

Table E1.gen. Electricity generation: World, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	733	737	380	196	108	70	57	-8.7%
Natural gas	6,700	6,692	6,914	7,080	7,585	8,316	8,933	1.0%
Coal	9,696	9,384	9,350	9,700	9,847	9,957	10,146	0.2%
Nuclear	2,666	2,786	3,037	3,195	3,290	3,324	3,406	0.9%
Renewables	8,448	9,966	12,025	13,931	15,851	17,808	19,456	3.0%
Hydro	4,320	4,706	4,971	5,253	5,337	5,447	5,533	0.9%
Wind	1,967	2,354	3,171	3,916	4,971	5,851	6,396	4.3%
Geothermal	67	110	190	212	236	248	255	4.9%
Solar	1,421	2,160	3,014	3,860	4,590	5,398	6,341	5.5%
Other	673	636	679	690	716	865	931	1.2%
Net generation to grid	28,243	29,564	31,706	34,102	36,680	39,475	41,997	1.4%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430 and Annual Energy Outlook 2023 (March 2023), www.eia.gov/aeo

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E2.gen. Electricity generation: Americas, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	158	159	75	34	16	6	6	-11.1%
Natural gas	2,260	2,057	2,078	2,003	2,106	2,254	2,398	0.2%
Coal	934	852	595	632	655	671	653	-1.3%
Nuclear	889	891	912	873	847	824	812	-0.3%
Renewables	2,491	2,844	3,488	3,978	4,292	4,612	5,011	2.5%
Hydro	1,472	1,541	1,629	1,723	1,730	1,737	1,744	0.6%
Wind	611	716	1,124	1,320	1,494	1,680	1,917	4.2%
Geothermal	25	21	37	40	43	48	55	2.8%
Solar	260	461	598	802	941	1,059	1,203	5.6%
Other	122	105	100	93	84	88	93	-1.0%
Net generation to grid	6,732	6,802	7,147	7,521	7,917	8,367	8,880	1.0%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430 and Annual Energy Outlook 2023 (March 2023), www.eia.gov/aeo

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E3.gen. Electricity generation: United States, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	11	10	8	8	7	5	5	-2.7%
Natural gas	1,686	1,459	1,414	1,314	1,394	1,542	1,667	0.0%
Coal	849	787	525	514	477	458	426	-2.4%
Nuclear	772	782	775	734	734	734	734	-0.2%
Renewables	1,003	1,300	1,805	2,146	2,317	2,441	2,621	3.5%
Hydro	276	299	300	298	294	294	293	0.2%
Wind	440	513	884	1,026	1,067	1,092	1,149	3.5%
Geothermal	16	17	20	23	26	31	38	3.2%
Solar	205	403	530	723	851	942	1,055	6.0%
Other	67	68	72	76	79	82	86	0.9%
Net generation to grid	4,321	4,339	4,528	4,716	4,928	5,181	5,453	0.8%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430 and Annual Energy Outlook 2023 (March 2023), www.eia.gov/aeo

