COLUMBIA POWER TECHNOLOGIES

power from the next wave

Attachment 3
Pre-Project TAEP calculations

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1   INTRODUCTION

Simulations and calculations are carried out according to 'Energy Production Assessment for DOE LCOE and SPA Reporting'.

2   PERFORMANCE AND LOSS MATRICES

Performance matrices are depicted, with simulation conditions specified by the midpoint of each populated cell in the matrix. Mechanical power extracted (Figure 1) is calculated before any mechanical or electrical losses. Electrical power captured (Figure 2) is calculated as grid quality power, after all mechanical and electrical losses.

Losses are calculated as described in 'Energy Production Assessment for DOE LCOE and SPA Reporting'. PTO losses (Figure 3) include mechanical losses from the main bearings, idler bearings, and seals. Generator losses (Figure 4) include mechanical losses from the novel rail bearing system and electrical losses from the generator. Ancillary losses (Figure 5) include losses from power electronics, hotel loads and transformer.

The sea states where the fore-in-aft configuration was modeled are depicted in matrix form in Figure 6.
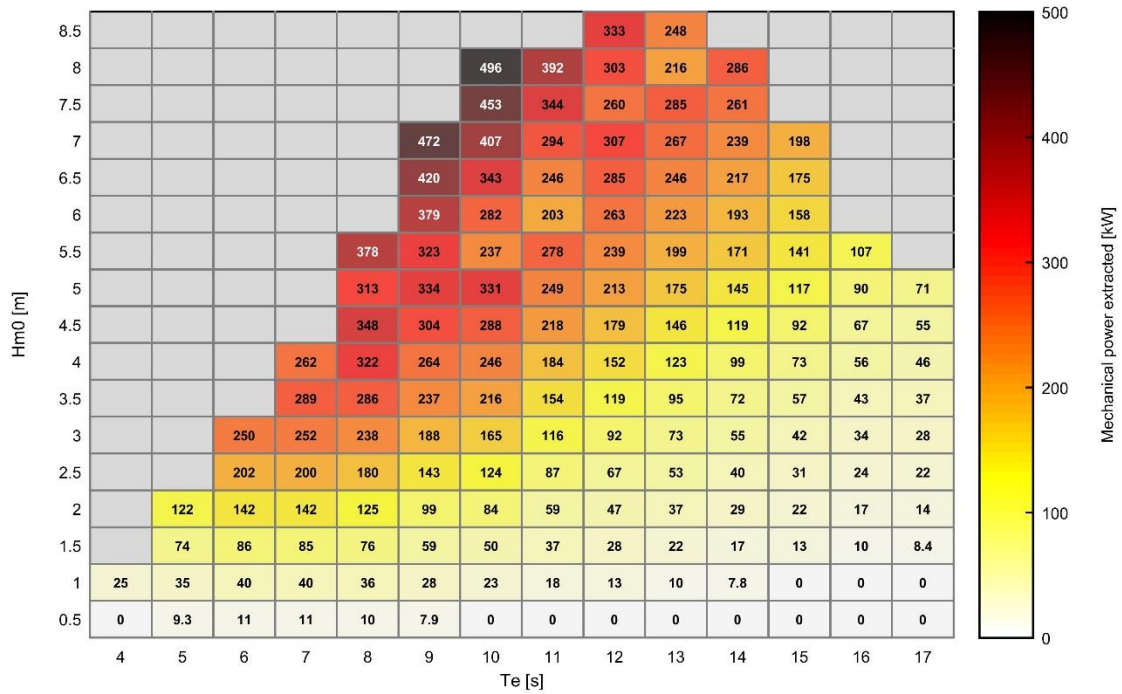
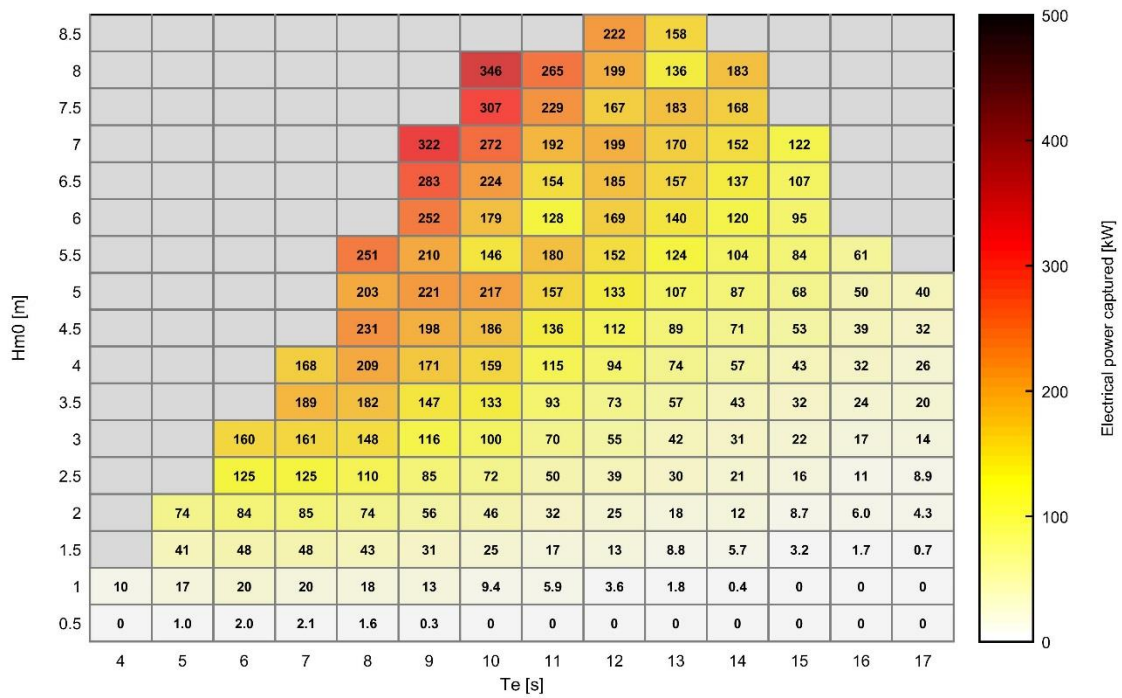**Figure 1 – Performance matrix of mechanical power extracted.**

