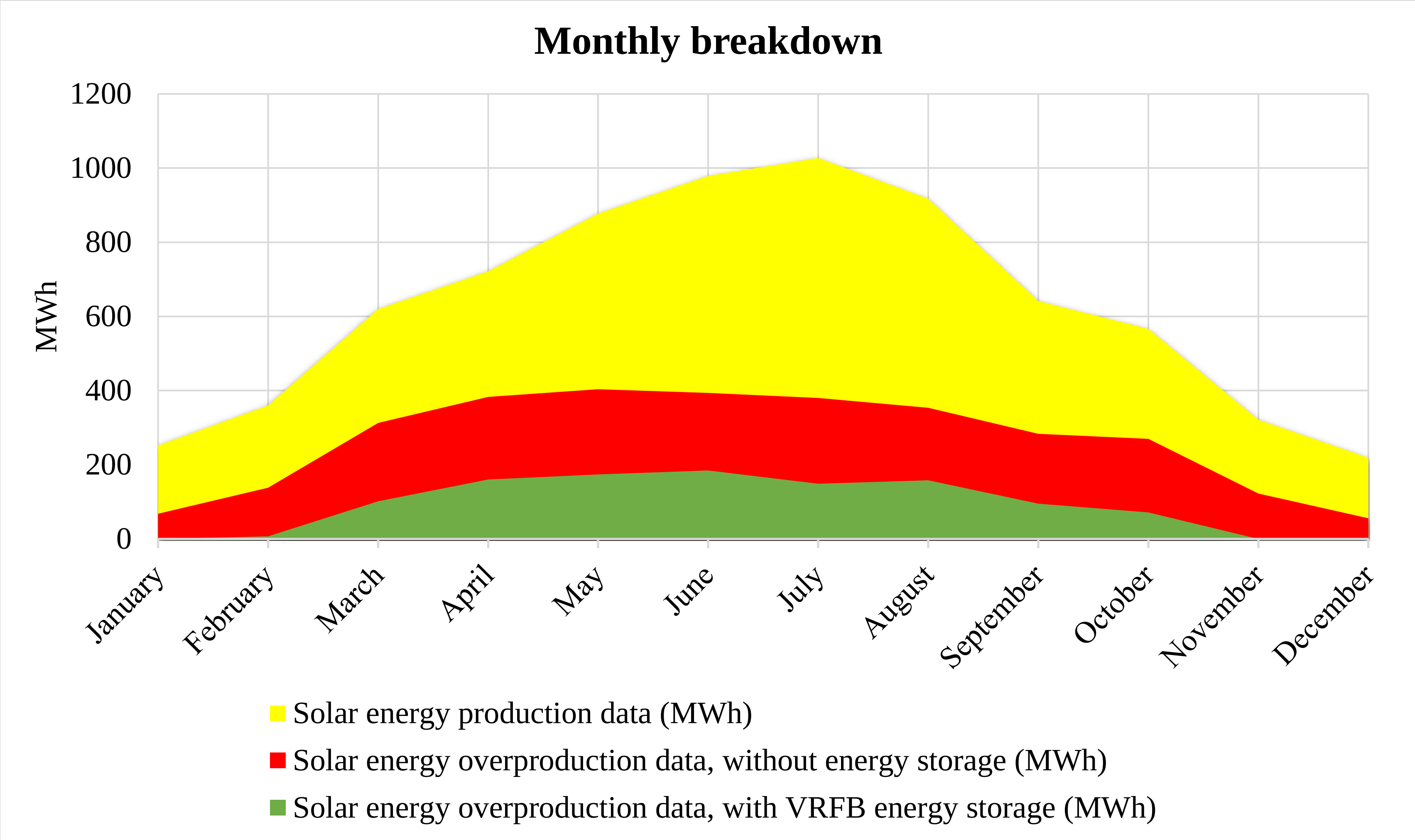

Figure 74. VRFB model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 2

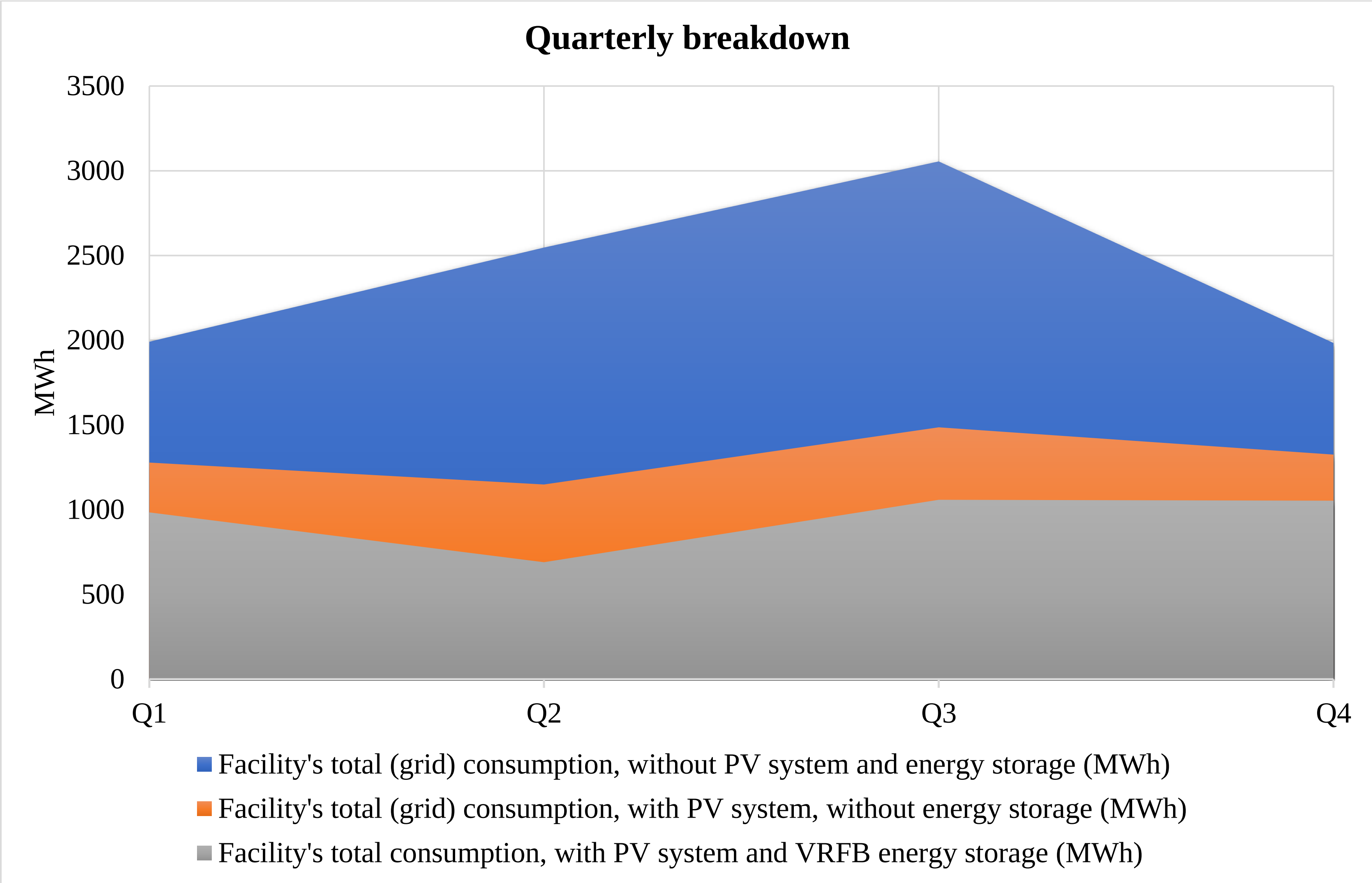

Figure 75. VRFB model-based energy efficiency analysis for total consumption, quarterly breakdown, Scenario 2

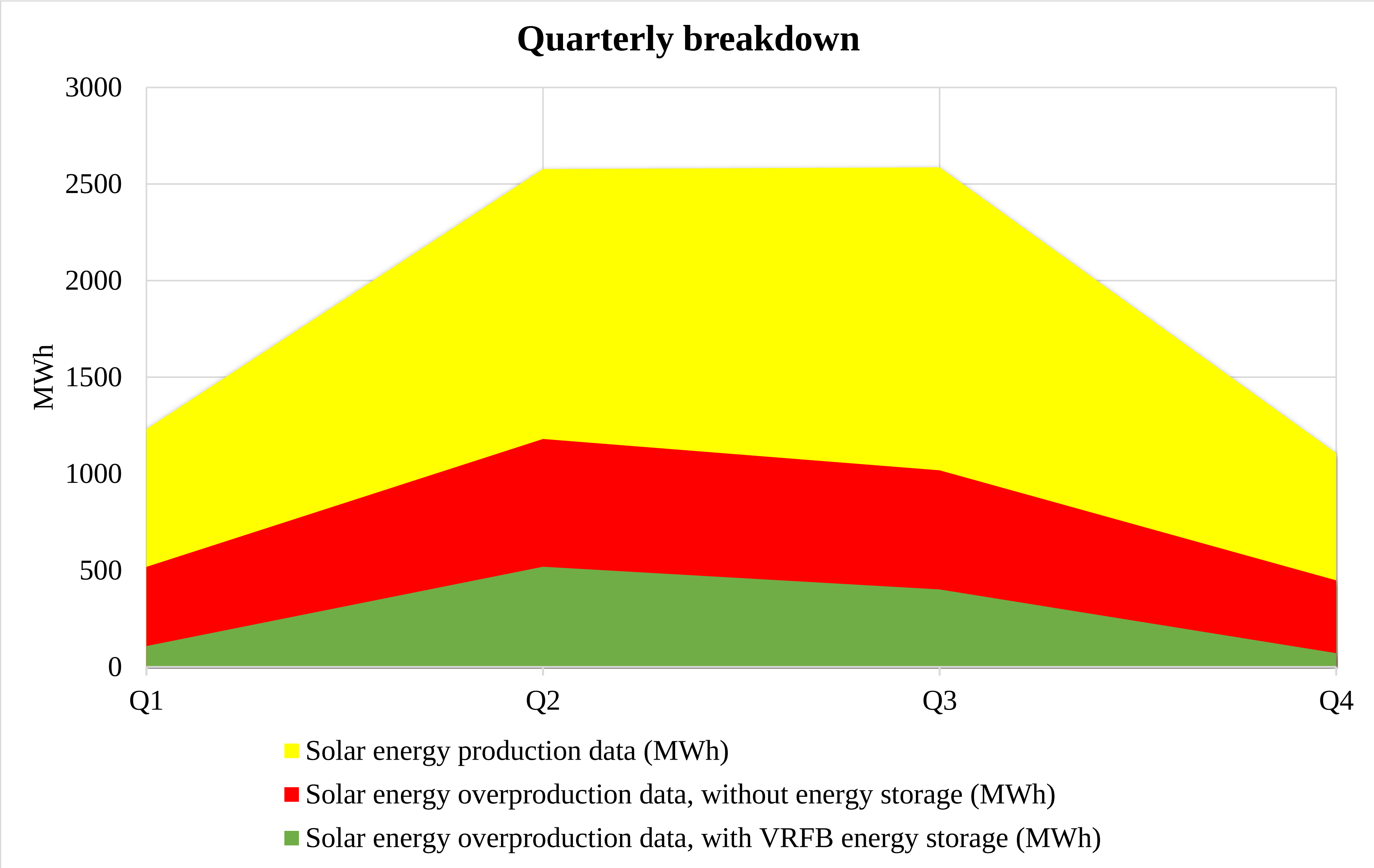

Figure 76. VRFB model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 2

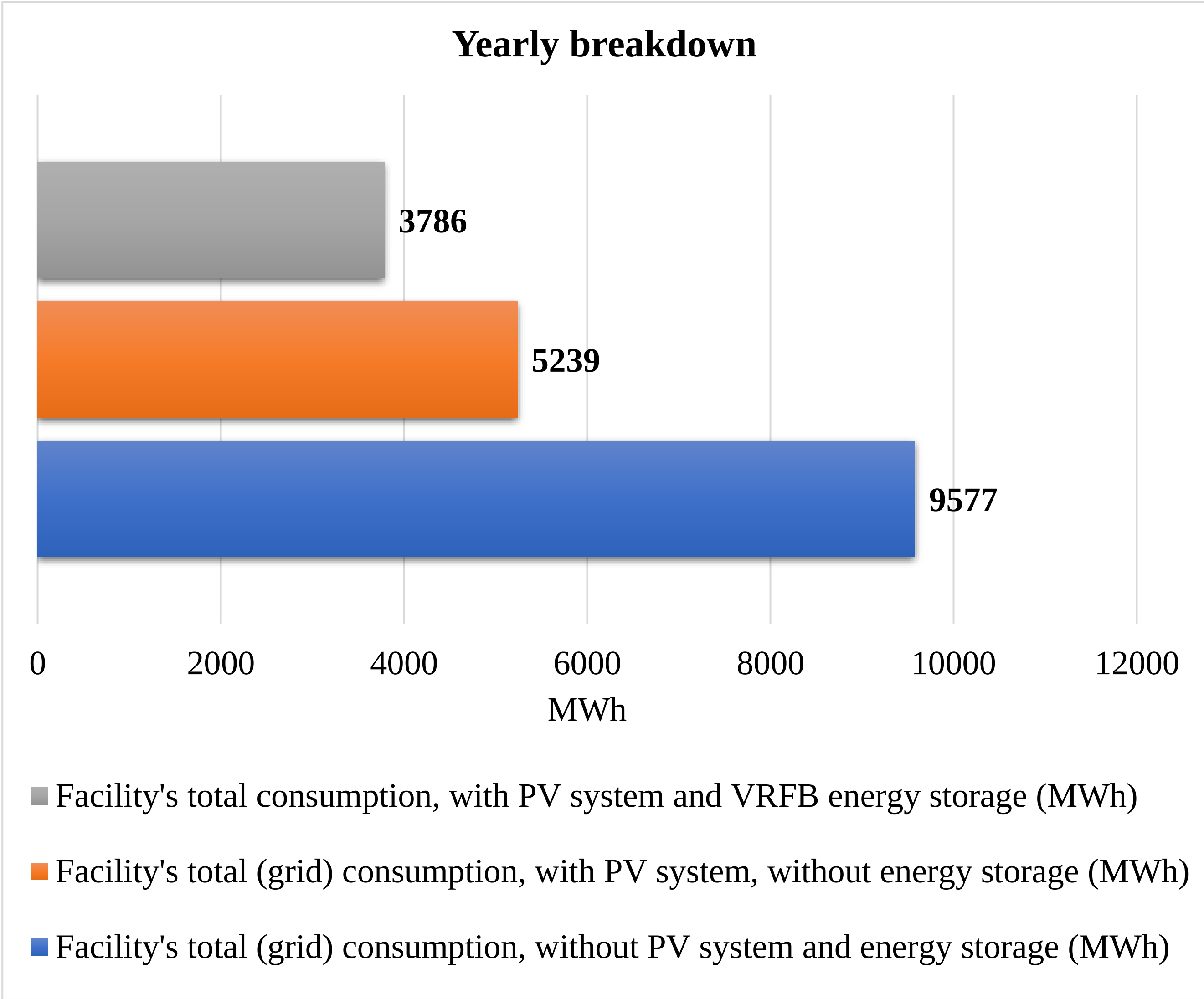

Figure 77. VRFB model-based energy efficiency analysis for total consumption, yearly breakdown, Scenario 2

