Exh. DCG-9C
Dockets UE-170033/UG-170034
Witness: David C. Gomez
CONFIDENTIAL VERSION

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**DOCKETS UE-170033 and UG-170034 (*Consolidated*)**

EXHIBIT TO
TESTIMONY OF

David C. Gomez

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

PSE's Response to Staff DR No. 176, Attachment G, DNV Evaluation of Hopkins Ridge and Wild Horse Pre-Construction Net Energy Estimates

June 30, 2017

CONFIDENTIAL PER PROTECTIVE ORDER – CONFIDENTIAL VERSION

August 3, 2010

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Steven St. Clair
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Subject: DNV Evaluation of Hopkins Ridge and Wild Horse Pre-Construction Net Energy Estimates

Dear Mr. St. Clair:

DNV conducted a preliminary evaluation of the net energy estimates for the Hopkins Ridge and Wild Horse projects. This evaluation was based on a review of the following pre-construction energy assessment reports prepared by Garrad Hassan (GH):

- *Assessment of the Energy Production of the Proposed Hopkins Ridge Wind Farm*, dated November 29, 2004.
- *Assessment of the Energy Production of the Proposed Wild Horse Wind Farm*, dated September 9, 2005.

DNV did not independently analyze the raw wind data, assess the energy production, or evaluate the uncertainties associated with the energy assessment. The net energy production estimates presented in this letter report do not consider actual project production data. DNV recommends that the historical operating data be evaluated to further develop the long-term net energy production estimates for these projects.

GH's energy assessment report for the Hopkins Ridge project is based on an 83-turbine layout. Four turbines were added to the Hopkins Ridge project after the GH report was issued. In order to present energy production estimates for the 87-turbine project we have assumed that the 4 turbines have average energy production and that the increase in the wake loss estimate due to these 4 turbines would be minimal. The Wild Horse estimates assume a 127-turbine project and do not include the Wild Horse Expansion project.

Evaluation Method

DNV reviewed the analysis methods and energy production estimates described in the GH Reports. The general steps used in this review were:

- Evaluate method used to adjust the short-term on-site measurement to represent long-term wind speeds.

- Evaluate long-term average hub-height wind speeds at the met tower location(s) based on a review of the report with consideration of assumptions and methods employed.
- Evaluate annual average hub-height wind speed for each turbine location, considering the long-term annual average hub-height wind speed at the met tower(s), the turbine elevations and turbine exposures.
- Evaluate the reasonableness of the gross energy estimate based on the site air density, turbine power curve, and long-term annual wind speed frequency distribution.
- Evaluate energy loss estimates.

To the extent possible, any discrepancies between DNV's standard methods and estimates and the GH Report were broadly quantified and included in DNV's preliminarily net energy production estimates.

Results

The results of DNV's evaluation of the Hopkins Ridge and Wild Horse pre-construction net energy estimates are presented in Appendix A. In general, DNV found GH's methods and gross energy estimates to be reasonable. However, we estimated a lower gross energy estimate (approximately 2% lower) for the Hopkins Ridge project due to differences in extrapolating the met tower wind speeds to the turbine locations. DNV reviewed GH's assigned turbine wind speeds, considering the met tower hub-height wind speed, wind flow modeling method, terrain, and the turbine elevations and exposure and estimated lower wind speeds for some turbine locations.

To estimate the net energy production for the project, energy loss estimates were applied to the gross energy estimates. Overall, DNV's net production estimates were 6.7% and 6.5% lower than the GH estimates for the Hopkins Ridge and Wild Horse projects, respectively. The difference between the DNV and GH net energy estimates is primarily due to differences in energy loss estimates, specifically the turbine availability, wake, and environmental loss estimates. The differences between these loss estimates are summarized below:

- For these reports, GH estimated an availability loss of 3.2% which is consistent with their estimates in 2004/2005; whereas, our availability estimate is 5.8%. In the past couple of years, it is common knowledge in the wind industry that GH has modified their availability loss estimate to a value closer to DNV's estimate.
- GH used a wake calculation method in the WindFarmer software, which is a common industry tool. DNV did not independently estimate the wake losses for these projects, but typically takes a different approach to estimating wake losses. Due to this difference in approach, DNV's wake loss estimate is typically 30% higher than GH's estimate. We have assumed this typical relationship applies to the Hopkins Ridge and Wild Horse projects and have increased the wake loss estimate accordingly.

- GH's environmental loss estimates are 1.0% and 2.0% for the Hopkins Ridge and Wild Horse projects, respectively. DNV's environmental loss estimates of 2.9% and 3.2% are based on analysis conducted by DNV for Puget Sound Energy (PSE) related to nearby wind projects (the Lower Snake River and Wild Horse Expansion projects).

Estimated 12-Month by 24-Hour (12x24) Power Production Matrix

Appendix B presents the 12-month by 24-hour (12x24) estimated power production matrix for the Hopkins Ridge and Wild Horse projects. The 12x24 power production matrices are based on DNV's estimate of the long-term annual net energy production estimates and the 12x24 percent of production matrices that were provided to DNV by PSE on July 28, 2010. DNV has not independently verified the 12x24 percent of production pattern that was provided by PSE. The 12x24 matrices represent an estimate of the long-term average power production. The power production in any given hour or month of a specific year may deviate significantly from the pattern presented in the matrices.

Please contact me at (206) 387-4245 (Katy.Briggs@DNV.com) if you have questions about the information contained in this letter.

Best regards,
For DNV Renewables (USA) Inc.