Mechanical power extracted [kW]

Hm0 [m] \ Te [s]	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8.5									333	248				
8							496	392	303	216	286			
7.5							453	344	260	285	261			
7						472	407	294	307	267	239	198		
6.5						420	343	246	285	246	217	175		
6						379	282	203	263	223	193	158		
5.5					378	323	237	278	239	199	171	141	107	
5					313	334	331	249	213	175	145	117	90	71
4.5					348	304	288	218	179	146	119	92	67	55
4				262	322	264	246	184	152	123	99	73	56	46
3.5				289	286	237	216	154	119	95	72	57	43	37
3			250	252	238	188	165	116	92	73	55	42	34	28
2.5			202	200	180	143	124	87	67	53	40	31	24	22
2		122	142	142	125	99	84	59	47	37	29	22	17	14
1.5		74	86	85	76	59	50	37	28	22	17	13	10	8.4
1	25	35	40	40	36	28	23	18	13	10	7.8	0	0	0
0.5	0	9.3	11	11	10	7.9	0	0	0	0	0	0	0	0

Figure 2 – Performance matrix of electrical power captured.

Electrical power captured [kW]

Hm0 [m] \ Te [s]	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8.5									222	158				
8							346	265	199	136	183			
7.5							307	229	167	183	168			
7						322	272	192	199	170	152	122		
6.5						283	224	154	185	157	137	107		
6						252	179	128	169	140	120	95		
5.5					251	210	146	180	152	124	104	84	61	
5					203	221	217	157	133	107	87	68	50	40
4.5					231	198	186	136	112	89	71	53	39	32
4				168	209	171	159	115	94	74	57	43	32	26
3.5				189	182	147	133	93	73	57	43	32	24	20
3			160	161	148	116	100	70	55	42	31	22	17	14
2.5			125	125	110	85	72	50	39	30	21	16	11	8.9
2		74	84	85	74	56	46	32	25	18	12	8.7	6.0	4.3
1.5		41	48	48	43	31	25	17	13	8.8	5.7	3.2	1.7	0.7
1	10	17	20	20	18	13	9.4	5.9	3.6	1.8	0.4	0	0	0
0.5	0	1.0	2.0	2.1	1.6	0.3	0	0	0	0	0	0	0	0