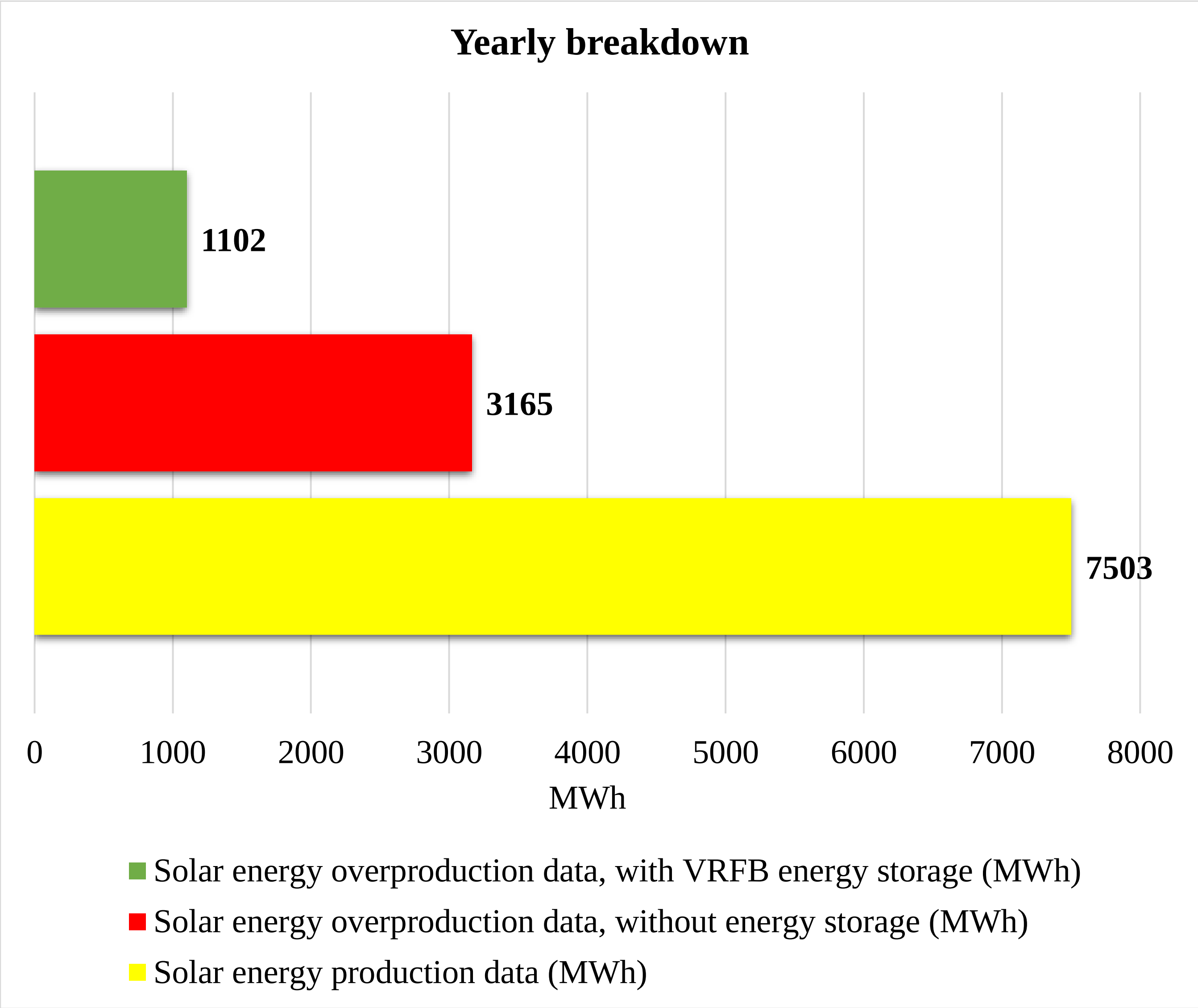

Figure 78. VRFB model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 2

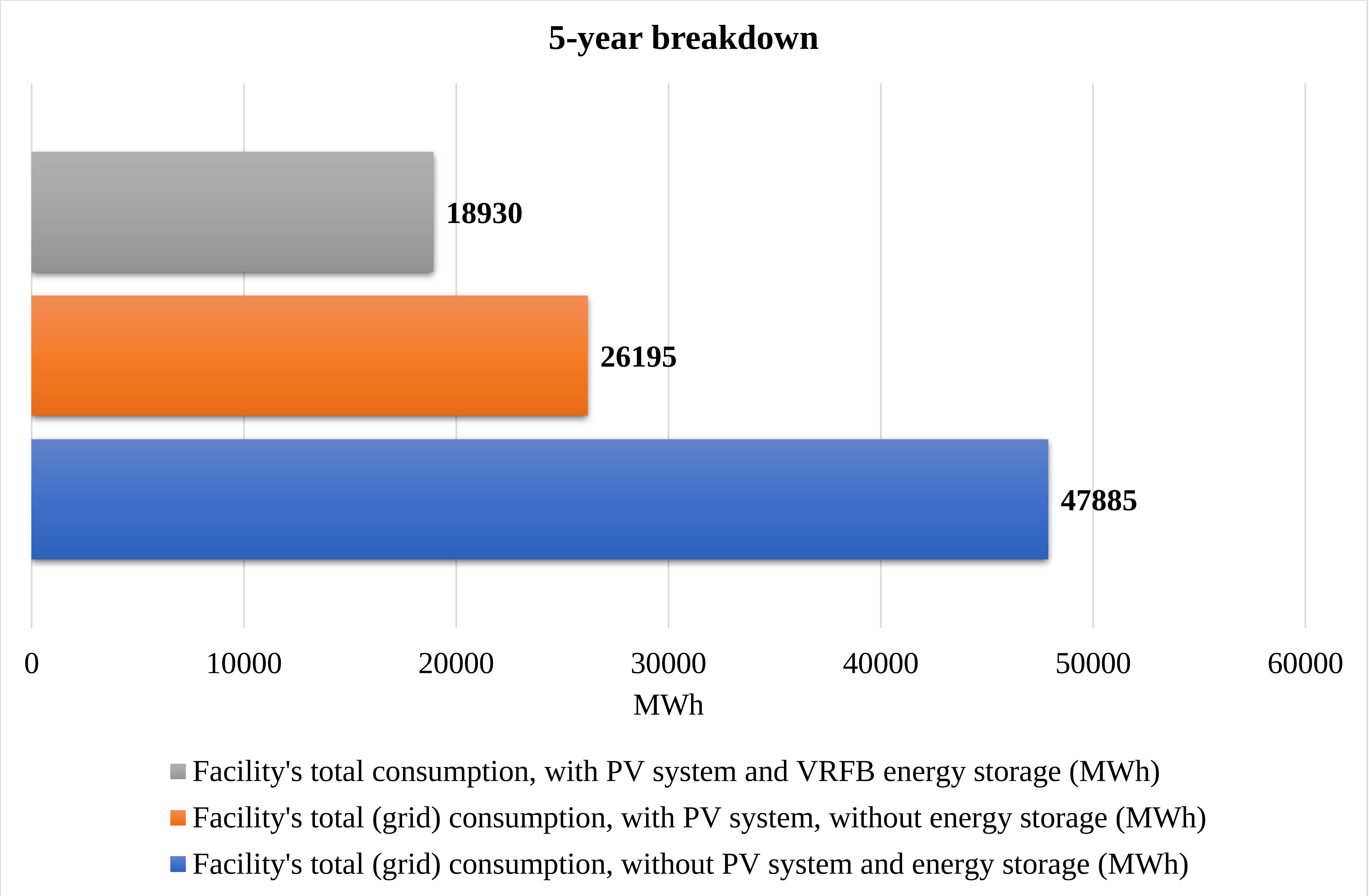

Figure 79. VRFB model-based energy efficiency analysis for total consumption, 5-year breakdown, Scenario 2

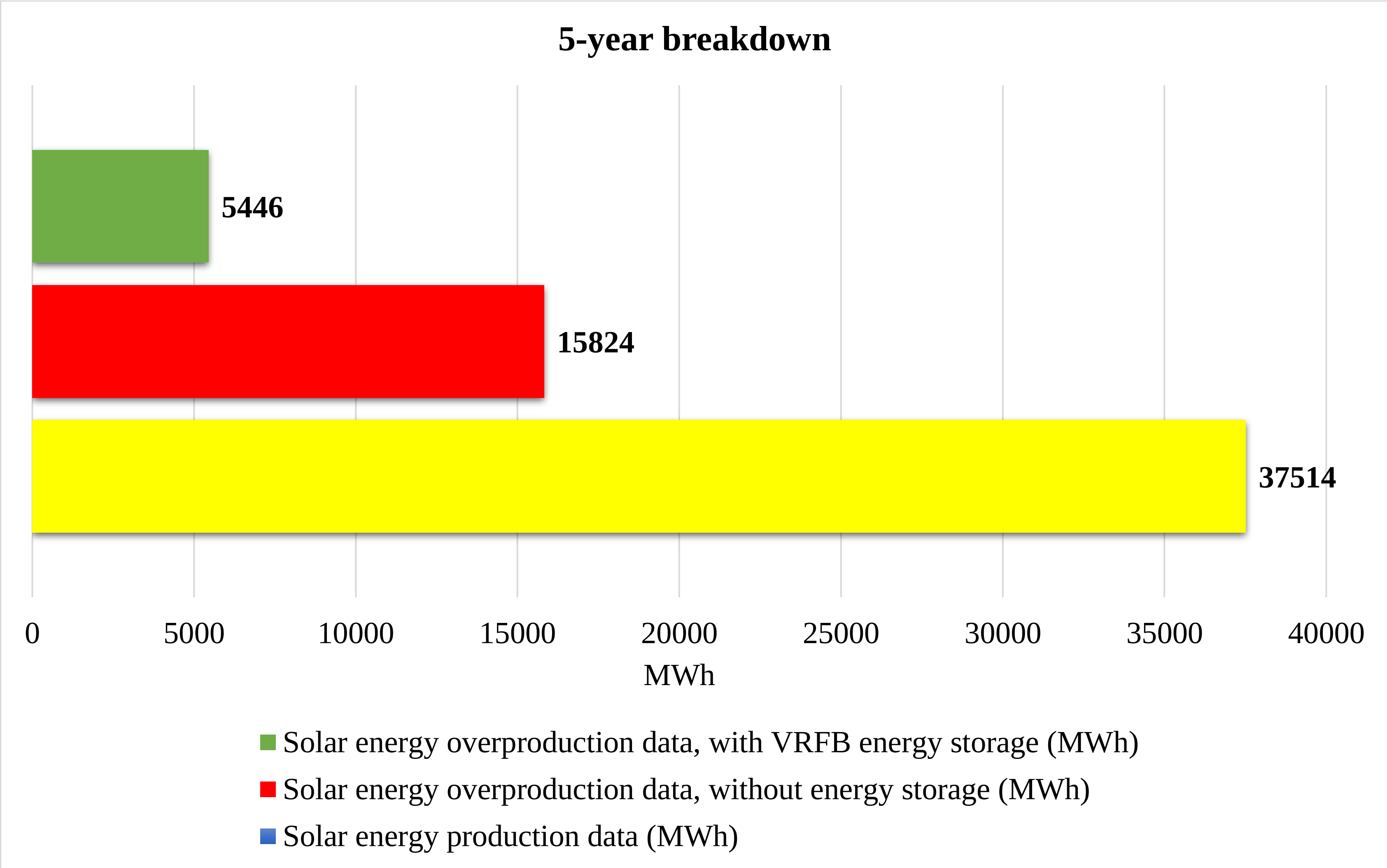

Figure 80. VRFB model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 2

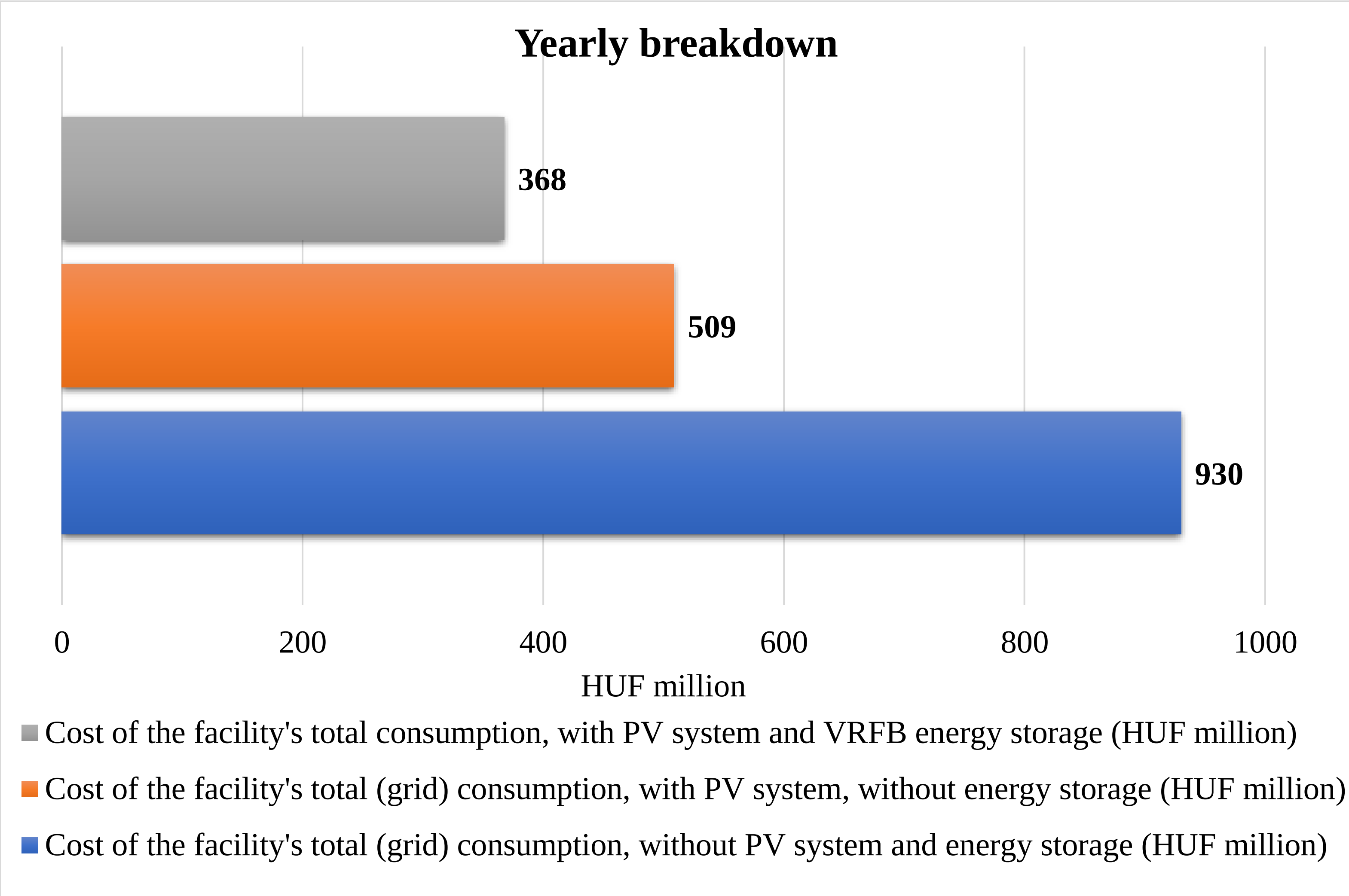

Figure 81. VRFB model-based energy efficiency analysis in terms of changes in the cost of total consumption, yearly breakdown, Scenario 2

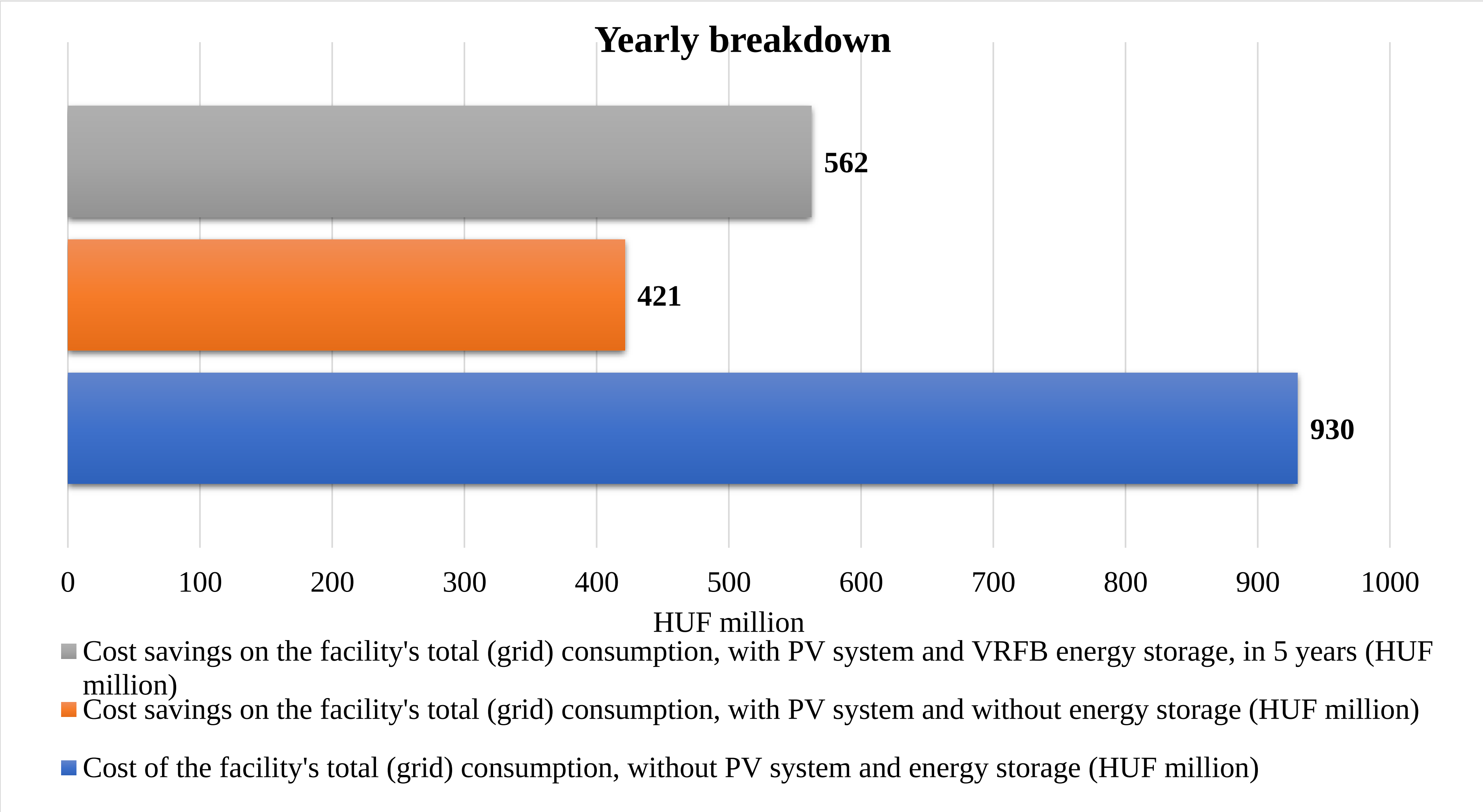

Figure 82. VRFB model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 2

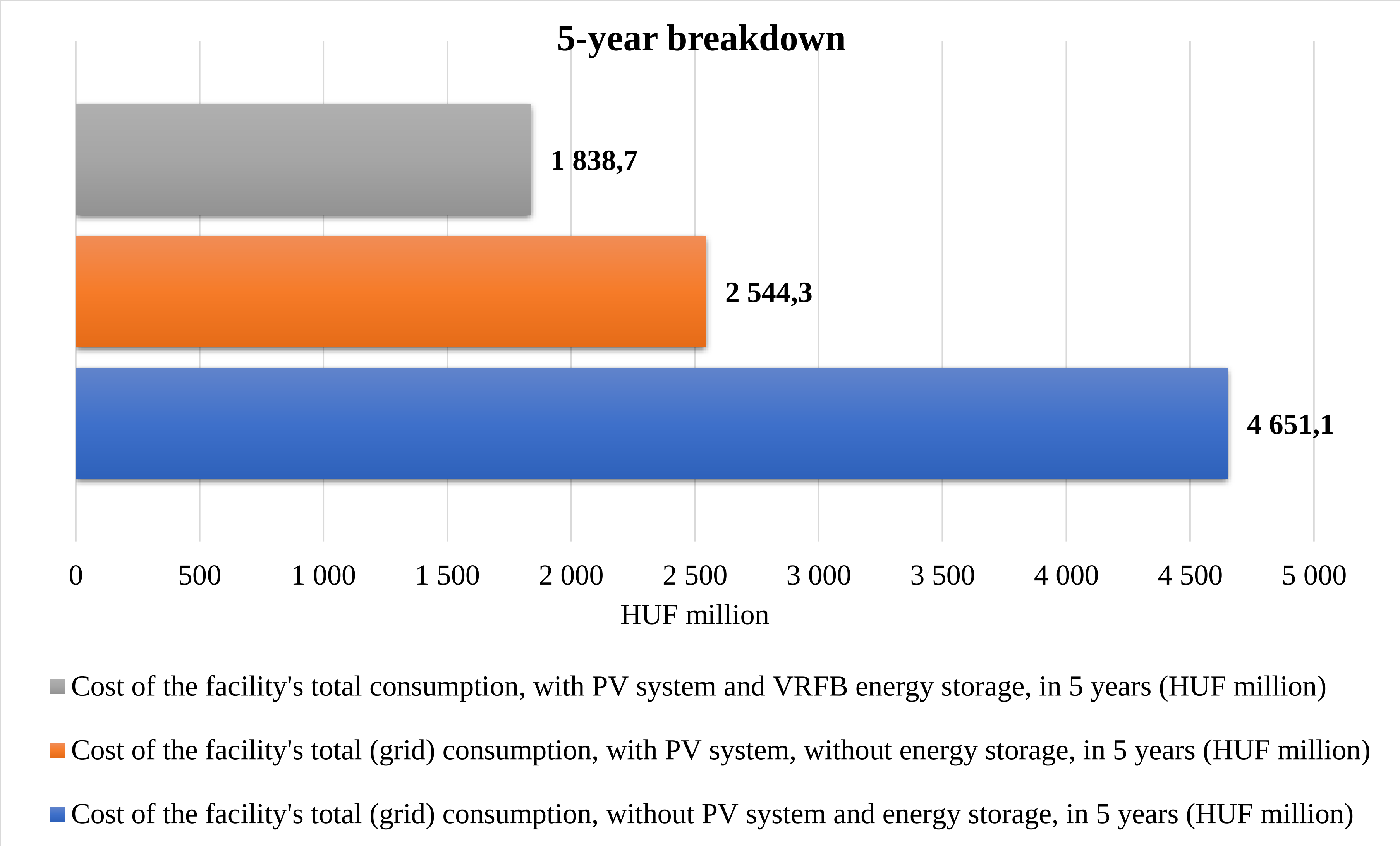

Figure 83. VRFB model-based energy efficiency analysis in terms of changes in the cost of total consumption, 5-year breakdown, Scenario 2