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E4.gen. Electricity generation: Canada, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	5	5	0	0	0	0	0	-13.5%
Natural gas	81	85	134	153	161	150	168	2.6%
Coal	39	18	0	0	0	0	0	-100.0%
Nuclear	79	71	77	72	51	39	28	-3.7%
Renewables	452	470	503	544	624	720	813	2.1%
Hydro	399	417	430	430	430	430	430	0.3%
Wind	41	45	64	106	185	282	375	8.3%
Geothermal	0	0	0	0	0	0	0	0.0%
Solar	6	6	6	6	6	6	5	-0.5%
Other	5	3	4	2	3	2	2	-2.8%
Net generation to grid	656	648	714	769	835	910	1,008	1.5%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E5.gen. Electricity generation: Mexico, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	46	48	23	12	5	0	0	-19.0%
Natural gas	191	195	196	213	245	259	263	1.2%
Coal	9	9	19	19	19	19	19	2.8%
Nuclear	11	11	20	28	23	17	17	1.4%
Renewables	86	80	103	113	123	150	181	2.7%
Hydro	32	33	39	39	39	39	40	0.8%
Wind	35	32	36	36	36	36	36	0.1%
Geothermal	5	0	8	8	8	8	8	1.5%
Solar	12	14	20	30	40	68	98	7.9%
Other	2	1	1	1	0	0	0	-100.0%
Net generation to grid	342	343	361	385	415	445	480	1.2%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E6.gen. Electricity generation: Brazil, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	23	23	9	1	0	0	0	-15.6%
Natural gas	97	110	110	89	73	69	66	-1.4%
Coal	13	13	9	9	13	9	9	-1.3%
Nuclear	14	14	23	23	23	18	18	0.9%
Renewables	531	561	588	660	692	728	758	1.3%
Hydro	410	430	462	536	539	539	539	1.0%
Wind	62	83	85	90	131	165	195	4.2%
Geothermal	0	0	0	0	0	0	0	0.0%
Solar	21	21	22	22	22	22	22	0.1%
Other	38	26	19	12	0	1	2	-9.5%
Net generation to grid	678	721	739	782	801	824	852	0.8%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E7.gen. Electricity generation: Other Americas, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	73	74	34	13	4	0	0	-18.4%
Natural gas	205	208	223	234	234	234	234	0.5%
Coal	25	25	42	90	146	185	200	7.7%
Nuclear	12	12	18	15	15	15	15	0.8%
Renewables	419	433	488	516	537	573	637	1.5%
Hydro	354	362	398	421	428	436	442	0.8%
Wind	34	43	56	62	76	104	161	5.7%
Geothermal	5	4	9	9	9	9	9	2.5%
Solar	16	17	20	21	22	22	22	1.2%
Other	10	6	4	3	1	2	2	-5.2%
Net generation to grid	734	752	805	869	937	1,008	1,086	1.4%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E8.gen. Electricity generation: Europe and Eurasia, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	117	116	76	55	41	40	39	-3.8%
Natural gas	1,473	1,499	1,586	1,633	1,730	1,846	1,989	1.1%
Coal	802	751	557	532	520	616	616	-0.9%
Nuclear	995	1,003	1,044	1,062	1,055	1,036	1,039	0.2%
Renewables	1,963	2,180	2,477	2,822	3,166	3,320	3,526	2.1%
Hydro	915	984	990	1,056	1,059	1,061	1,061	0.5%
Wind	483	552	632	710	956	974	1,004	2.6%
Geothermal	23	39	53	52	52	59	59	3.4%
Solar	218	197	338	501	563	651	783	4.7%
Other	324	409	464	502	536	575	618	2.3%
Net generation to grid	5,350	5,549	5,739	6,104	6,512	6,859	7,209	1.1%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E9.gen. Electricity generation: Western Europe, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	97	97	67	50	37	36	36	-3.5%
Natural gas	777	792	792	750	718	690	676	-0.5%
Coal	501	447	270	259	248	344	343	-1.3%
Nuclear	734	723	733	727	720	702	702	-0.2%
Renewables	1,649	1,863	2,145	2,460	2,811	2,962	3,168	2.4%
Hydro	621	697	706	753	756	756	756	0.7%
Wind	474	544	623	691	937	953	984	2.6%
Geothermal	22	38	52	51	51	57	57	3.4%
Solar	209	184	315	477	539	626	758	4.7%
Other	323	399	449	488	529	570	613	2.3%
Net generation to grid	3,758	3,921	4,007	4,246	4,534	4,735	4,925	1.0%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E10.gen. Electricity generation: Russia, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	17	16	6	2	2	1	1	-10.6%