Figure 3 – Matrix of PTO losses. (PTO losses [kW]; Hm0 [m] vs Te [s])

Hm0 \ Te	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8.5									21	17				
8						31	26	20	16	19				
7.5						35	23	18	19	15				
7					36	32	21	20	18	14	12			
6.5						33	28	22	16	14	13	11		
6						30	25	13	15	13	12	11		
5.5					30	26	22	16	14	13	11	9.8	8.4	
5					26	29	30	25	13	12	10.0	8.8	7.6	7.7
4.5					29	27	27	23	7.9	7.0	6.2	5.4	5.1	3.0
4				19	22	21	20	17	7.1	6.3	5.6	5.4	4.6	2.7
3.5				16	21	18	17	14	6.5	5.8	5.3	4.7	2.6	2.4
3			15	14	18	11	10	8.9	5.7	5.0	4.6	4.0	2.2	2.0
2.5			13	12	12	9.5	8.7	7.6	3.6	3.2	3.8	2.1	1.9	1.6
2		6.0	11	8.6	7.9	6.9	7.0	3.1	2.8	2.4	2.8	1.5	1.4	1.2
1.5		4.5	5.8	5.4	4.8	4.2	3.6	3.1	1.9	1.7	1.3	1.1	1.0	0.9
1	2.4	3.0	2.9	3.5	2.5	2.2	1.9	1.6	1.2	1.1	0.8	0	0	0
0.5	0	1.4	1.4	1.7	1.2	1.0	0	0	0	0	0	0	0	0

Figure 3 – Matrix of PTO losses.

Figure 4 – Matrix of generator losses. (Generator losses [kW]; Hm0 [m] vs Te [s])

Hm0 \ Te	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8.5									69	56				
8						89	77	65	50	65				
7.5						84	70	58	66	62				
7					85	78	63	70	63	58	50			
6.5						79	70	54	66	59	53	45		
6						74	61	48	62	54	49	41		
5.5					74	67	54	65	58	50	44	37	29	
5					65	65	63	51	53	45	38	32	25	16
4.5					66	60	57	45	46	39	32	26	16	14
4				59	71	54	51	40	40	34	27	17	13	12
3.5				66	65	57	53	36	30	24	17	14	11	9.6
3			59	60	57	48	43	28	23	19	13	10	8.8	7.6
2.5			50	50	46	38	33	22	18	14	9.9	8.2	6.6	7.0
2		33	37	38	34	28	23	18	14	11	8.6	6.9	5.6	4.8
1.5		21	24	24	22	17	15	11	8.6	6.9	5.4	4.2	3.5	3.0
1	7.6	10	12	12	11	9.0	7.5	5.7	4.4	3.5	2.8	0	0	0
0.5	0	3.1	3.6	3.6	3.3	2.8	0	0	0	0	0	0	0	0

Figure 4 – Matrix of generator losses.

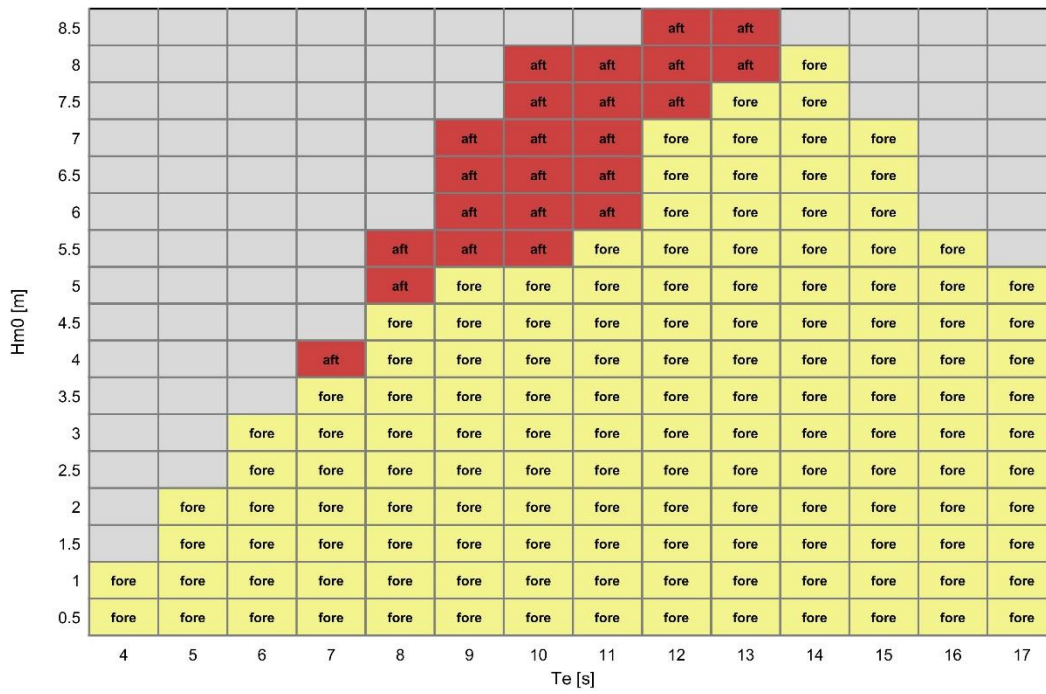Figure 5 – Matrix of ancillary losses.