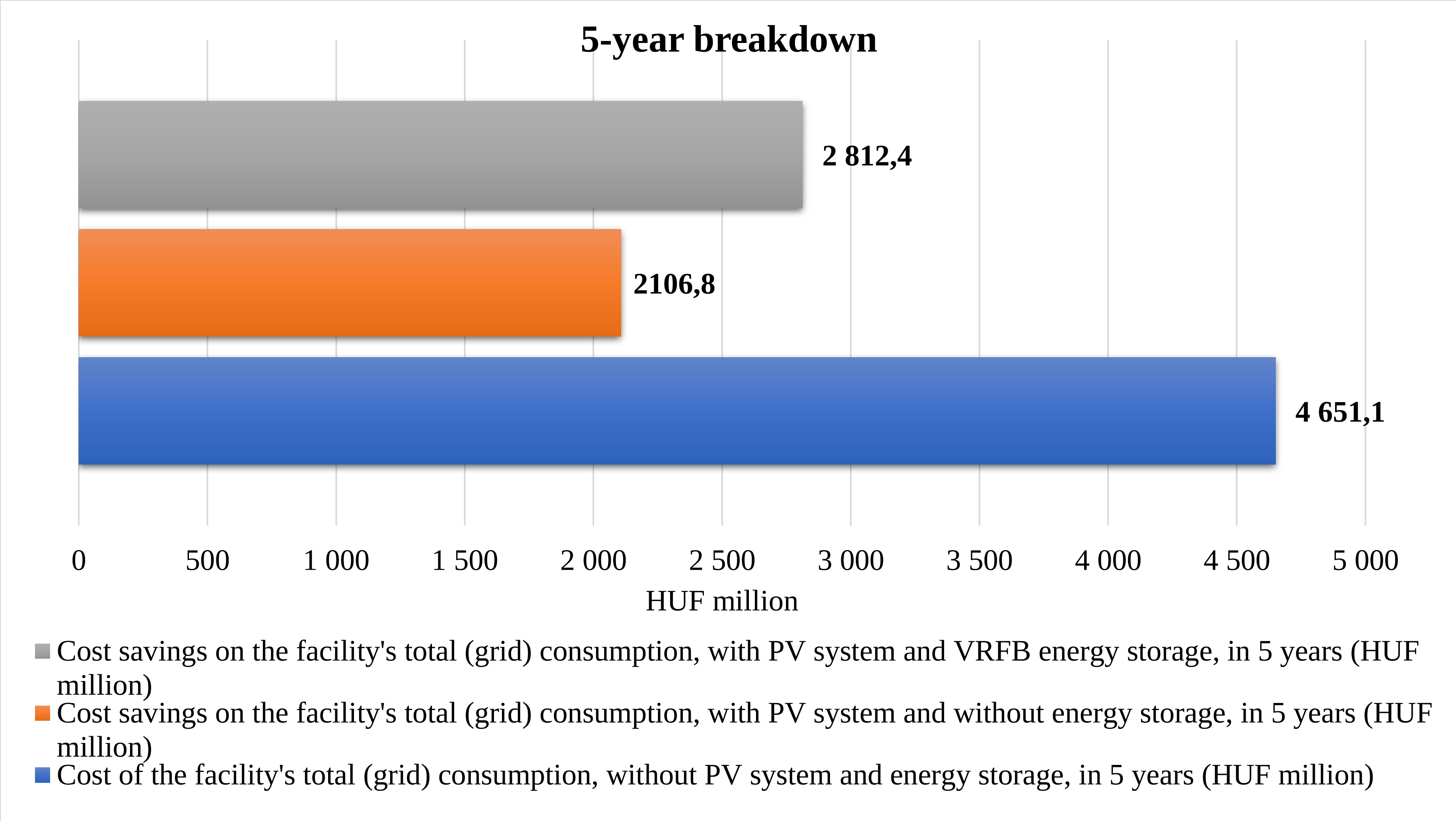

Figure 84. VRFB model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 2

3.9. H_2, Scenario 1

Table 22. H_2 model-based energy efficiency analysis, Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and H2 generation (MWh)	Facility's total (grid) consumption, with PV system, without H2 generation (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data, without H2 generation (MWh)	Solar energy oveproduction data, with H2 generation (MWh)	Liquid H2 generation potential, (with MC250 PEM generator), including loss (t)
January	635	451	252	68	2	1,2
February	661	438	360	138	25	2,1
March	695	388	620	313	89	4,2
April	669	330	722	383	136	4,6
May	868	394	877	404	142	4,9
June	1010	425	979	394	137	4,8
July	1118	470	1027	380	112	5,1
August	1136	572	918	354	125	4,3
September	802	444	642	284	94	3,6
October	714	417	566	270	76	3,7
November	622	423	322	123	14	2,0
December	648	485	219	56	3	1,0
Q1	1991	1278	1232	519	116	7,6
Q2	2546	1149	2578	1181	416	14,4
Q3	3055	1486	2587	1018	330	12,9
Q4	1984	1325	1107	448	92	6,7
1 year	9577	5239	7503	3165	955	41,6
5 years	47885	26195	37514	15824	4773	208,1

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Table 23. H_2 model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 1

Time interval	Facility's total (grid) consumption, without PV system and H2 generation (MWh)	Facility's total (grid) consumption, with PV system, without H2 generation (MWh)	Solar energy production data (MWh)	Solar energy overproduction data, without H2 generation (MWh)	Solar energy overproduction data, with H2 generation (MWh)
January	100%	71%	100%	27%	1%
February	100%	66%	100%	38%	7%
March	100%	56%	100%	50%	14%
April	100%	49%	100%	53%	19%
May	100%	45%	100%	46%	16%
June	100%	42%	100%	40%	14%
July	100%	42%	100%	37%	11%
August	100%	50%	100%	39%	14%
September	100%	55%	100%	44%	15%
October	100%	58%	100%	48%	13%
November	100%	68%	100%	38%	4%
December	100%	75%	100%	26%	1%
Q1	100%	64%	100%	42%	9%
Q2	100%	45%	100%	46%	16%
Q3	100%	49%	100%	39%	13%
Q4	100%	67%	100%	40%	8%
1 year	100%	55%	100%	42%	13%
5 years	100%	55%	100%	42%	13%

Table 24. H_2 model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 1

Time interval	Cost of the facility's total (grid) consumption, without PV system and H2 generation (HUF million)	Cost of the facility's total (grid) consumption, with PV system, without H2 generation (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system, without H2 generation (HUF million)	Facility's cost savings taking into account the solar energy oveproduction data, with the generation of liquid H2 (HUF million)	Cost savings with H2 generation (HUF million)
January	62	44	18	20	2,1
February	64	43	22	25	3,5
March	68	38	30	37	7,0
April	65	32	33	41	7,7
May	84	38	46	54	8,2
June	98	41	57	65	8,1
July	109	46	63	71	8,4
August	110	56	55	62	7,2
September	78	43	35	41	6,0
October	69	41	29	35	6,1
November	60	41	19	23	3,4
December	63	47	16	18	1,7
Q1	193	124	69	82	12,6
Q2	247	112	136	160	24,0
Q3	297	144	152	174	21,6
Q4	193	129	64	75	11,2
1 year	930	509	421	491	69,3
5 years	4 651	2 544	2 107	2 453	346,5