Natural gas	499	502	588	661	714	771	832	1.8%
Coal	184	187	148	122	121	121	121	-1.5%
Nuclear	217	229	234	234	234	234	227	0.2%
Renewables	220	210	212	237	230	228	228	0.1%
Hydro	211	199	195	211	211	211	211	0.0%
Wind	5	1	2	10	10	10	10	2.4%
Geothermal	0	0	0	1	1	1	1	1.0%
Solar	3	2	3	3	3	3	3	0.0%
Other	0	8	13	13	6	4	4	16.6%
Net generation to grid	1,137	1,144	1,188	1,256	1,301	1,355	1,409	0.8%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E11.gen. Electricity generation: Eastern Europe and Eurasia, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	3	3	3	3	3	3	3	-0.5%
Natural gas	197	205	205	222	299	385	481	3.2%
Coal	117	117	140	151	151	151	151	0.9%
Nuclear	44	52	77	101	101	101	111	3.4%
Renewables	94	107	119	125	124	129	129	1.1%
Hydro	82	88	89	92	92	95	95	0.5%
Wind	4	7	7	9	9	10	10	3.8%
Geothermal	0	0	1	1	1	1	1	--
Solar	6	10	20	21	21	22	22	4.7%
Other	2	2	2	2	1	1	1	-1.2%
Net generation to grid	455	484	544	602	678	769	875	2.4%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E12.gen. Electricity generation: Asia Pacific, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	110	108	49	27	16	11	9	-8.7%
Natural gas	1,617	1,738	1,829	1,789	1,899	2,161	2,329	1.3%
Coal	7,746	7,591	7,976	8,295	8,423	8,394	8,601	0.4%
Nuclear	746	837	993	1,143	1,253	1,329	1,420	2.3%
Renewables	3,726	4,540	5,492	6,494	7,685	9,055	10,008	3.6%
Hydro	1,745	1,949	2,101	2,206	2,257	2,304	2,344	1.1%
Wind	842	1,021	1,302	1,764	2,399	3,072	3,350	5.1%
Geothermal	13	44	67	74	78	78	78	6.7%
Solar	902	1,407	1,912	2,359	2,858	3,404	4,020	5.5%
Other	225	119	110	91	94	197	216	-0.1%
Net generation to grid	13,945	14,815	16,340	17,749	19,276	20,950	22,367	1.7%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E13.gen. Electricity generation: Japan, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	29	29	15	9	6	6	6	-5.6%
Natural gas	363	383	383	339	305	307	295	-0.7%
Coal	291	283	167	182	182	182	182	-1.7%
Nuclear	78	115	139	139	121	102	102	0.9%
Renewables	210	203	237	265	320	349	377	2.1%
Hydro	72	83	83	86	86	86	86	0.6%
Wind	8	8	8	14	37	57	76	8.5%
Geothermal	3	3	3	4	4	4	4	0.8%
Solar	105	101	136	154	164	173	182	2.0%
Other	23	8	8	7	30	30	30	0.9%
Net generation to grid	972	1,014	942	934	933	946	961	0.0%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E14.gen. Electricity generation: South Korea, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	8	7	3	3	2	2	2	-4.6%
Natural gas	177	174	175	161	148	139	139	-0.9%
Coal	149	143	145	152	157	160	160	0.2%
Nuclear	201	228	228	228	228	218	214	0.2%
Renewables	50	53	79	106	131	161	181	4.7%
Hydro	3	4	4	5	5	5	5	1.1%
Wind	5	18	33	58	83	113	133	12.6%
Geothermal	0	0	0	0	0	0	0	0.0%
Solar	26	26	26	26	26	26	26	0.0%
Other	16	6	15	17	17	17	17	0.2%
Net generation to grid	586	606	631	649	665	679	695	0.6%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E15.gen. Electricity generation: Australia and New Zealand, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	4	4	0	0	0	0	0	-11.9%
Natural gas	56	52	52	41	32	38	38	-1.3%
Coal	111	104	123	131	136	136	134	0.7%
Nuclear	0	0	0	0	0	0	0	0.0%
Renewables	127	149	166	196	229	248	279	2.8%
Hydro	36	41	45	45	45	45	45	0.8%
Wind	42	57	67	86	98	104	115	3.7%
Geothermal	9	9	9	9	9	9	9	0.0%
Solar	38	41	45	55	77	90	109	3.8%
Other	2	1	1	0	0	0	0	-10.0%
Net generation to grid	298	308	341	369	397	423	452	1.5%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E16.gen. Electricity generation: China, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	13	12	1	0	0	0	0	-16.8%
Natural gas	302	357	398	494	712	975	1,155	4.9%
Coal	5,248	5,137	5,203	5,299	5,099	4,844	4,857	-0.3%
Nuclear	383	416	538	674	799	903	998	3.5%
Renewables	2,573	3,064	3,575	3,815	4,265	4,744	4,840	2.3%