Figure 6 – Fore float configuration depicted in matrix format.

3 AEP CALCULATIONS

3.1 Summary

TAEP at various stages of power conversion chain are given below for four resources. Further details are given in the following sections for each site. Availability and transmission losses are accounted for in the main body of 'MS13.1 EE-0006399 LCOE and SPA'.

Table 1 – Mean annual power at four sites of interest.

Site	Mean Power [kW]			
	Mech extracted	Mech into generator (pre rail bear)	Elec out of generator	Elec captured
DOE Reference (NDBC 46212)	106	98	71	62
Hawaii (WETS B)	94	87	62	54
Oregon (NDBC 46050)	129	120	88	78
Ireland (AMETS A)	183	169	127	114

Table 2 – TAEP at four sites of interest.

Site	Theoretical Annual Energy Production [MWh]			
	Mech extracted	Mech into generator (pre rail bearing)	Elec out of generator	Elec captured
DOE Reference (NDBC 46212)	926	862	622	547
Hawaii (WETS B)	822	767	546	476
Oregon (NDBC 46050)	1134	1053	771	685
Ireland (AMETS A)	1600	1482	1109	1000
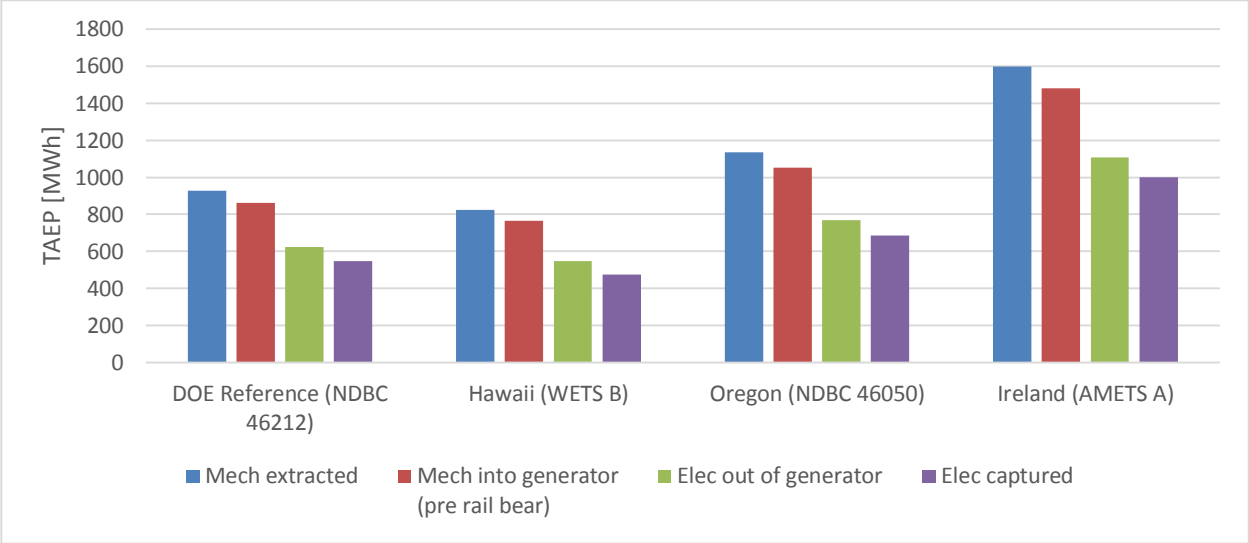
Figure 7 – TAEP at four sites of interest.