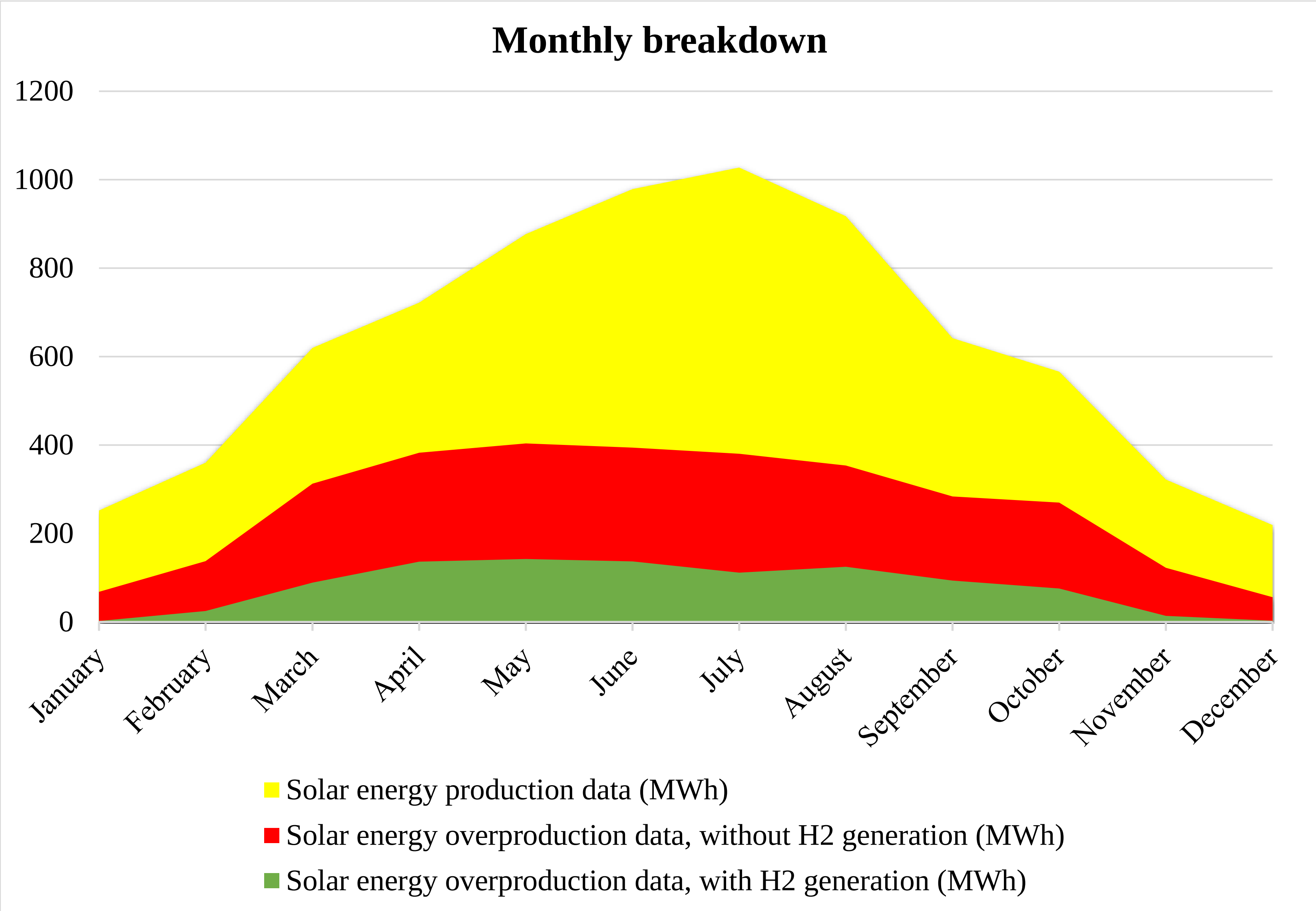


Figure 85. H_2 model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 1

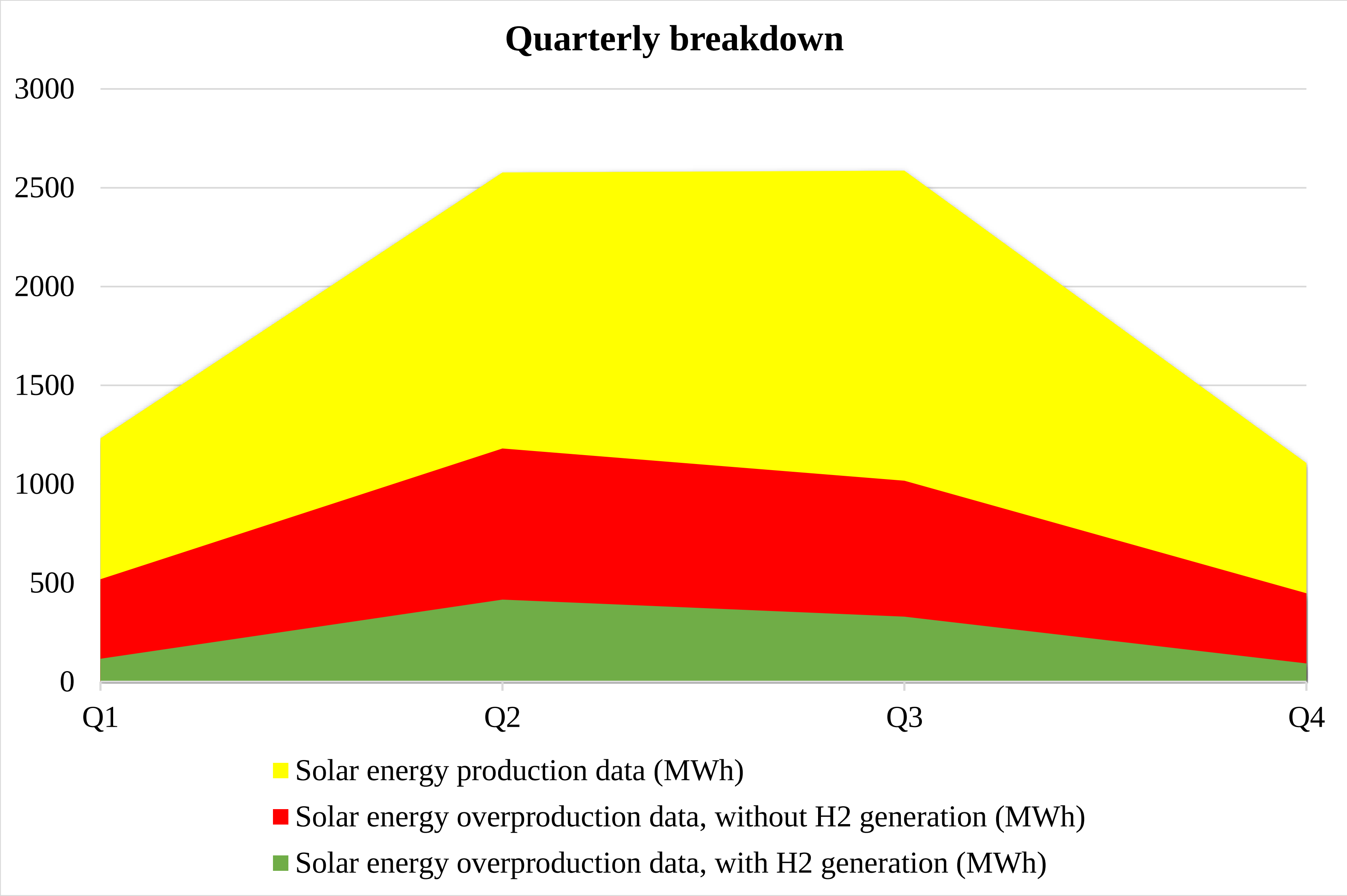


Figure 86. H_2 model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 1

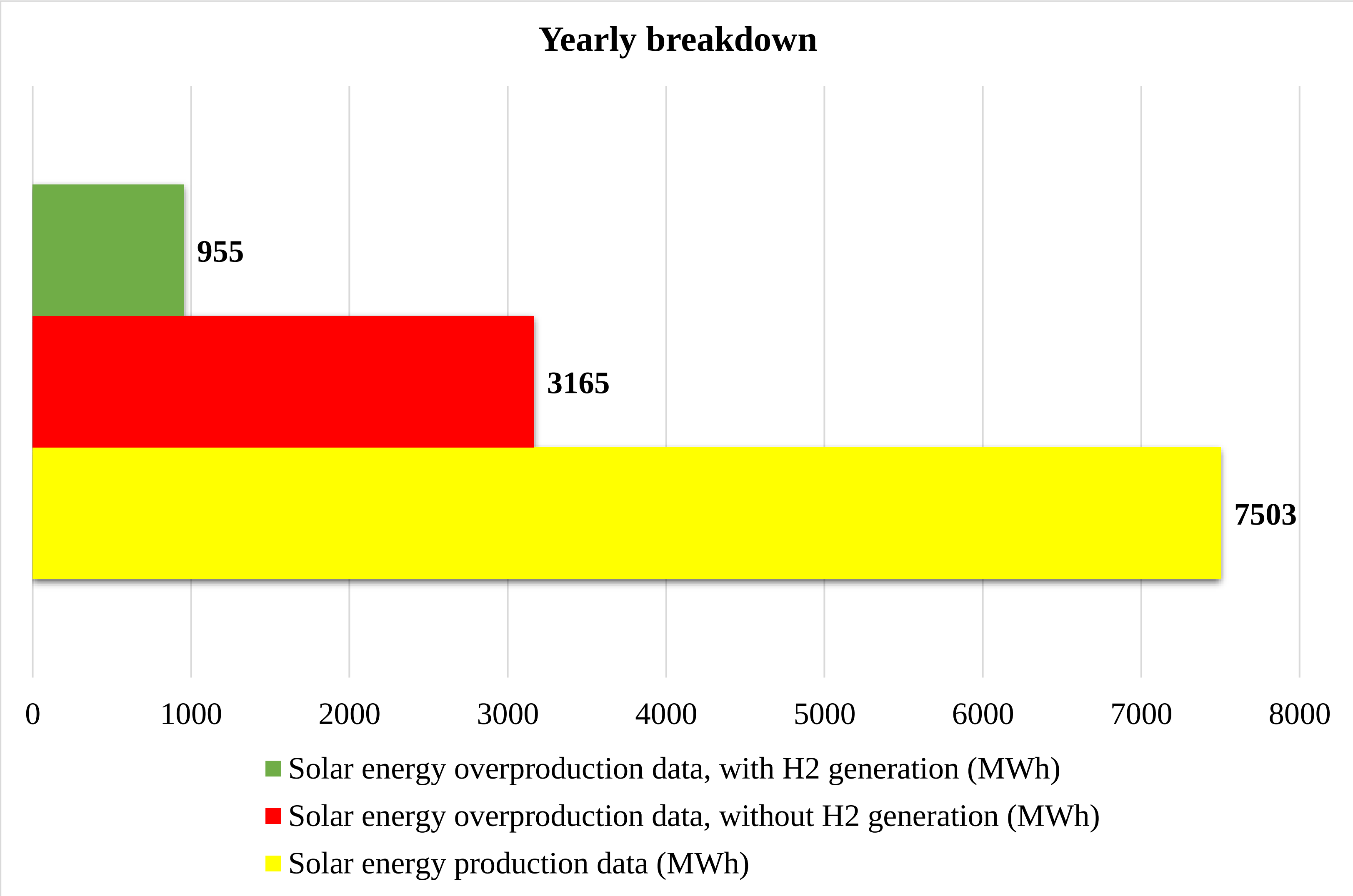


Figure 87. H_2 model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 1

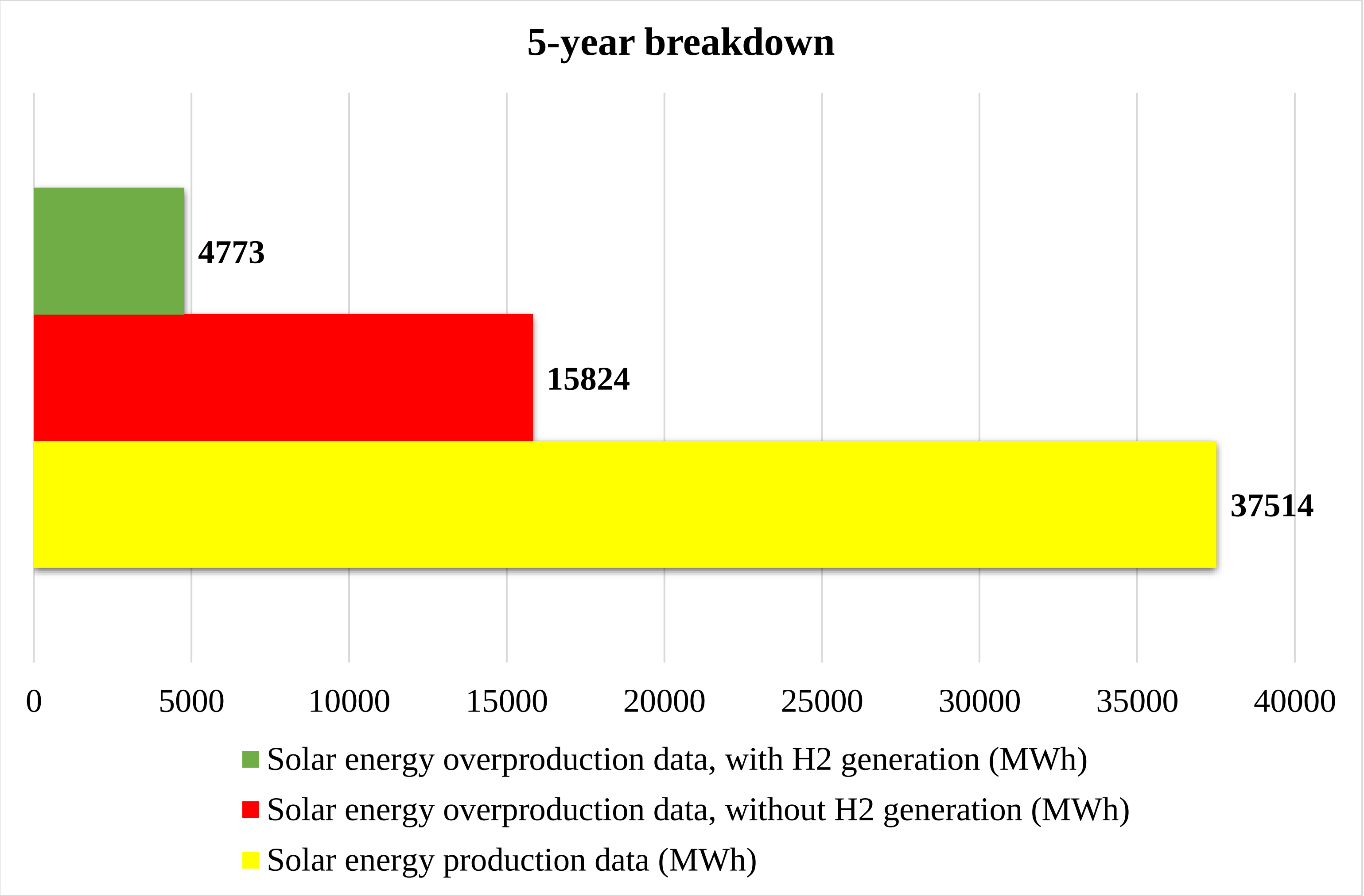


Figure 88. H_2 model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 1

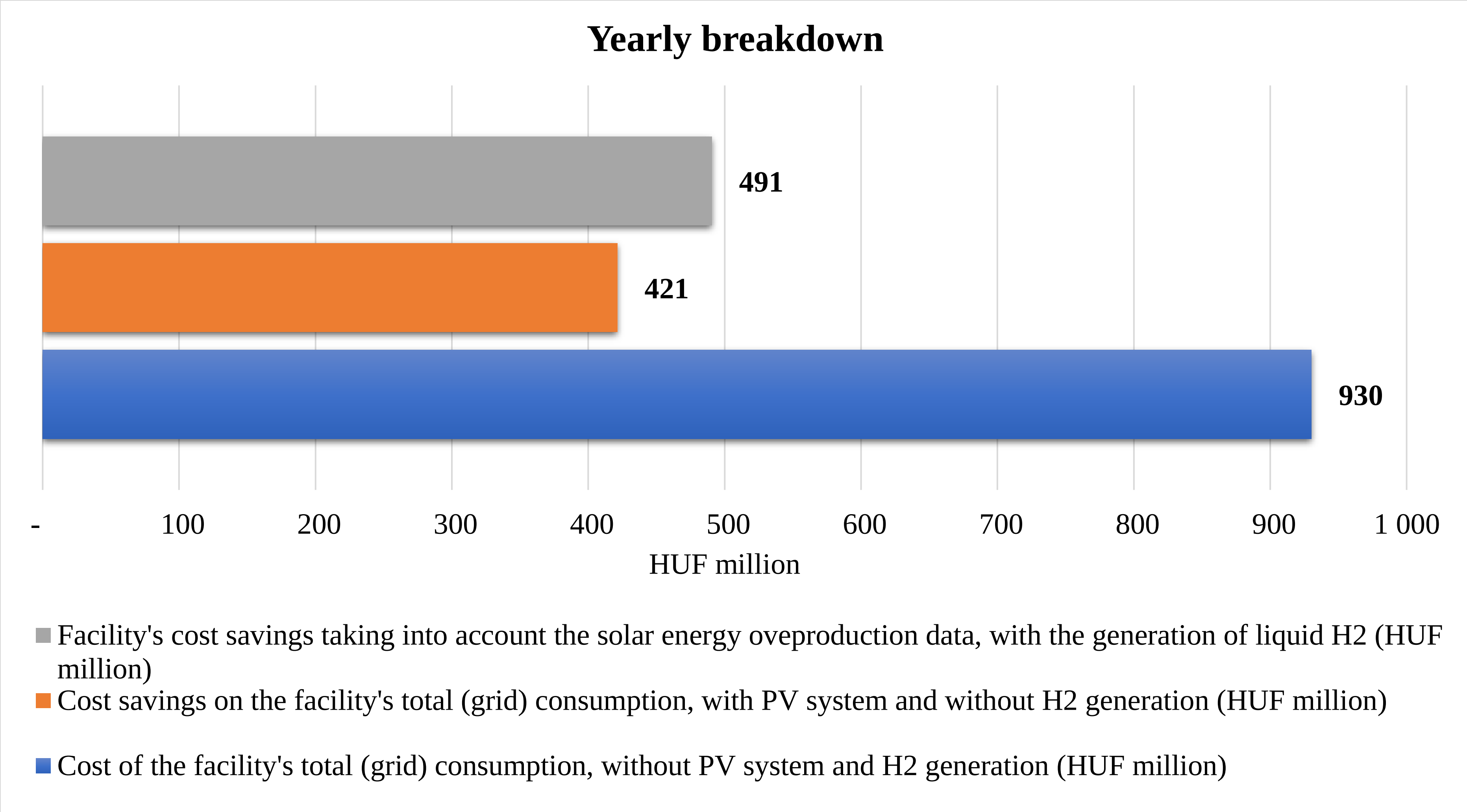


Figure 89. H_2 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 1

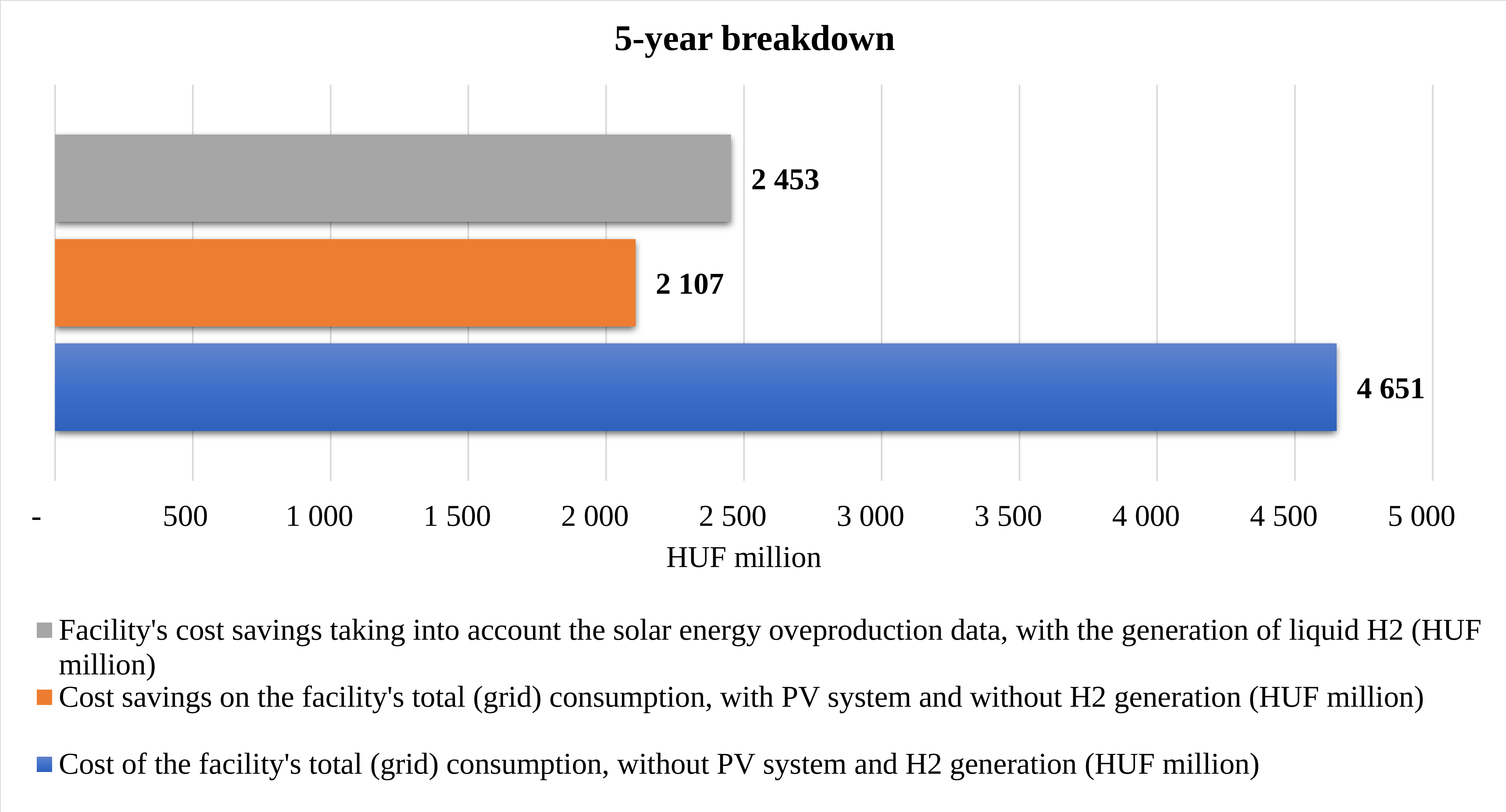


Figure 90. H_2 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 1

3.9. H_2, Scenario 2

Table 25. H_2 model-based energy efficiency analysis, Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and H2 generation (MWh)	Facility's total (grid) consumption, with PV system, without H2 generation (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data without H2 generation (MWh)	Solar energy oveproduction data, with H2 generation (MWh)	Liquid H2 generation potential, (with MC250 PEM generator), including loss (t)
January	635	451	252	68	0	1,3
February	661	438	360	138	0	2,6
March	695	388	620	313	5	5,8
April	669	330	722	383	20	6,8
May	868	394	877	404	26	7,1
June	1010	425	979	394	23	7,0
July	1118	470	1027	380	10	7,0
August	1136	572	918	354	16	6,4
September	802	444	642	284	15	5,1
October	714	417	566	270	7	4,9
November	622	423	322	123	0	2,3
December	648	485	219	56	0	1,1
Q1	1991	1278	1232	519	5	9,7
Q2	2546	1149	2578	1181	70	20,9
Q3	3055	1486	2587	1018	42	18,4
Q4	1984	1325	1107	448	7	8,3
1 year	9577	5239	7503	3165	124	57,3
5 years	47885	26195	37514	15824	618	286,4

Table 26. H_2 model-based energy efficiency analysis in terms of costs and cost savings (%), Scenario 2

Time interval	Facility's total (grid) consumption, without PV system and H2 generation (MWh)	Facility's total (grid) consumption, with PV system, without H2 generation (MWh)	Solar energy production data (MWh)	Solar energy oveproduction data without H2 generation (MWh)	Solar energy oveproduction data, with H2 generation (MWh)
January	100%	71%	100%	27%	0%
February	100%	66%	100%	38%	0%
March	100%	56%	100%	50%	1%
April	100%	49%	100%	53%	3%
May	100%	45%	100%	46%	3%
June	100%	42%	100%	40%	2%
July	100%	42%	100%	37%	1%
August	100%	50%	100%	39%	2%
September	100%	55%	100%	44%	2%
October	100%	58%	100%	48%	1%
November	100%	68%	100%	38%	0%
December	100%	75%	100%	26%	0%
Q1	100%	64%	100%	42%	0%
Q2	100%	45%	100%	46%	3%
Q3	100%	49%	100%	39%	2%
Q4	100%	67%	100%	40%	1%
1 year	100%	55%	100%	42%	2%
5 years	100%	55%	100%	42%	2%

Table 27. H_2 model-based energy efficiency analysis in terms of costs and cost savings (HUF million), Scenario 2

Time interval	Cost of the facility's total (grid) consumption, without PV system and H2 generation (HUF million)	Cost of the facility's total (grid) consumption, with PV systems, without H2 generation (HUF million)	Cost savings on the facility's total (grid) consumption, with PV systems, without H2 generation (HUF million)	Cost savings of the facility with consideration to the solar energy overproduction data and liquid H2 generation (HUF million)	Cost savings with H2 generation (HUF million)
January	62	44	18	20	2,1
February	64	43	22	26	4,3
March	68	38	30	39	9,6
April	65	32	33	44	11,4
May	84	38	46	58	11,8
June	98	41	57	68	11,6
July	109	46	63	74	11,6
August	110	56	55	65	10,6
September	78	43	35	43	8,4
October	69	41	29	37	8,2
November	60	41	19	23	3,8
December	63	47	16	18	1,8
Q1	193	124	69	85	16,1
Q2	247	112	136	171	34,8
Q3	297	144	152	183	30,6
Q4	193	129	64	78	13,8
1 year	930	509	421	517	95,4
5 years	4 651	2 544	2 107	2 584	476,8