Katy Briggs
Energy Assessment Lead

Appendix A – Comparison of GH and DNV Energy Production Estimates

Table A-1. Comparison of GH and DNV Estimates for the Hopkins Ridge Project

Hopkins Ridge Project	**GH Estimate**	**DNV Estimate**
Gross Energy Estimate[1] (GWh/yr) - 83 Turbines	516	507
Gross Energy Estimate[1] (GWh/yr) - 87 Turbines	NA	531
Energy Loss Estimates		
- Availability Loss	3.2%	5.8%
- Wake Effects Loss	3.3%	4.3%
- Turbine Performance Loss	1.2%	1.2%
- Electrical Loss	3.0%	2.5%
- Environmental Loss	1.0%	2.9%
- Curtailment Loss	0.0%	0.0%
- Other Losses	0.0%	0.0%
Total Energy Loss	15.9%	21.4%
Net Energy (GWh/yr) - 83 Turbines	458	427
Net Energy (GWh/yr) - 87 Turbines	NA	448
Net Capacity Factor	**35.0%**	**32.6%**

1. Includes Topographic Effects

Table A-2. Comparison of GH and DNV Estimates for the Wild Horse Project

Wild Horse Project - 127 Turbines	**GH Estimate**	**DNV Estimate**
Gross Energy Estimate[1] (GWh/yr)	769	769
Energy Loss Estimates		
- Availability Loss	3.2%	5.8%
- Wake Effects Loss	7.7%	10.0%
- Turbine Performance Loss	1.4%	1.2%
- Electrical Loss	2.1%	2.5%
- Environmental Loss	2.0%	3.2%
- Curtailment Loss[2]	0.5%	0.5%
- Other Losses	0.0%	0.0%
Total Energy Loss	15.9%	21.4%
Net Energy (GWh/yr)	647	605
Net Capacity Factor	**32.3%**	**30.2%**

1. Includes Topographic Effects

2. The curtailment loss estimate only considers wind sector management. Other types of curtailment were not evaluated.

Appendix B – 12-Month by 24-Hour Power Production Estimates

Table B-1. Hopkins Ridge Preliminary 12-Month by 24-Hour Power Production Estimate (MW) - 87 Turbines

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	55	46	82	51	64	58	66	59	58	45	49	56
2	56	45	81	57	62	64	69	64	64	45	46	56
3	56	45	82	60	62	67	75	65	61	48	46	56
4	56	45	79	55	64	72	77	66	61	49	48	55
5	58	48	77	55	65	72	72	66	60	49	49	52
6	58	48	77	54	62	69	69	59	55	48	52	56
7	59	51	75	55	58	66	65	53	52	48	51	52
8	62	51	74	54	61	64	61	53	49	49	49	56
9	61	48	75	58	62	57	56	48	46	49	45	56
10	56	50	77	58	62	49	52	38	45	46	49	59
11	56	51	81	55	62	43	45	32	43	46	51	55
12	55	54	84	51	61	40	40	29	40	46	52	55
13	52	50	84	43	59	37	38	27	40	45	51	53
14	58	45	82	39	55	36	38	26	39	40	49	48
15	55	42	78	37	51	31	36	25	37	38	46	45
16	51	35	75	36	49	30	35	23	39	35	45	46
17	53	30	69	39	49	31	35	22	36	36	45	46
18	55	32	68	33	43	31	29	22	33	33	46	48
19	55	30	65	31	43	31	26	22	36	33	46	51
20	58	34	64	31	46	37	30	25	39	33	45	51
21	65	34	62	33	49	45	38	30	40	38	48	52
22	65	34	66	39	58	49	43	36	48	40	52	56
23	62	37	74	42	61	54	55	45	54	43	52	59
24	65	43	79	46	65	55	65	52	54	45	51	59
Average	**58**	**43**	**75**	**46**	**57**	**50**	**51**	**41**	**47**	**43**	**49**	**53**

Table B-2. Wild Horse Preliminary 12-Month by 24-Hour Power Production Estimate (MW)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	84	82	70	73	70	75	68	66	48	66	85	55
2	84	82	70	71	72	75	62	64	48	66	83	55
3	84	80	64	75	72	73	62	59	46	62	79	57
4	82	78	66	77	70	71	59	59	42	64	75	60
5	80	76	60	75	72	67	55	59	44	62	81	59
6	84	71	57	75	64	62	47	59	46	64	77	59
7	80	69	59	77	62	62	45	60	44	66	73	64
8	80	76	60	77	66	62	43	64	42	64	71	60
9	78	76	60	79	62	60	41	62	40	62	73	59
10	82	73	64	81	68	60	41	57	36	66	71	51
11	78	73	66	79	72	65	45	57	40	70	77	43
12	74	71	70	79	76	67	53	57	44	68	75	45
13	70	73	72	77	78	71	57	57	46	70	77	45
14	70	73	74	77	74	75	66	60	44	70	75	47
15	74	71	76	77	72	77	78	68	46	74	69	51
16	80	69	72	75	78	81	84	72	52	72	65	53
17	82	65	74	75	88	89	96	80	54	70	67	51
18	78	69	74	75	96	95	99	86	56	72	69	59
19	76	76	74	71	88	93	103	86	56	72	69	59
20	78	78	70	67	84	93	99	92	56	70	73	62
21	80	82	68	71	72	89	92	88	52	70	77	59
22	82	84	74	75	78	79	80	82	52	72	79	59
23	86	82	76	73	80	77	70	74	50	72	77	64
24	84	82	70	73	80	75	66	66	48	70	81	62
Average	**80**	**76**	**69**	**75**	**75**	**74**	**67**	**68**	**48**	**68**	**74**	**56**