3.2 DOE Reference (NDBC 46212)

Table 3 – Mean annual power and losses for DOE reference site.

Source data: L2228-N2673 and L2228-N2674
Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	CA (DOE ref)
Mechanical power extracted	105.7
Mechanical power into generator (before rail bearing losses)	98.4
Mechanical power into generator (after rail bearing losses)	93.1
Electrical power out of generator	71.0
Electrical power capture (used for TAEP calculation)	62.4
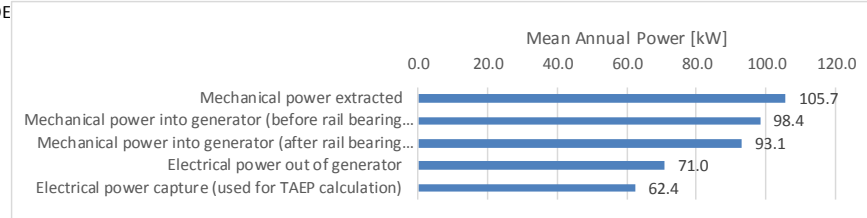
Losses [kW]	CA (DOE ref)
Fore primary bearing	0.3
Fore secondary bearing	1.1
Fore idler bearing	1.9
Fore seals	0.3
Fore rail bearing	2.9
Fore generator electrical	12.9
Aft primary bearing	0.4
Aft secondary bearing	0.9
Aft idler bearing	2.2
Aft seals	0.2
Aft rail bearing	2.4
Aft generator electrical	9.2
Power electronics	3.5
Hotel loads	2.9
Transformer	2.1
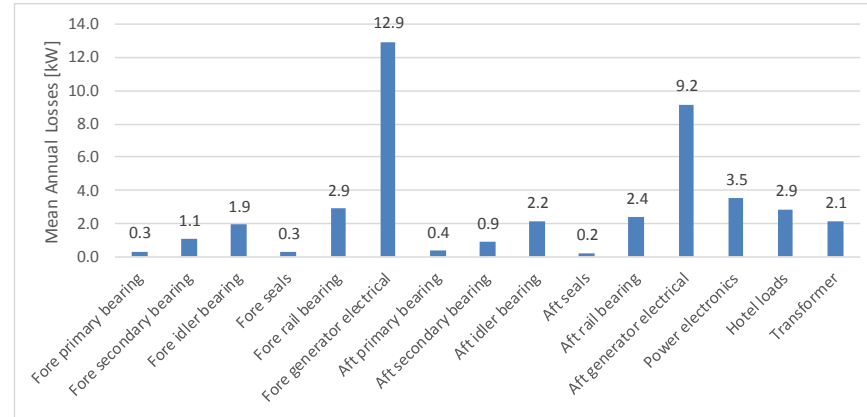
Losses by stage [kW]	CA (DOE ref)	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	7.3	93%	Mech power extracted
Generator losses (rail + generator electrical)	27.4	72%	Mech power into gen (before rail losses)
Generator rail losses	5.3	95%	Mech power extracted
Generator electrical losses	22.1	76%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	8.5	88%	Elec power out of generator

3.3   Hawaii (WETS B)

Table 4 – Mean annual power and losses for Hawaii (WETS B).