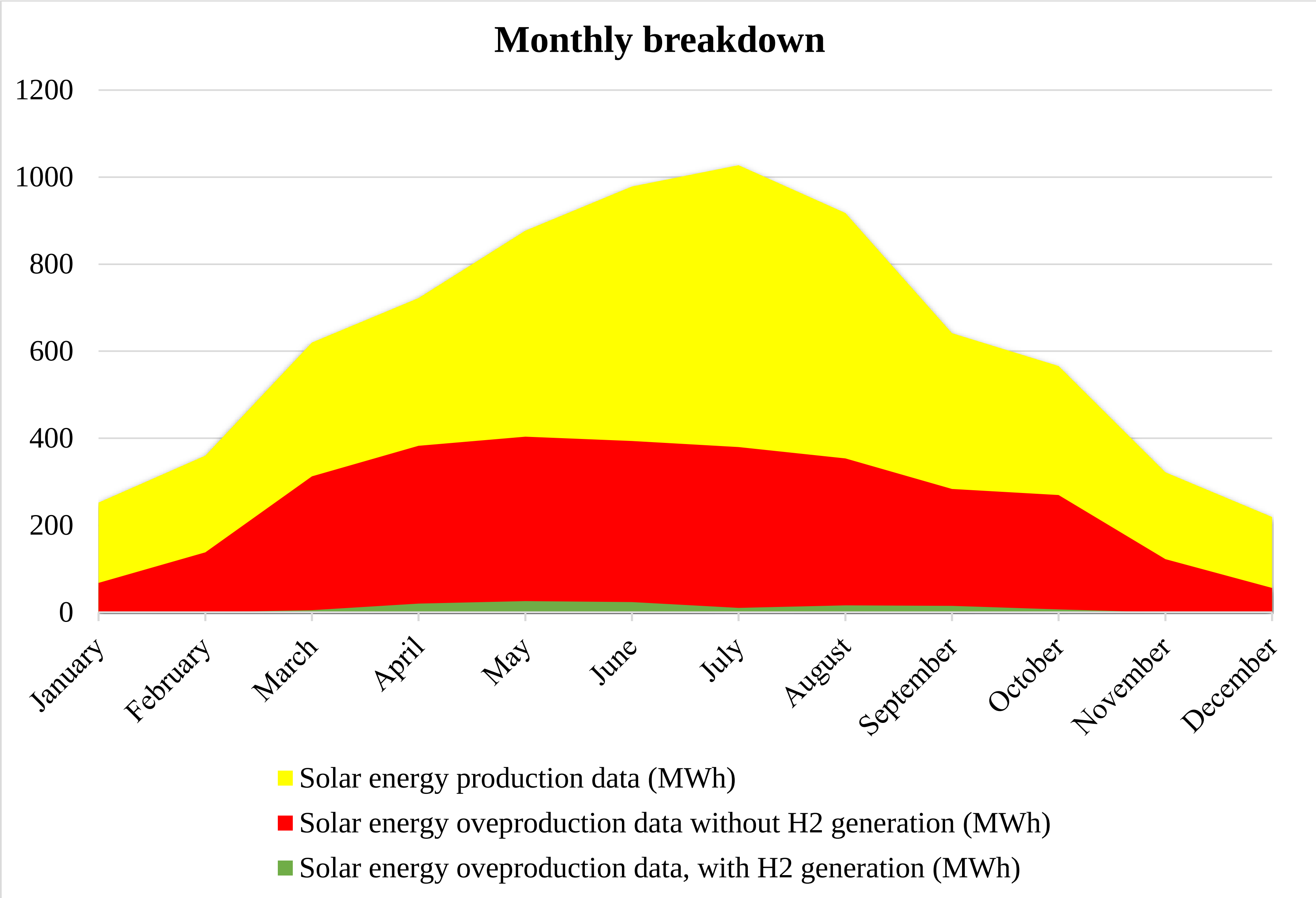


Figure 91. H_2 model-based energy efficiency analysis for solar energy production data, monthly breakdown, Scenario 2

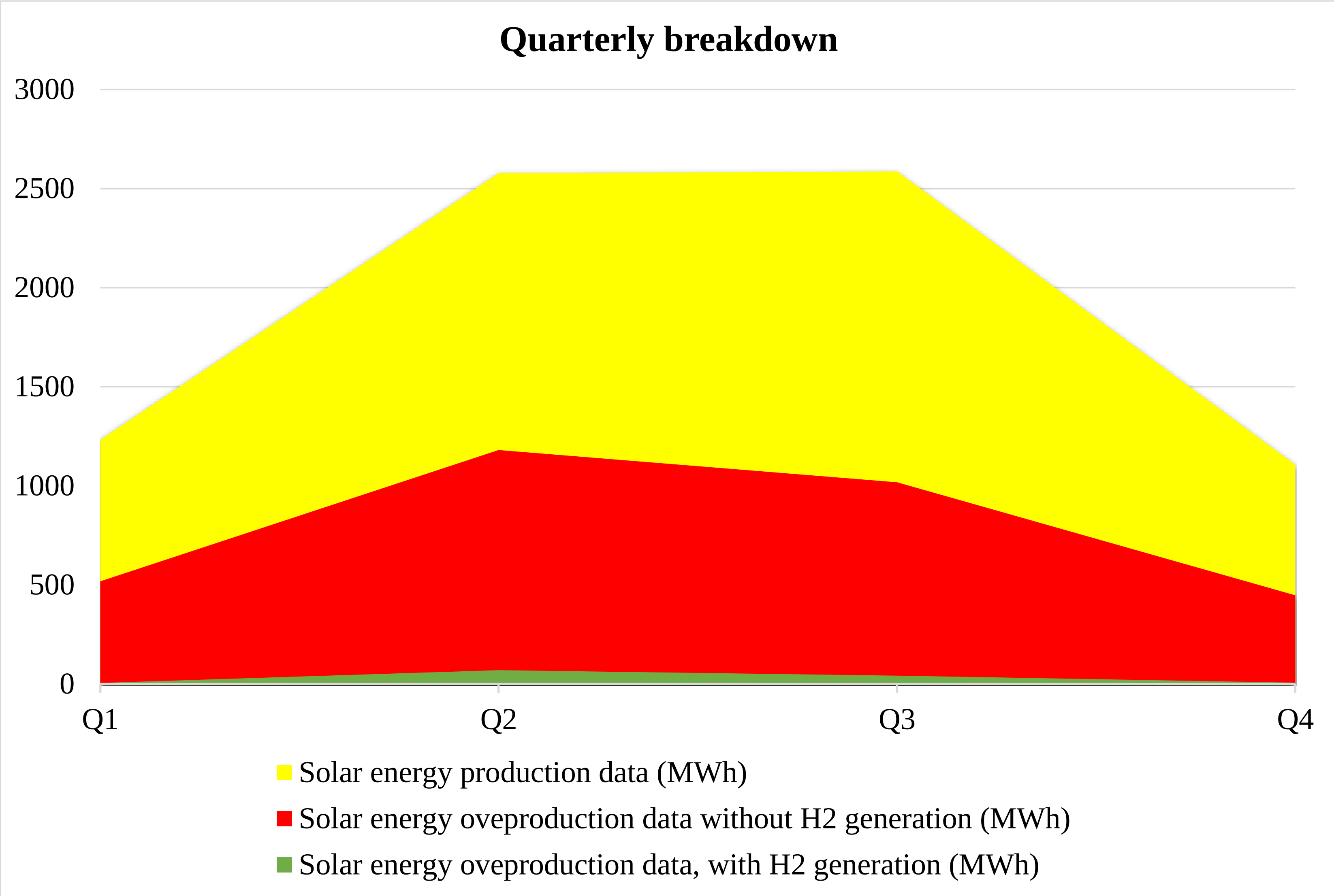


Figure 92. H_2 model-based energy efficiency analysis for solar energy production data, quarterly breakdown, Scenario 2

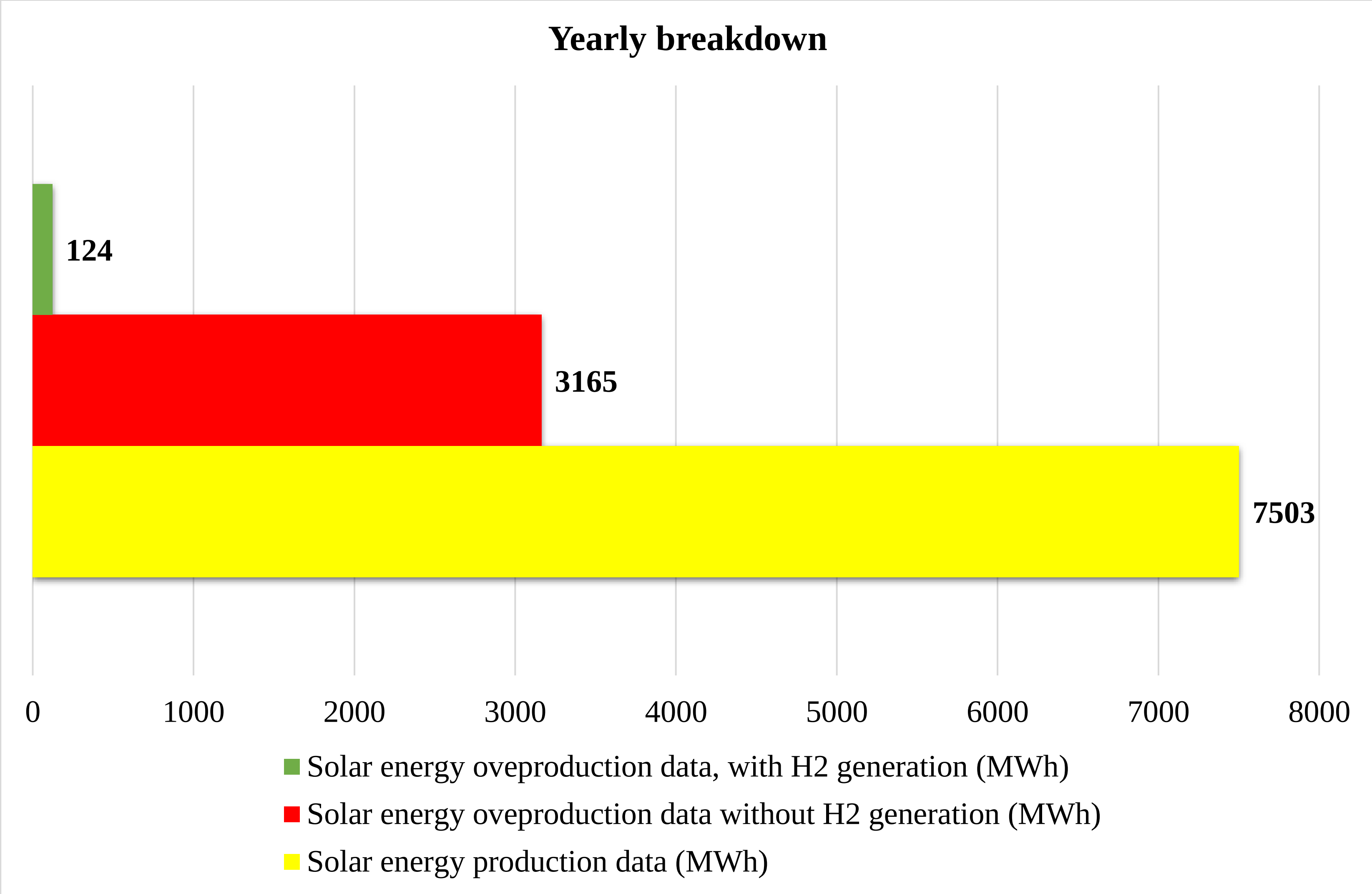


Figure 93. H_2 model-based energy efficiency analysis for solar energy production data, yearly breakdown, Scenario 2

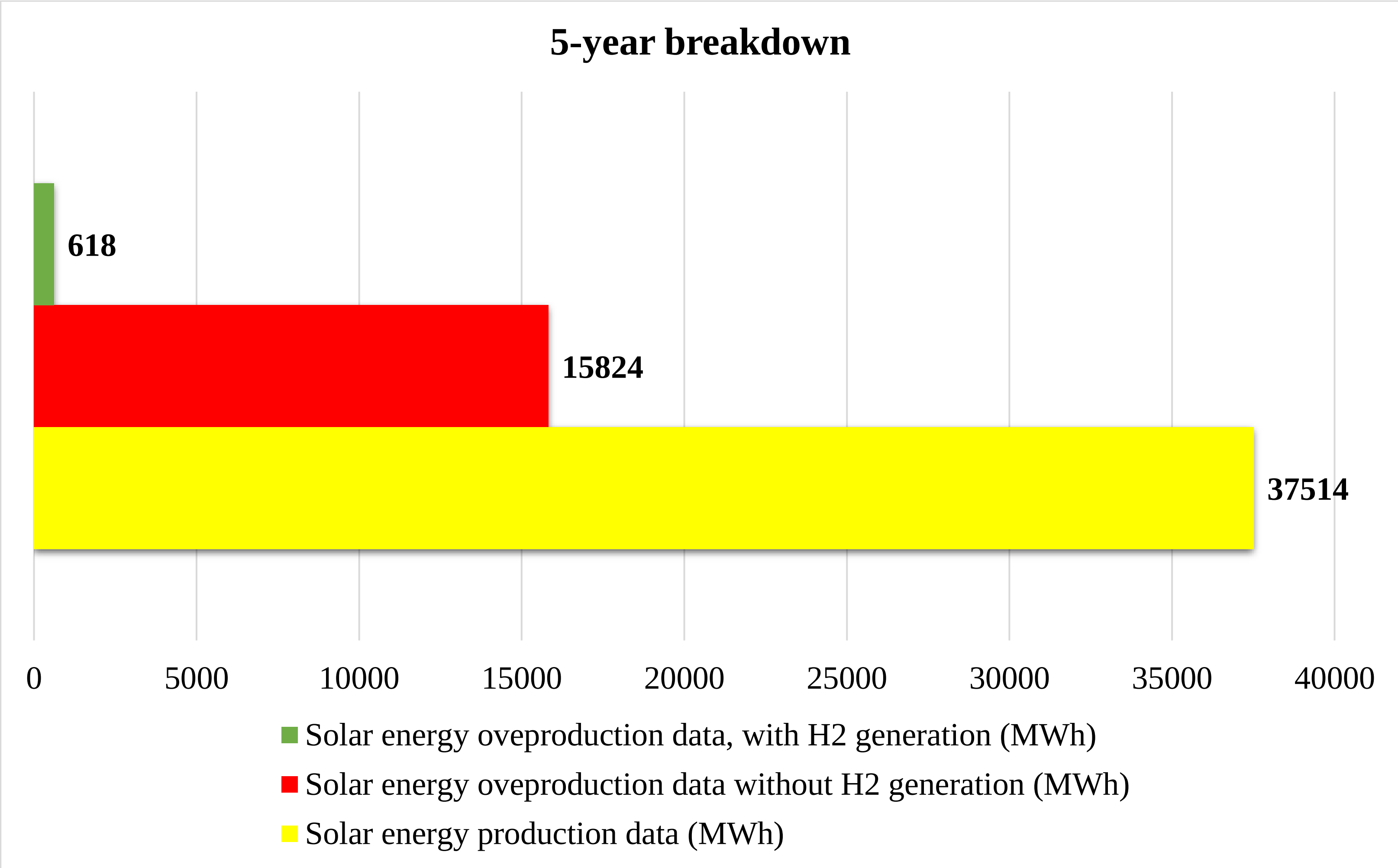


Figure 94. H_2 model-based energy efficiency analysis for solar energy production data, 5-year breakdown, Scenario 2

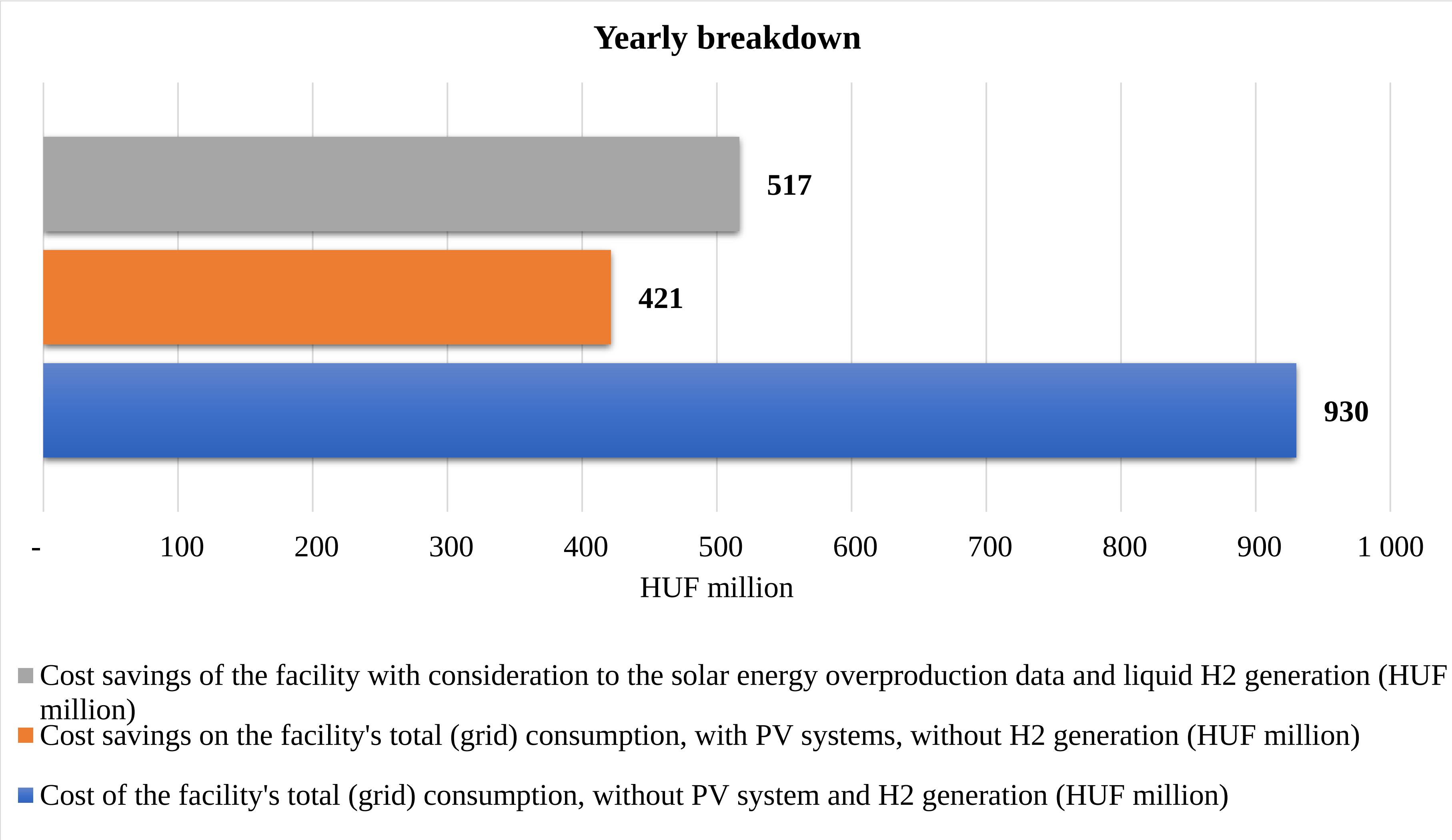


Figure 95. H_2 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, yearly breakdown, Scenario 2