Hydro	1,221	1,300	1,379	1,428	1,474	1,515	1,551	0.9%
Wind	653	724	870	1,063	1,448	1,822	1,835	3.8%
Geothermal	0	0	0	0	0	0	0	0.1%
Solar	575	986	1,284	1,293	1,301	1,268	1,285	2.9%
Other	123	54	42	31	43	140	169	1.1%
Net generation to grid	8,519	8,986	9,716	10,282	10,875	11,467	11,851	1.2%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E17.gen. Electricity generation: India, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	4	4	1	0	0	0	0	-14.7%
Natural gas	78	73	118	127	143	143	143	2.2%
Coal	1,240	1,260	1,473	1,523	1,607	1,572	1,501	0.7%
Nuclear	41	42	52	67	70	70	70	1.9%
Renewables	395	583	819	1,326	1,818	2,562	3,312	7.9%
Hydro	154	195	197	199	201	203	205	1.0%
Wind	119	193	285	448	618	857	1,072	8.2%
Geothermal	0	0	0	0	0	0	0	0.0%
Solar	99	176	321	665	998	1,501	2,035	11.4%
Other	23	18	16	14	0	0	0	-100.0%
Net generation to grid	1,757	1,962	2,463	3,043	3,637	4,347	5,026	3.8%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E18.gen. Electricity generation: Other Asia Pacific, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	52	53	28	15	8	3	1	-14.9%
Natural gas	641	699	703	627	559	559	559	-0.5%
Coal	706	664	864	1,008	1,243	1,500	1,768	3.3%
Nuclear	43	36	36	36	36	36	36	-0.6%
Renewables	369	487	615	787	923	990	1,020	3.7%
Hydro	258	326	393	444	446	451	452	2.0%
Wind	15	21	39	96	115	118	118	7.8%
Geothermal	1	32	55	61	65	65	65	17.9%
Solar	58	77	101	165	292	345	383	6.9%
Other	37	32	28	22	5	11	0	-15.1%
Net generation to grid	1,812	1,939	2,247	2,473	2,768	3,088	3,383	2.3%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E19.gen. Electricity generation: Africa and Middle East, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	348	354	180	80	35	13	3	-15.3%
Natural gas	1,349	1,398	1,422	1,654	1,849	2,054	2,216	1.8%
Coal	214	190	222	241	249	276	276	0.9%
Nuclear	37	54	87	116	135	135	135	4.8%
Renewables	269	403	569	636	707	821	911	4.4%
Hydro	188	232	251	268	292	344	383	2.6%
Wind	30	65	113	121	122	126	126	5.2%
Geothermal	6	6	33	46	63	63	63	8.6%
Solar	42	95	165	198	228	284	335	7.7%
Other	2	4	5	3	2	5	3	1.2%
Net generation to grid	2,217	2,399	2,480	2,727	2,975	3,299	3,541	1.7%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E20.gen. Electricity generation: Africa, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	48	47	16	3	0	0	0	-16.4%
Natural gas	358	367	391	490	591	702	792	2.9%
Coal	214	190	222	241	249	275	276	0.9%
Nuclear	13	13	30	43	52	52	52	5.1%
Renewables	227	307	413	467	530	632	714	4.2%
Hydro	165	207	224	240	263	315	354	2.8%
Wind	28	46	76	81	82	83	83	4.0%
Geothermal	6	6	33	46	63	63	63	8.6%
Solar	26	44	75	98	121	167	211	7.8%
Other	2	3	5	2	2	5	3	0.5%
Net generation to grid	861	924	1,072	1,243	1,423	1,662	1,835	2.7%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.

Table E21.gen. Electricity generation: Middle East, High Zero-carbon Technology Cost case

billion kilowatthours

Fuel	2022	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2022–2050
Liquid fuels	300	307	164	77	34	13	3	-15.2%
Natural gas	990	1,031	1,031	1,164	1,258	1,353	1,424	1.3%
Coal	0	0	0	0	0	0	0	-6.2%
Nuclear	24	41	58	73	83	83	83	4.6%
Renewables	42	96	155	169	177	189	197	5.7%
Hydro	23	25	27	29	29	29	29	0.8%
Wind	3	19	37	40	40	42	42	10.4%
Geothermal	0	0	0	0	0	0	0	0.0%
Solar	16	51	91	100	108	117	125	7.5%
Other	0	0	0	0	0	0	1	--
Net generation to grid	1,357	1,475	1,408	1,484	1,552	1,637	1,706	0.8%

Data source: U.S. Energy Information Administration, World Energy Projection System (2023), run hz_230821.151430

Note: Totals may not equal sum of components due to independent rounding. Net generation to grid represents gross generation minus losses from thermal efficiency and parasitic load.