Source data: L2228-N2673 and L2228-N2674
Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	HI (WETS)
Mechanical power extracted	93.8
Mechanical power into generator (before rail bearing losses)	87.5
Mechanical power into generator (after rail bearing losses)	82.5
Electrical power out of generator	62.3
Electrical power capture (used for TAEP calculation)	54.3
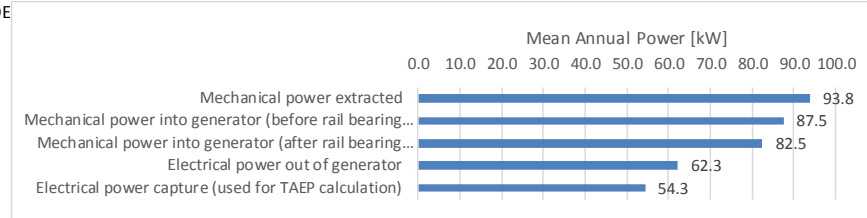
Losses [kW]	HI (WETS)
Fore primary bearing	0.3
Fore secondary bearing	1.0
Fore idler bearing	1.6
Fore seals	0.3
Fore rail bearing	2.8
Fore generator electrical	12.2
Aft primary bearing	0.3
Aft secondary bearing	0.8
Aft idler bearing	1.8
Aft seals	0.2
Aft rail bearing	2.2
Aft generator electrical	8.0
Power electronics	3.1
Hotel loads	2.8
Transformer	2.0
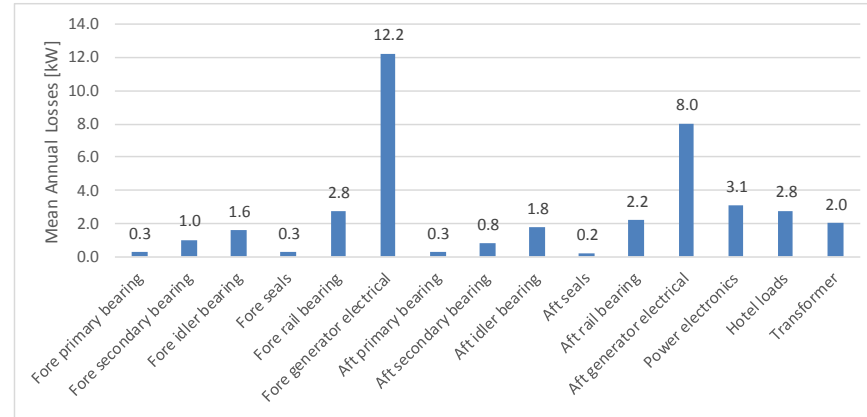
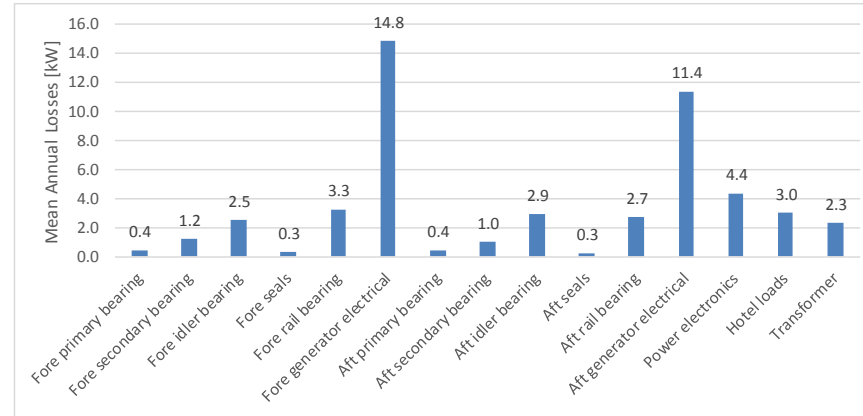| Losses by stage [kW]	HI (WETS)	Efficiency	Efficiency is with respect to…
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	6.3	93%	Mech power extracted
Generator losses (rail + generator electrical)	25.2	71%	Mech power into gen (before rail losses)
Generator rail losses	5.0	95%	Mech power extracted
Generator electrical losses	20.3	75%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	7.9	87%	Elec power out of generator

3.4 Oregon (NDBC 46050)

Table 5 – Mean annual power and losses for Oregon (NDBC 46050).

Source data: L2228-N2673 and L2228-N2674
Working folder:Z:\Engineering\LandRAY\Design Files\0000 Design Conditions and Response\LCOE

Power Annual Power [kW]	OR (ndbc46050)
Mechanical power extracted	129.3
Mechanical power into generator (before rail bearing losses)	120.1
Mechanical power into generator (after rail bearing losses)	114.1
Electrical power out of generator	87.9
Electrical power capture (used for TAEP calculation)	78.2
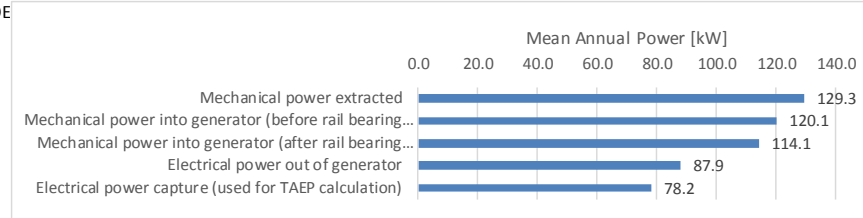
Losses [kW]	OR (ndbc46050)
Fore primary bearing	0.4
Fore secondary bearing	1.2
Fore idler bearing	2.5
Fore seals	0.3
Fore rail bearing	3.3
Fore generator electrical	14.8
Aft primary bearing	0.4
Aft secondary bearing	1.0
Aft idler bearing	2.9
Aft seals	0.3
Aft rail bearing	2.7
Aft generator electrical	11.4
Power electronics	4.4
Hotel loads	3.0
Transformer	2.3