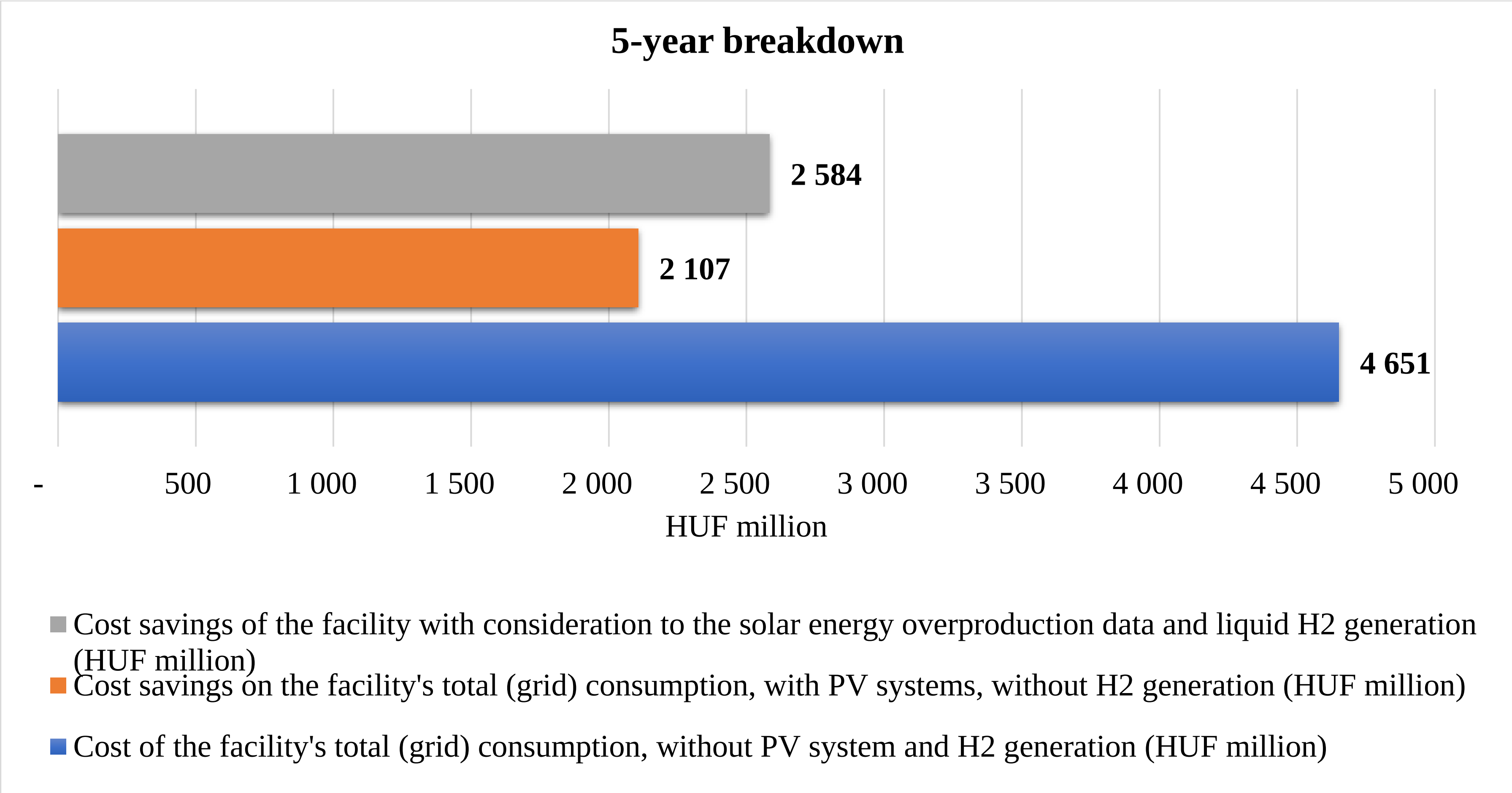


Figure 96. H_2 model-based energy efficiency analysis in terms of changes in cost savings on total consumption, 5-year breakdown, Scenario 2

4. Evaluation of the modelling results

4.1. Changes in total grid consumption and solar energy production with the studied technologies in the given scenarios

This subsection presents the total grid consumption and the changes in solar generation data for the studied technologies and scenarios (Tables 28-29 and Figures 97-100). It has been found that over a period of one year and five years, the total (grid) consumption of the facility without a PV system and an energy storage solution would equal 9,577 MWh and 47,885 MWh, respectively. This can be reduced to 55% with a PV system without an energy storage system, as well as to 48-50% with an energy storage solution (Scenario 1) or to 40-41% (Scenario 2).
The results on the energy production of solar power plants have shown that over a period of one year and five years, PV plants produce 7,503 MWh and 37 514 MWh of electricity respectively. Without an energy storage solution, the facility would be unable to use 42% of this energy for own consumption. With the studied electrochemical energy storage solutions this value could be reduced to 31-33% (Scenario 1) or 15-20% (Scenario 2) over a year and to 31-36% (Scenario 1) or 15-22% (Scenario 2) over a period of five years. With H_2 generation, only 13% (Scenario 1) and 2% (Scenario 2) of the electricity generated by the PV system would not be directly consumed by the facility over each time horizon.

Table 28. Changes in the total grid consumption and in solar energy production data with the studied technologies and scenarios, over a period of 1 year and 5 years, respectively

Time interval	Initial data		Scenario 1					Scenario 2				
	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system and without energy storage (MWh)	Facility's total consumption, with PV system and LiFePO4 energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Facility's total consumption, with PV system and H2 generation (MWh)	Facility's total consumption, with PV system and LiFePO4 energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Facility's total consumption, with PV system and H2 generation (MWh)
1 year	9577	5239	4626	4626	Not relevant	4634	Not relevant	3766	3766	3786	3786	Not relevant
5 years	47885	26195	24097	24097	Not relevant	23168	Not relevant	19460	19460	18930	18930	Not relevant

Time interval	Initial data		Scenario 1					Scenario 2				
	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)	Solar energy overproduction data, with Li-ion energy storage (MWh)	Solar energy overproduction data, with NaS energy storage (MWh)	Solar energy overproduction data, with VRFB energy storage (MWh)	Solar energy overproduction data, with H2 generation (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)	Solar energy overproduction data, with Li-ion energy storage (MWh)	Solar energy overproduction data, with NaS energy storage (MWh)	Solar energy overproduction data, with VRFB energy storage (MWh)	Solar energy overproduction data, with H2 generation (MWh)
1 year	7503	3165	2469	2461	Not relevant	2300	955	1491	1472	1182	1102	124
5 years	37514	15824	13440	13413	Not relevant	11501	4773	8171	8083	5872	5446	618

Table 29. Changes in the total grid consumption and in solar energy production data with the studied technologies and scenarios, over a period of 1 year and 5 years, respectively (%)

Time interval	Initial data		Scenario 1					Scenario 2				
	Facility's total (grid) consumption, without PV system and energy storage (MWh)	Facility's total (grid) consumption, with PV system and without energy storage (MWh)	Facility's total consumption, with PV system and LiFePO4 energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Facility's total consumption, PV system, with H2 generation (MWh)	Facility's total consumption, with PV system and LiFePO4 energy storage (MWh)	Facility's total consumption, with PV system and Li-ion energy storage (MWh)	Facility's total consumption, with PV system and NaS energy storage (MWh)	Facility's total consumption, with PV system and VRFB energy storage (MWh)	Facility's total consumption, PV system, with H2 generation (MWh)
1 year	100%	55%	48%	48%	Not relevant	48%	Not relevant	39%	39%	40%	40%	Not relevant
5 years	100%	55%	50%	50%	Not relevant	48%	Not relevant	41%	41%	40%	40%	Not relevant

Time interval	Initial data		Scenario 1					Scenario 2				
	Solar energy production data (MWh)	Solar energy overproduction data, without energy storage (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)	Solar energy overproduction data, with Li-ion energy storage (MWh)	Solar energy overproduction data, with NaS energy storage (MWh)	Solar energy overproduction data, with VRFB energy storage (MWh)	Solar energy overproduction data, with H2 generation (MWh)	Solar energy overproduction data, with LiFePO4 energy storage (MWh)	Solar energy overproduction data, with Li-ion energy storage (MWh)	Solar energy overproduction data, with NaS energy storage (MWh)	Solar energy overproduction data, with VRFB energy storage (MWh)	Solar energy overproduction data, with H2 generation (MWh)
1 year	100%	42%	33%	33%	Not relevant	31%	13%	20%	20%	16%	15%	2%
5 years	100%	42%	36%	36%	Not relevant	31%	13%	22%	22%	16%	15%	2%

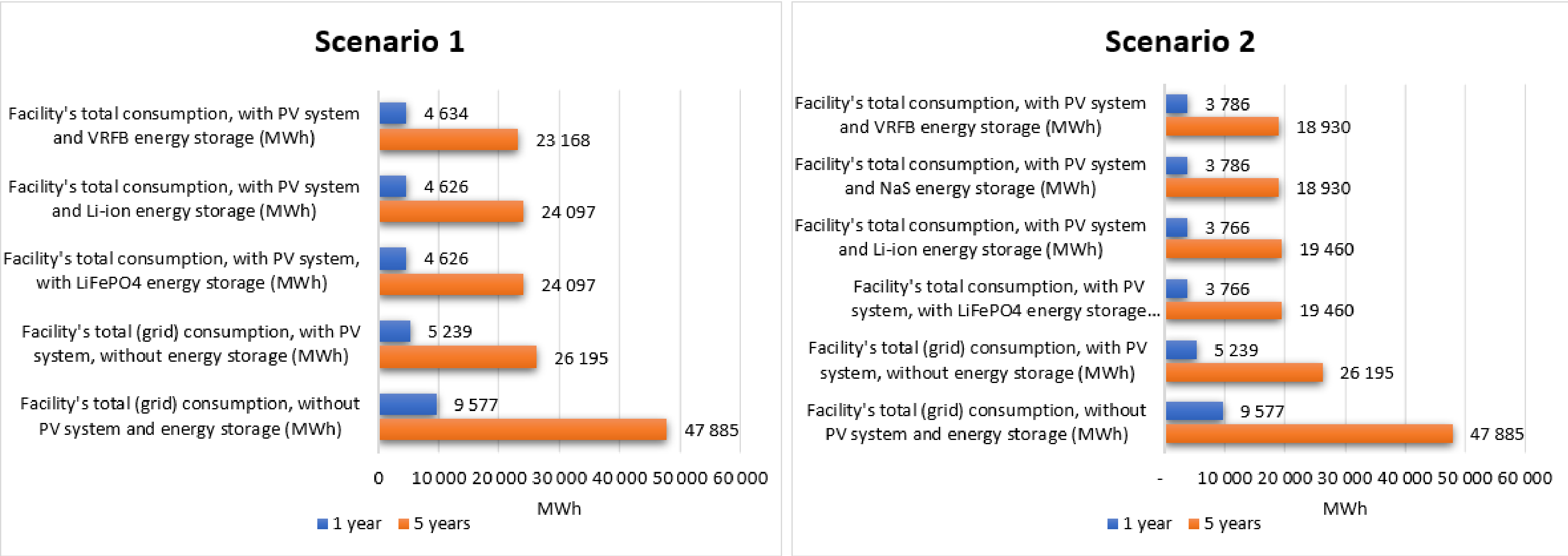


Figure 97. Changes in the total grid consumption with the studied technologies and scenarios (MWh), over a period of 1 year and 5 years

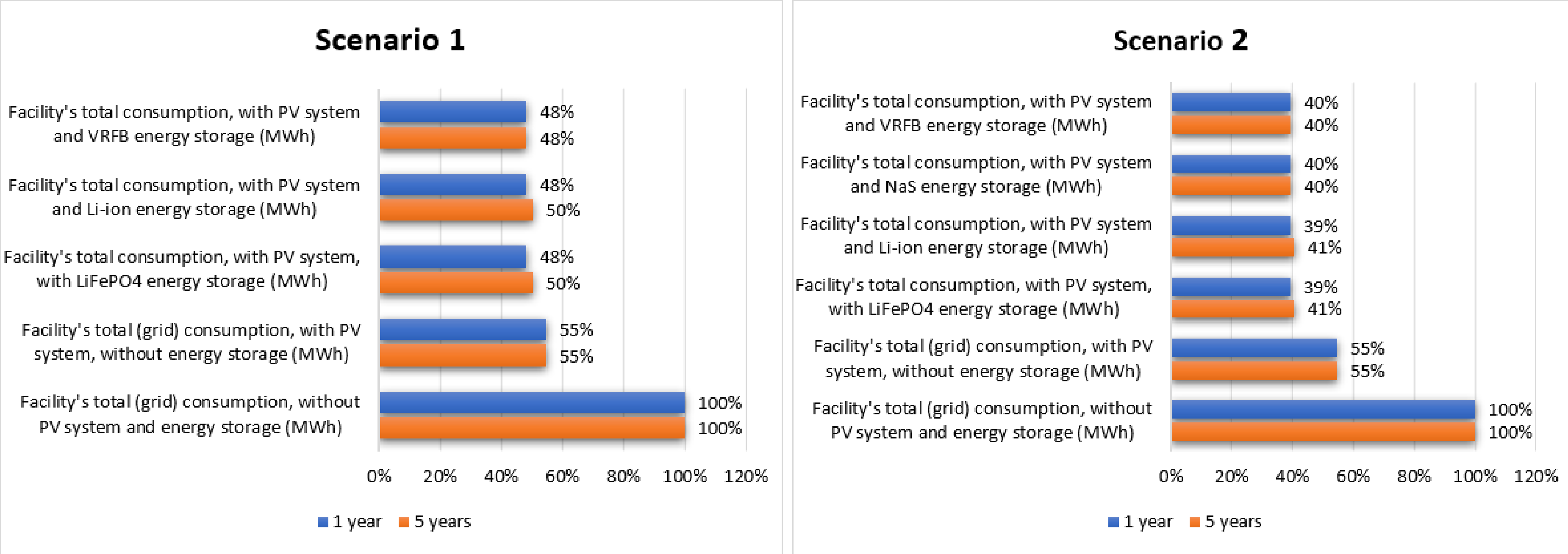


Figure 98. Change in the total grid consumption with the studied technologies and scenarios (%), over a period of 1 year and 5 years

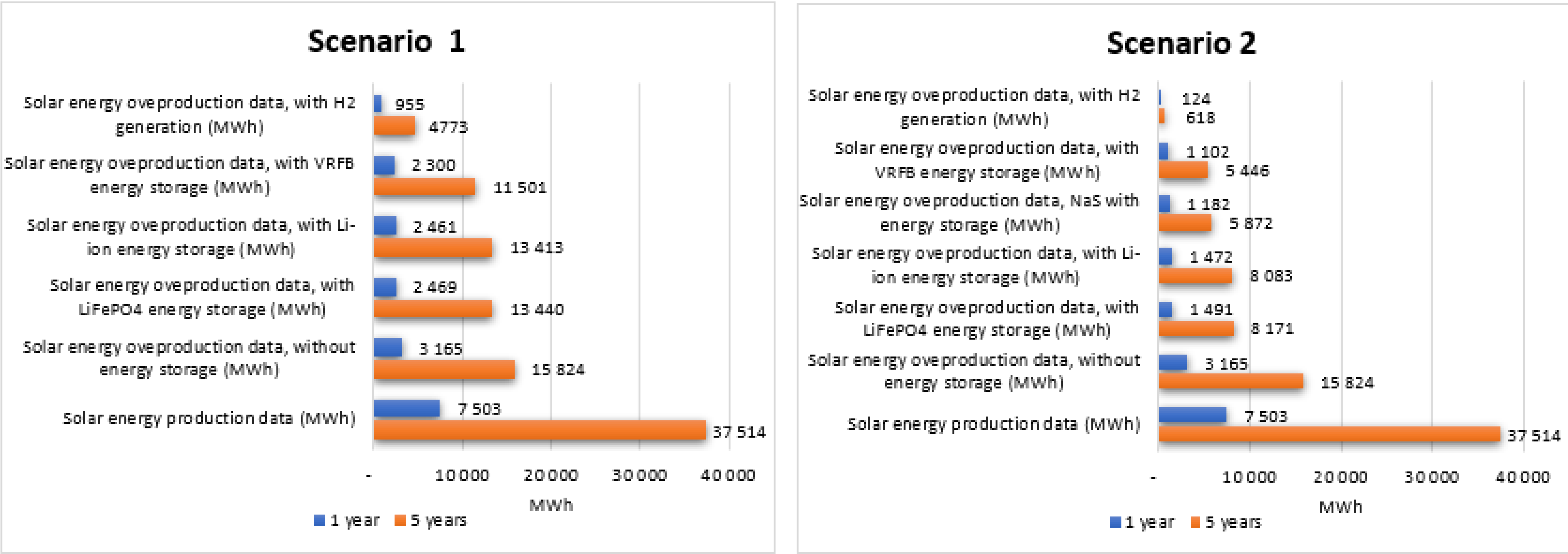


Figure 99. Change in the amount of solar energy produced and not consumed with the studied technologies and scenarios (MWh), over a period of 1 year and 5 years

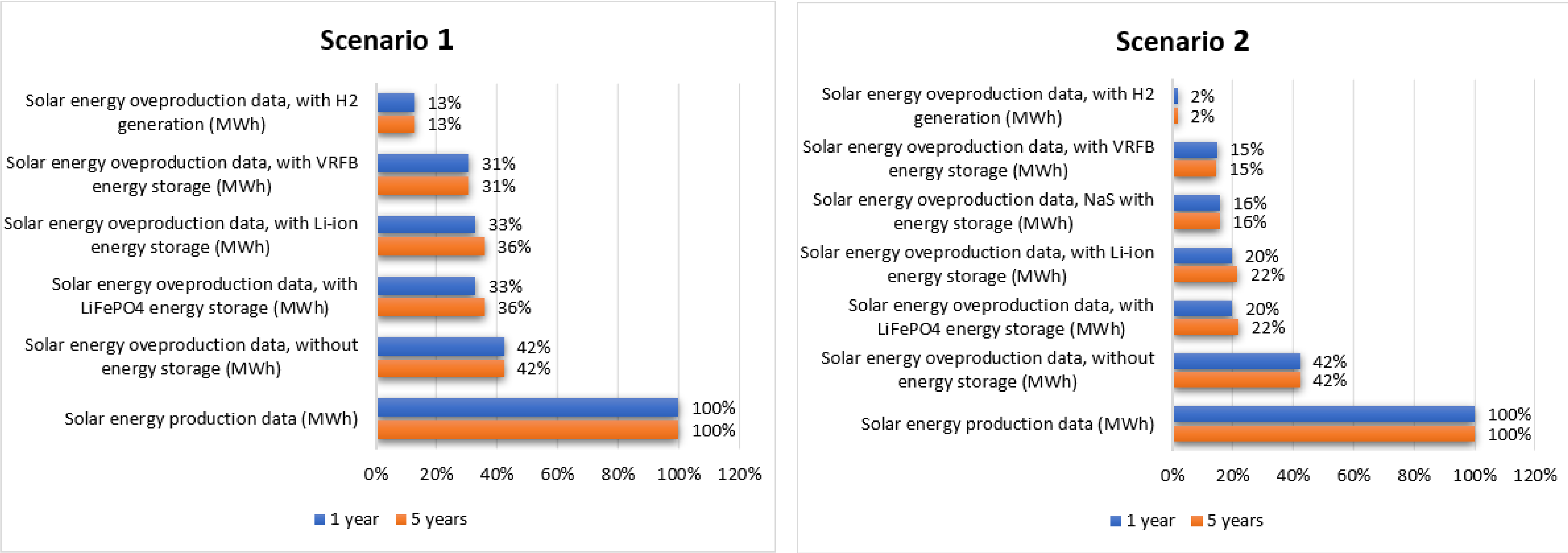


Figure 100. Change in the amount of solar energy produced and not consumed with the studied technologies and scenarios (%), over a period of 1 year and 5 years

4.2. Changes in total grid consumption costs and cost savings with the studied technologies in the given scenarios

This subsection presents the total grid consumption costs and the changes in cost savings with the studied technologies and scenarios (Table 30 and Figures 101-102). It has been found that over a 5-year period, the cost of the facility's total (grid) consumption without a PV system and an energy storage solution would equal HUF 4,651.1 million, which could be reduced to HUF 2,544.3 million with a PV system without an energy storage solution. With energy storage solutions, this amount could be reduced to: HUF 2,340.5 million with a LiFePO4 based energy storage system; to HUF 2,340.6 with a Li-ion based energy storage system; to HUF 2,250.4 million with a VRFB based energy storage system (Scenario 1) and to: HUF 1,890.2 million with a LiFePO4 based energy storage system; to HUF 1,890.2 with a Li-ion based energy storage system; to HUF 1,838.7 million with a NaS based energy storage system; and to 1,838.7 million with a VRFB based energy storage system (Scenario 2).

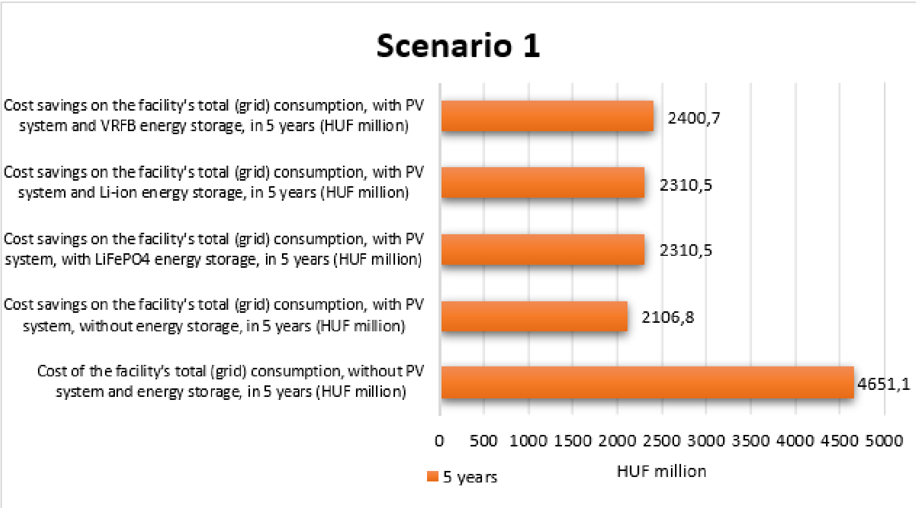
The cost savings achievable by the facility with the studied energy storage technologies and scenarios are the following:

- Over 5 years, the cost savings on the facility's total (grid) consumption with a PV system but without an energy storage solution would equal HUF 2,107 million. This amount could be reduced to HUF 2,311 million with LiFePO4, to HUF 2,310 million with Li-ion, to HUF 2,401 million with VRFB batteries (Scenario 1), as well as to HUF 2,761 million with LiFePO4, to HUF 2,761 million with Li-ion, to HUF 2,812 million with NaS, and to HUF 2,812 million with VRFB batteries (Scenario 2).

Table 30. Total grid consumption as well as solar energy production data with the studied technologies and scenarios, over a period of 5 years

Time interval	Initial data		Scenario 1					Scenario 2				
	Cost of the facility's total (grid) consumption, without PV system and energy storage, in 5 years (HUF million)	Cost of the facility's total (grid) consumption, with PV system and without energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and LiFePO4 energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, PV system and with NaS energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost of the facility's total consumption with PV system and H2 generation, in 5 years (MWh)	Cost of the facility's total consumption, with PV system and LiFePO4 energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and NaS energy storage, in 5 years (HUF million)	Cost of the facility's total consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost of the facility's total consumption with PV system and H2 generation, in 5 years (MWh)
5 years	4651,1	2544,3	2340,5	2340,6	Not relevant	2250,4	Not relevant	1890,2	1890,2	1838,7	1838,7	Not relevant

Time interval	Initial data		Scenario 1					Scenario 2				
	Cost of the facility's total (grid) consumption, without PV system and energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and without energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and LiFePO4 energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and NaS energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and H2 generation in 5 years, in 5 years (Milliárd Ft)	Cost savings on the facility's total (grid) consumption, with PV system and LiFePO4 energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and Li-ion energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and NaS energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and VRFB energy storage, in 5 years (HUF million)	Cost savings on the facility's total (grid) consumption, with PV system and H2 generation in 5 years, in 5 years (Milliárd Ft)
5 years	4651	2107	2311	2310	Not relevant	2401	Not relevant	2761	2761	2812	2812	Not relevant



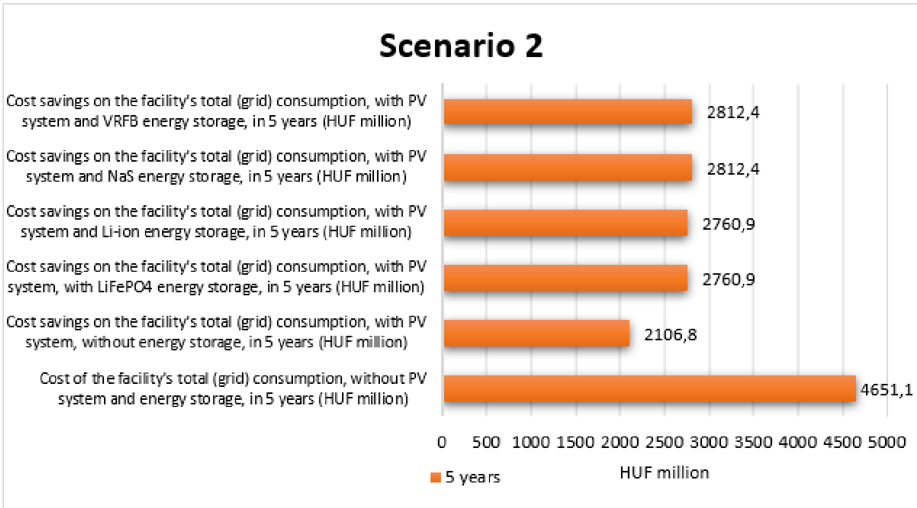


Figure 101. Cost savings on the total grid consumption with the studied technologies and scenarios, over a period of 5 years

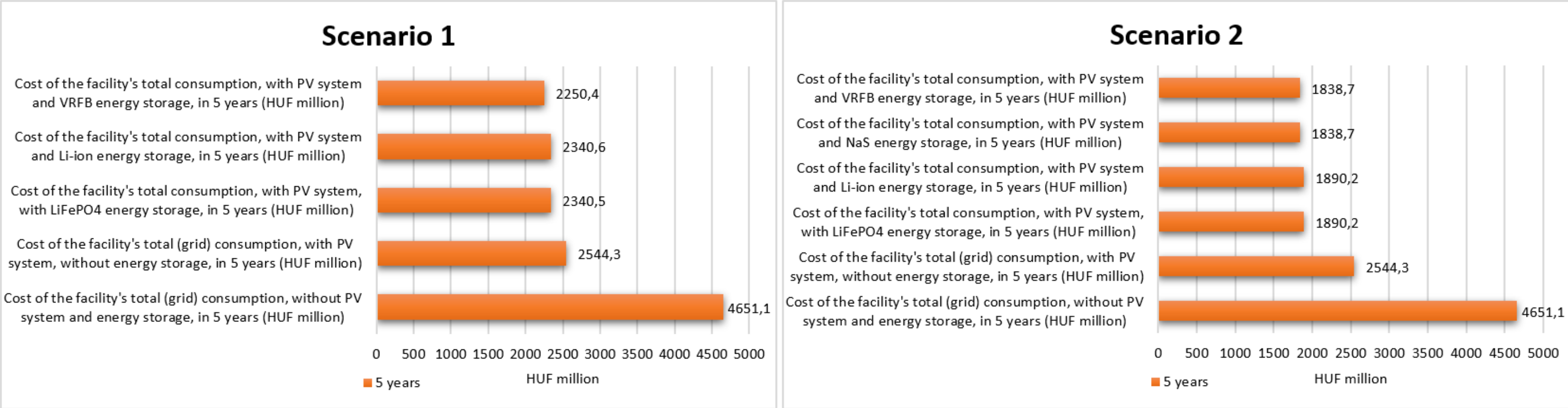


Figure 102. Changes in the costs of the total grid consumption with the studied technologies and scenarios, over a period of 5 years

4.3. Energy and cost savings achievable with the studied technologies in the given scenarios

This subsection presents the energy and cost savings achievable with the studied technologies and scenarios (Tables 31-32 and Figures 103-104). It has been found that the discharge rate of energy storage technologies differs in the different scenarios, not only due to the different electric to electric efficiency, but also due to the level of technical depreciation. In this context, it should be noted that in the VRFB and NaS energy storage technologies, the condition of the energy storage devices does not depend on the cycle count, so practically they are not subject to technical depreciation. However, in Li-based technologies, the number of cycles has a negative impact on the energy storage capacity, which is 0.003% per cycle. Based on these results, the discharge demand of the energy storage technologies over 5 years is the following: 2,098 MWh for LiFePO4, 2,097 MWh for Li-ion, 3,026 MWh for VRFB (Scenario 1), and 6,735 MWh for LiFePO4, 6,734 MWh for Li-ion, 7,265 MWh for NaS and 7,264 MWh for VRFB (Scenario 2). In addition, the amount of solar energy used for H_2 production, taking into account the solar energy overproduction data, equals 1,1051 MWh (Scenario 1) and 15,206 MWh (Scenario 2). Most of the overproduction of solar energy by the PV system can be handled with the help of H_2 generation. The cost savings are as follows:

- Scenario 1
  - LiFePO4: HUF 203.7 million
  - Li-ion: HUF 203.7 million
  - VRFB: HUF 293.9 million
  - H_2: HUF 346.5 million
- Scenario 2
  - LiFePO4: HUF 654.1 million
  - Li-ion: HUF 654.1 million
  - NaS: HUF 705.6 million
  - VRFB: HUF 705.6 million
  - H_2: HUF 476.8 million

Table 31. Discharge demands of the studied energy storage technologies and the amount of excess solar energy considered for H_2 generation over 5 years for the given scenarios

Time interval	Scenario 1					Scenario 2				
	Discharge demand of the LiFePO4 battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the Li-ion battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the Nas battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the VRFB battery, with regard to the electricity to electricity efficiency (MWh)	Solar energy used for H2 generation, with consideration to the solar energy overproduction data (MWh)	Discharge demand of the LiFePO4 battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the Li-ion battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the NaS battery, with regard to the electricity to electricity efficiency (MWh)	Discharge demand of the VRFB battery, with regard to the electricity to electricity efficiency (MWh)	Solar energy used for H2 generation, with consideration to the solar energy overproduction data (MWh)
5 years	2098	2097	Not relevant	3026	11051	6735	6734	7265	7264	15206

Table 32. Changes in cost savings of the studied energy storage technologies and scenarios over a 5-year period

Time interval	Scenario 1					Scenario 2				
	Cost savings with the LiFePO4 energy storage system (HUF million)	Cost savings with the Li-ion energy storage system (HUF million)	Cost savings with the NaS energy storage system (HUF million)	Cost savings with the VRFB energy storage system (HUF million)	Cost savings with H2 generation (HUF million)	Cost savings with the LiFePO4 energy storage system (HUF million)	Cost savings with the Li-ion energy storage system (HUF million)	Cost savings with the NaS energy storage system (HUF million)	Cost savings with the VRFB energy storage system (HUF million)	Cost savings with H2 generation (HUF million)
5 years	203,7	203,7	Not relevant	293,9	346,5	654,1	654,1	705,6	705,6	476,8

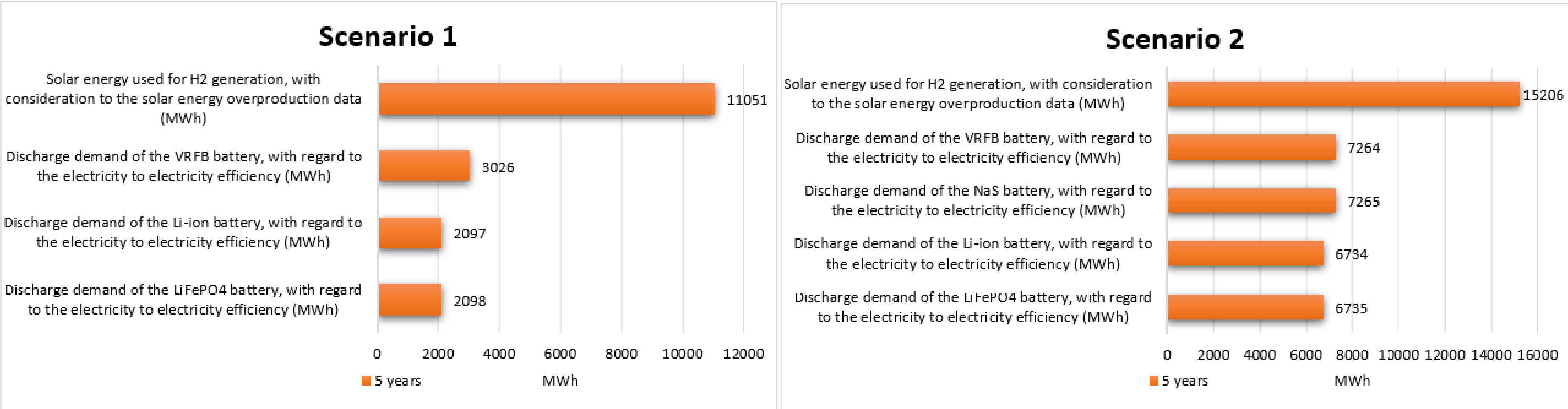


Figure 103. Discharge demands of the different energy storage technologies and the excess solar energy required for H_2 generation in the studied scenarios, over a period of 5 years

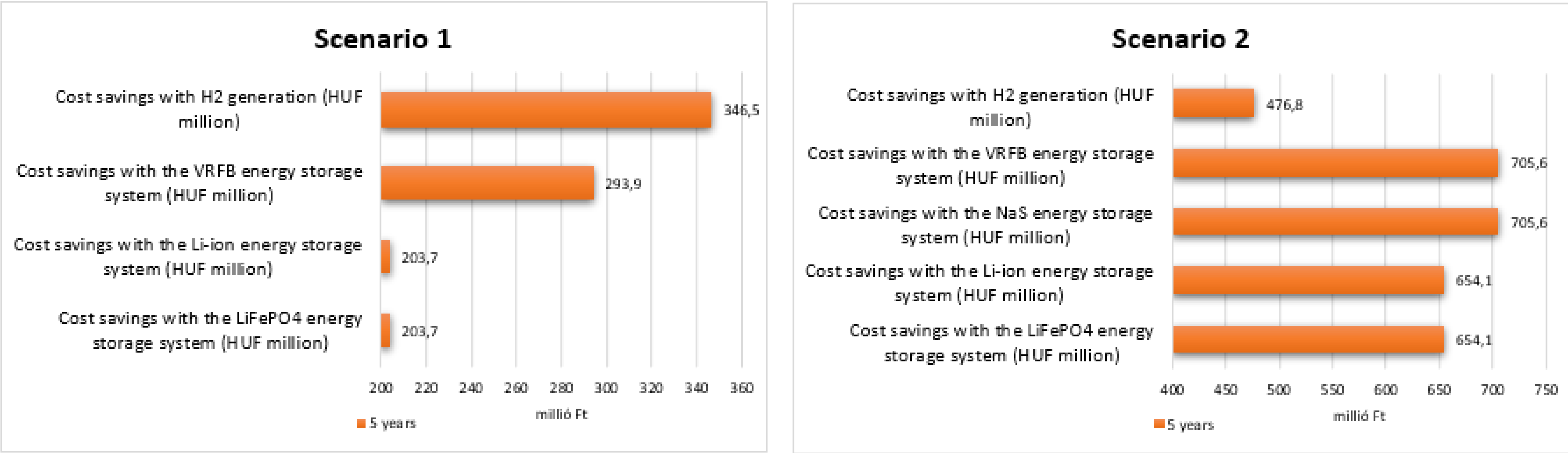


Figure 104. Changes in cost savings with the studied energy storage technologies and scenarios over a period of 5 years

4.4. Capital expenses and maintenance costs of the studied technologies in the given scenarios

This subsection presents the capital expenses and maintenance costs of the studied technologies studied for each scenario (Tables 33-35 and Figures 105-106).