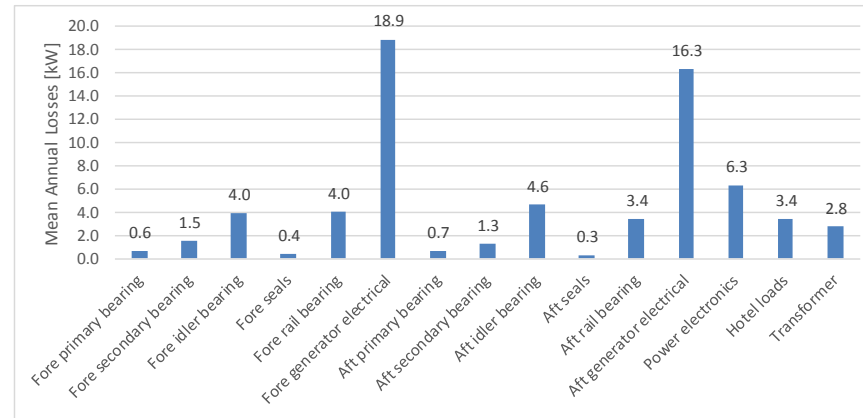| Losses by stage [kW]	OR (ndbc46050)	Efficiency	Efficiency is with respect to...
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	9.2	93%	Mech power extracted
Generator losses (rail + generator electrical)	32.2	73%	Mech power into gen (before rail losses)
Generator rail losses	6.0	95%	Mech power extracted
Generator electrical losses	26.2	77%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	9.7	89%	Elec power out of generator

3.5   Ireland (AMETS A)

Table 6 – Mean annual power and losses for Ireland (AMETS A).

Power Annual Power [kW]	IRL (ametsA)
Mechanical power extracted	182.6
Mechanical power into generator (before rail bearing losses)	169.1
Mechanical power into generator (after rail bearing losses)	161.6
Electrical power out of generator	126.5
Electrical power capture (used for TAEP calculation)	114.0
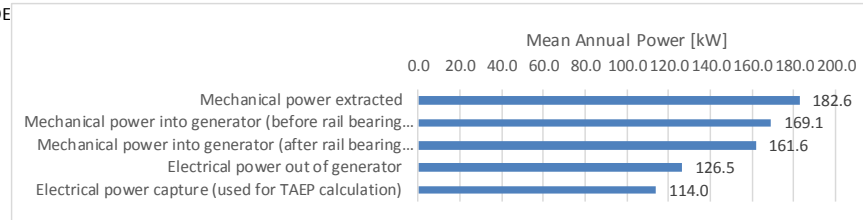
Losses [kW]	IRL (ametsA)
Fore primary bearing	0.6
Fore secondary bearing	1.5
Fore idler bearing	4.0
Fore seals	0.4
Fore rail bearing	4.0
Fore generator electrical	18.9
Aft primary bearing	0.7
Aft secondary bearing	1.3
Aft idler bearing	4.6
Aft seals	0.3
Aft rail bearing	3.4
Aft generator electrical	16.3
Power electronics	6.3
Hotel loads	3.4
Transformer	2.8

Losses by stage [kW]	IRL (ametsA)	Efficiency	Efficiency is with respect to…
PTO mechanical losses (prim/sec bearings + idler bearings + seals)	13.5	93%	Mech power extracted
Generator losses (rail + generator electrical)	42.6	75%	Mech power into gen (before rail losses)
Generator rail losses	7.4	96%	Mech power extracted
Generator electrical losses	35.1	78%	Mech power into gen (after rail losses)
Ancillary losses (PE + hotel + Transformer)	12.5	90%	Elec power out of generator