It has been found that among the different battery technologies, the NaS technology has the lowest capital expenses (200-300 EUR/kWh), the lowest capital expenses for the complete system (300-400 EUR/kWh) and the lowest annual maintenance costs, which equal 1-2% of the battery price. This system can be used for larger energy storage capacities. Therefore, in Scenario 2, the capital expenses of the NaS battery are estimated to be EUR 1,320-1,980 thousand, the capital expenses of the complete system are expected to equal EUR 1,980-2,640 thousand, and the annual maintenance costs are estimated to total EUR 13-40 thousand. For long-term energy storage, the NaS technology has been found to show the most favourable values in terms of capital expenses and maintenance costs alike. Today, even the initial capital expenses of NaS batteries are lower than those of LiFePO4 and Li-ion batteries, and the maintenance costs are also lower than those of the other technologies. It is worth noting that VRFB batteries are the most expensive, both in terms of capital expenses and maintenance costs. For safety, operational and maintenance reasons, the LiFePO4 technology is preferable to Li-ion technology for short-term energy storage (Scenario 1). In this respect it is worth noting that LiFePO4 batteries have a more stable chemical structure and are therefore less prone to fires than Li-ion batteries.

The average capital expenses of equipment required for the investigated liquid H_2 generation technology is estimated to be EUR 2.2 million (Scenario 1) and EUR 4.4 million (Scenario 2); the total capital expenses are estimated to be EUR 3.5 million (Scenario 1) and EUR 7 million (Scenario 2); and the annual maintenance costs are expected to equal EUR 0.1-0.17 million (Scenario 1) and EUR 0.21-0.35 million (Scenario 2). This also means that this option is the most expensive of all the technologies we studied.

Table 33. Capital expenses and maintenance costs of the studied battery technologies per 1 kWh in the given scenarios

Battery type	Capital expenses of the battery (EUR/kWh)	Capital expenses of the complete system (EUR/kWh)	Annual maintenance costs
Li-ion	300-400	400-500	5-10% of the cost of the battery
LiFePO4	350-450	450-550	2-5% of the cost of the battery
VRFB	450-550	550-650	1-2% of the cost of the battery
NaS	200-300	300-400	1-2% of the cost of the battery

Table 34. Capital expenses and maintenance costs of the studied battery technologies in the given scenarios

	Scenario 1					Scenario 2				
Battery type	Min. capital expenses on battery (EUR thousand)	Max. capital expenses on battery (EUR thousand)	Min. capital expenses on complete system (EUR thousand)	Max. capital expenses on complete system (EUR thousand)	Annual maintenance costs (EUR thousand)	Min. capital expenses on battery (EUR thousand)	Max. capital expenses on battery (EUR thousand)	Min. capital expenses on complete system (EUR thousand)	Max. capital expenses on complete system (EUR thousand)	Annual maintenance costs (EUR thousand)

	Szcenárió 1					Szcenárió 2				
Akkumulátor típus	Akkumulátor minimális beruházási költsége (ezer €)	Akkumulátor maximális beruházási költsége (ezer €)	Komplett rendszer minimális beruházási költsége (ezer €)	Komplett rendszer maximális beruházási költsége (ezer €)	Éves fenntartási költség, (ezer €)	Akkumulátor minimális beruházási költsége (ezer €)	Akkumulátor maximális beruházási költsége (ezer €)	Komplett rendszer minimális beruházási költsége (ezer €)	Komplett rendszer maximális beruházási költsége (ezer €)	Éves fenntartási költség, (ezer €)
Li-ion	660	880	880	1 100	33-88	1 980	2 640	2 640	3 300	99-264
LiFePO4	770	990	990	1 210	15-50	2 310	2 970	2 970	3 630	46-149
VRFB	990	1 210	1 210	1 430	10-24	2 970	3 630	3 630	4 290	30-73
NaS	Nem releváns					1 320	1 980	1 980	2 640	13-40

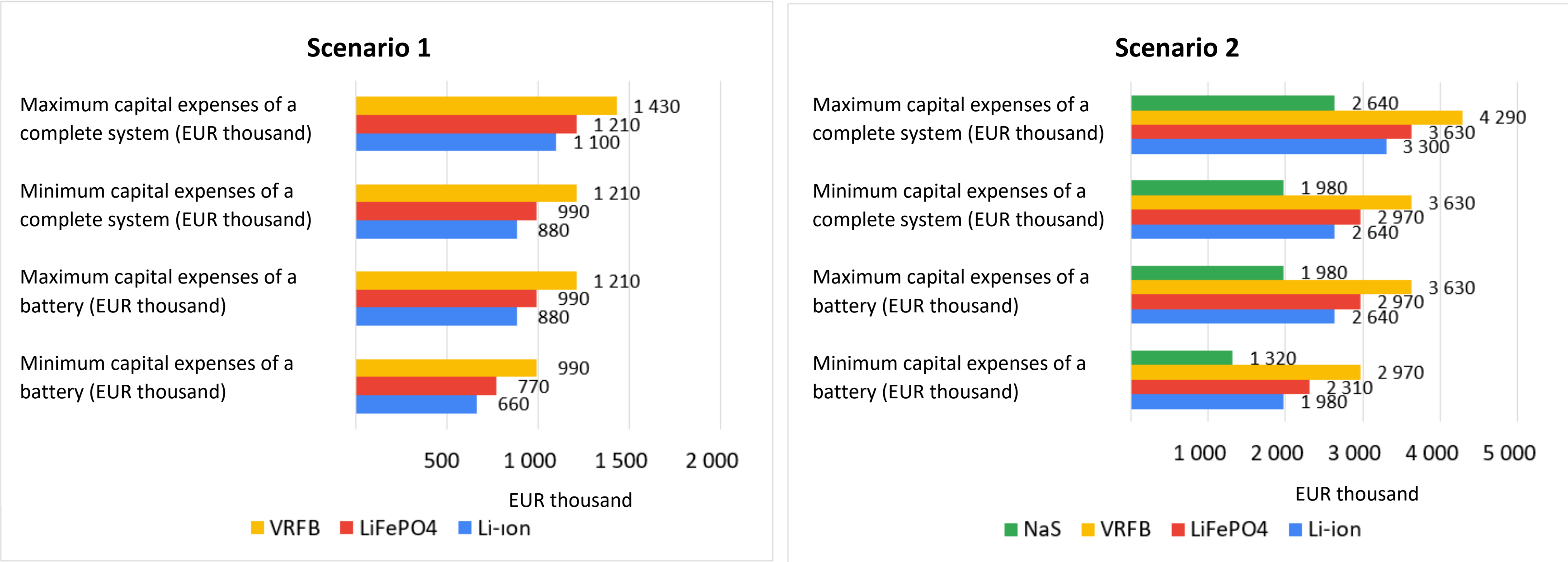


Figure 105. Capital expenses of the studied battery technologies in the given scenarios

Table 35. Capital expenses and maintenance costs of the studied H_2 technologies in the given scenarios

Scenario 1			**Scenario 2**		
Average capital expenses of equipment required for liquid H_2 generation (EUR million)	Total capital expenses of equipment required for liquid H_2 generation, avg. (EUR million)	Annual maintenance costs (EUR million)	Average capital expenses of equipment required for liquid H_2 generation (EUR million)	Total capital expenses of equipment required for liquid H_2 generation, avg. (EUR million)	Annual maintenance costs (EUR million)
2.2	3.5	0.10–0.17	4.4	7.0	0.21–0.35

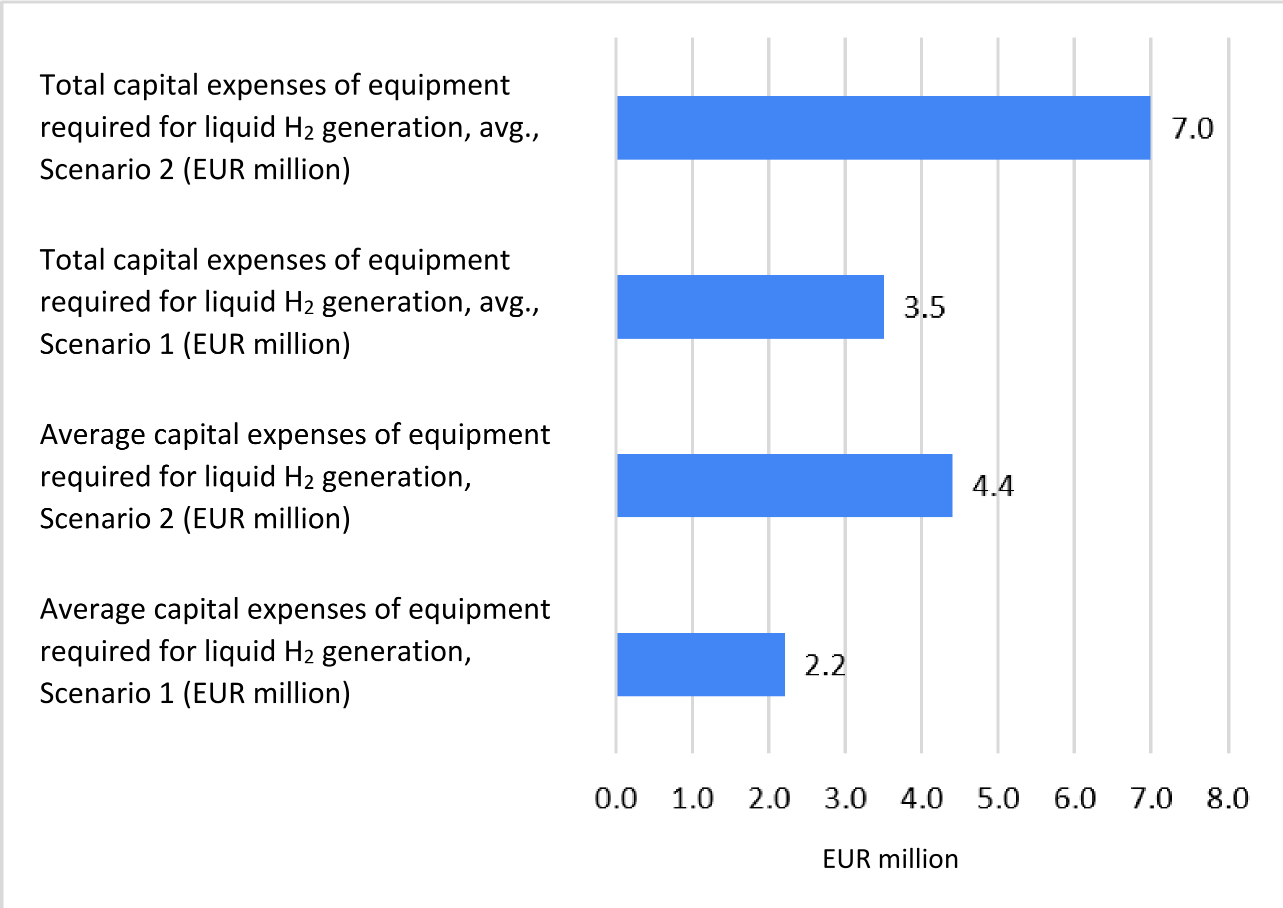


Figure 106. Capital expenses of the studied H_2 technologies in the given scenarios

Table 36. Summary of the battery modelling results

Description	Time interval 5 years							
Facility's total consumption (without anything) (MWh)	47885							
Solar energy production (MWh)	37514							
Facility's total consumption with PV, without battery (MWh)	26195							
Solar energy oveproduction data (MWh)	15824							
Used energy storage technology	LiFePO4, scenario 1	LiFePO4, scenario 2	Li-ion, scenario 1	Li-ion, scenario 2	VRFB, scenario 1	VRFB, scenario 2	NaS, scenario 1	NaS, scenario 2
Recommended optimum size for the energy storage device (analyzed scenarios) (MW/MWh)	1,1/2,2	1,1/6,6	1,1/2,2	1,1/6,6	1,1/2,2	1,1/6,6	-	1,1/6,6
*,**Efficiency of the technology (battery) (%)	Not investigated separately; forms part of the electricity to electricity efficiency in the model (see *)							
*,**Auxiliary system requirement of the technology (MWh)	Not investigated separately; forms part of the electricity to electricity efficiency in the model (see *)							
,*Energy extractable from a storage device (retrievability of solar energy) (MWh)	2098	6735	2097	6734	3026	7264	-	7265
*,**Total storage efficiency (together with the auxiliary system) (%)	87		88		70		73	
***Battery capital expenses, min.-max. (EUR thousand)	770-990	2310-2970	660-880	1980-2640	990-1210	2970-3630	-	1320-1980
Annual operating and maintenance costs, min.-max. (EUR thousand)	15-50	46-149	33-88	99-264	10-24	30-73	-	20-40
Energy tariff (kWh)	97,13							
ROI in 5 years (%)	35-48	37-51	33-49	35-52	47-58	38-47		62-86
***Total capital expenses (EUR thousand)	990-1210	2970-3630	880-1100	2640-3300	1210-1430	3630-4290	-	1980-2640
*,**Round trip efficiency (RTE) (%)	87		88		70		73	
Electricity bill	Consumption data were provided by ELI-HU Non-Profit Ltd., and were used as a basis for modelling							
Degradation in 5 years (%)	02.máj				0			
Cost savings with the battery (EUR thousand)	509	1635	509	1635	735	1764	-	1764

**For LiFePO4, Li-ion and VRFB based technologies, the electric to electric efficiency takes into account the average RTE loss of the battery module or cell, the "Balance of Systems" (BOS) loss of the system accessories, and the average effect of auxiliary systems (e.g. cooling, heating).*

*** For NaS based technology, the electric to electric efficiency takes into account the average RTE loss of the battery module or cell, the average Balance of Systems (BOS) loss of the system accessories, the average effect of auxiliary systems and heat losses.*

**** The average values used in the table have been validated by Hungarian and international market players, the prices in the table reflect European and Hungarian averages, more precise values can be established on the basis of specific quotations.*

Table 37. Summary of the battery modelling results for a concrete LiFePO4 quotation

Description	Time interval: 5 years							
Facility's total consumption (without anything) (MWh)	47885							
Solar energy production (MWh)	37514							
Facility's total consumption with PV, without battery (MWh)	26195							
Solar energy oveproduction data (MWh)	15824							
Used energy storage technology	LiFePO4, scenario 1, based on quotation	LiFePO4, scenario 2, based on quotation	Li-ion, scenario 1	Li-ion, scenario 2	VRFB, scenario 1	VRFB, scenario 2	NaS, scenario 1	NaS, scenario 2
Recommended optimum size for the energy storage device (analyzed scenarios) (MW/MWh)	1,1/2,2	1,1/6,6	1,1/2,2	1,1/6,6	1,1/2,2	1,1/6,6	-	1,1/6,6
*,**Efficiency of the technology (battery) (%)	Not investigated separately; forms part of the electricity to electricity efficiency in the model (see *)							
*,**Auxiliary system requirement of the technology (MWh)	Not investigated separately; forms part of the electricity to electricity efficiency in the model (see *)							
,*Energy extractable from a storage device (retrievability of solar energy) (MWh)	2098	6735	2097	6734	3026	7264	-	7265
*,**Total storage efficiency (together with the auxiliary system) (%)	87		88		70		73	
***Battery capital expenses, min.-max. (EUR thousand)	No data available		660-880	1980-2640	990-1210	2970-3630	-	1320-1980
Annual operating and maintenance costs, min.-max. (EUR thousand)	16	48	33-88	99-264	10-24	30-73	-	20-40
Energy tariff (kWh)	97,13							
ROI in 5 years (%)	78	83	33-49	35-52	47-58	38-47		62-86
***Total capital expenses (EUR thousand)	638	1962	880-1100	2640-3300	1210-1430	3630-4290	-	1980-2640
*,**Round trip efficiency (RTE) (%)	87		88		70		73	
Electricity bill	Consumption data were provided by ELI-HU Non-Profit Ltd., and were used as a basis for modelling							
Degradation in 5 years (%)	5,2				0			
Cost savings with the battery (EUR thousand)	509	1635	509	1635	735	1764	-	1764

**For LiFePO4, Li-ion and VRFB based technologies, the electric to electric efficiency takes into account the average RTE loss of the battery module or cell, the "Balance of Systems" (BOS) loss of the system accessories, and the average effect of auxiliary systems (e.g. cooling, heating).*

*** For NaS based technology, the electric to electric efficiency takes into account the average RTE loss of the battery module or cell, the average Balance of Systems (BOS) loss of the system accessories, the average effect of auxiliary systems and heat losses.*

**** The average values used in the table have been validated by Hungarian and international market players, the prices in the table reflect European and Hungarian averages, more precise characteristics can be established on the basis of specific quotations.*

*****LiFePO4 values are based on specific quotations*

Tables 36 to 37 show that a concrete purchasing decision can only be taken when concrete market offers are available. This is because there are significant differences between the average capital expenses and maintenance costs in Europe and in Hungary (Table 36) (Table 37).

Based on the results presented in Table 36, the NaS technology is recommended for long-term energy storage needs. For short-term energy storage, the VRFB technology is preferable to lithium-based technologies.

Taking into account the results in Table 37, which includes a specific quotation, we recommend the use of either the LiFePO4 or the NAS technologies.

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