Northwest **Power** and
Conservation Council

November 5, 2019

MEMORANDUM

TO: **Council Members**

FROM: **Mike Starrett**

SUBJECT: **Onshore Wind Generation Reference Plant**

BACKGROUND:

Presenter: Mike Starrett

Summary: A reference plant defines the size, cost, operating characteristics, and maximum build out of a given generating resource type and configuration. A single technology type could have multiple reference plants to differentiate, for example, a Montana-based wind resource from a wind resource located in the Columbia Gorge.

Reference plants serve as a key input for the Council's portfolio expansion modeling tools and are also used by other entities throughout the region.

Draft reference plants are developed in coordination with the Generating Resources Advisory Committee and are then brought to the Council before being incorporated into the tools used in the development of the Plan.

This presentation will introduce the draft reference plants for Onshore Wind.

Workplan: Prepare for 2021 Power Plan

More Info: Reference plants for the 7th Power Plan are described in Appendix H

Wind Reference Plant for the 2021 Power Plan

Mike Starrett, Ph.D.

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Defining a Reference Plant

- A **reference plant** describes how a particular technology is represented in the Council's planning models
- Captures characteristics such as
  - Overnight capital cost ($/kW)
  - Generation shape/profile (renewables)
  - Efficiency/heat rate
  - Learning curves
  - *Etc.*

Example: 7th Power Plan – CC Gas

Table H - 3: CCCT Reference Plants

Reference Plant	CCCT Adv 1 Wet Cool East	CCCT Adv 2 Dry Cool East	CCCT Adv 2 Dry Cool West
Configuration	1 gas turbine x 1 steam turbine and wet cooling system	1 gas turbine x 1 steam turbine and dry cooling system	1 gas turbine x 1 steam turbine and dry cooling system
Note	Based on Siemens H-Class. Number of plants with wet cooling may be limited	Based on MHI J-Class	Based on MHI J-Class. Assumed to require gas pipeline expansion on West side
Location	East side	East side	West side
Earliest In-Operation Date	2020	2021	2021
Development Period (Years)	2	2	2
Construction Period (Years)	3	3	3
Economic Life (Years)	30	30	30
Financial Sponsor	IOU	IOU	IOU
Capacity (MW)	370	425	426
Fuel	Natural Gas East	Natural Gas East	Natural Gas West with pipeline expansion
Heat Rate (btu/kWh)	6,770	6,704	6,704
Overnight Capital Cost ($/kW)	1,147	1,287	1,282
Fixed O&M Cost ($/kW-yr)	15.37	15.37	15.37
Variable O&M Cost ($/MWh)	3.27	3.27	3.27
Transmission	BPA point to point	BPA point to point	BPA point to point with transmission deferral credit
Maximum build-out (MW) as modeled	1,110	5,950	1,278

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Council Input on Reference Plants

Staff develops candidate reference plants → Staff engages GRAC to solidify draft reference plants → Staff brings draft plants to Council → Reference plants are incorporated into models

Two important points:

- Most reference plant details are "just the facts" and are presented to the Council as background
- Some characteristics are a matter of judgement and are presented to the Council for discussion and direction taking

Focus Area

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Wind in the 7th Plan

1) **Montana** represented high quality (but somewhat limited) resource

2) **Columbia Basin** represented lower quality (but plentiful) resource

Reminder from last time: Maximum build being "limited" referred to a limited inventory of long term firm P2P transmission

7th Power Plan - Wind

Table H - 13: Wind Power Reference Plants

Reference Plant	Wind Columbia Basin	Wind MT w/existing Transmission	Wind MT w/ new Transmission	Wind MT w/ Transmission Upgrade	Wind MT w/ Colstrip Transmission
Configuration	40 x 2.5 MW wind turbine generators	40 x 2.5 MW wind turbine generators	40 x 2.5 MW wind turbine generators	40 x 2.5 MW wind turbine generators	40 x 2.5 MW wind turbine generators
Note		Very limited transmission available to bring to Western load centers	New 230kV transmission line rolled into capital cost	New 230kV transmission line and Path 8 Upgrade	Using Colstrip Transmission
Location	OR/WA	MT	MT	MT	MT
Earliest In-Operation Date	2019	2019	2020	2020	n/a
Development Period (Years)	2	2	2	2	2
Construction Period (Years)	2	2	2	2	2
Economic Life (Years)	25	25	25	25	25
Financial Sponsor	IOU	IOU	IOU	IOU	IOU
Capacity (MW)	100	100	100	100	100
Capacity Factor	0.32	0.40	0.40	0.40	0.40
Overnight Capital Cost ($/kW)	2,240	2,240	2,349	2,349	2,240
Fixed O&M Cost ($/kW-yr)	35.00	35.00	35.00	35.00	35.00
Variable O&M Cost ($/MWh)	2.00	2.00	2.00	2.00	2.00
Transmission	BPA point to point	NorthWestern Energy, Montana Intertie, BPA	NorthWestern Energy, Montana Intertie, BPA	NorthWestern Energy, Montana Intertie, BPA	Colstrip Trans. System, Montana Intertie, BPA
Maximum build-out (MW) as modeled	6,500	100	200	900	2000

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Detour! Maximum Build out for the 2021 Plan

(Applicable to all resource type)

Maximum build-out

- Utilities still need to be able to deliver sufficient capacity to meet their system peak, but perhaps may be flexible around the makeup of energy
- A higher max build out for any resource type allows the model to test the economics of such a future given all other options, system operational constraints, policy, *etc*. Nothing more.

Table H - 11: Solar PV Reference Plants

Reference Plant	Solar PV S. ID	Solar PV S. ID w/ Transmission Expansion	Solar PV Low Cost S. ID	Solar PV W. WA	Solar PV Low Cost W. WA
Configuration	20 MW installation with crystalline silicon panels and single axis tracker system	20 MW installation with crystalline silicon panels and single axis tracker system	50 MW installation with crystalline silicon panels and single axis tracker system	50 MW installation with crystalline silicon panels and single axis tracker system	50 MW installation with crystalline silicon panels and single axis tracker system
Note	Mid-range capital cost estimate	Mid-range capital cost estimate	Low range capital cost estimate	Mid-range capital cost estimate	Low range capital cost estimate
Location	Southern Idaho	Southern Idaho	Southern Idaho	Western WA	Western WA
Earliest In-Operation Date	2018	2021	2020	2020	2020
Development Period (Years)	2	2	2	2	2
Construction Period (Years)	1	1	1	1	1
Economic Life (Years)	30	30	30	30	30
Financial Sponsor	IPP	IPP	IPP	IPP	IPP
Investment Tax Credit*	30%/10 %	30%/10 %	30%/10 %	30%/10 %	30%/10 %
Capacity (MW)	17.4	17.4	48	48	48
Capacity Factor	0.26	0.26	0.26	0.19	0.19
Overnight Capital Cost ($/kW)	2,413	2,413	1,685	2,413	1,685
Fixed O&M Cost ($/kW-yr)	16.63	16.63	11.62	16.63	11.62
Variable O&M Cost ($/MWh)	0	0	0	0	0
Transmission	Idaho Power	Transmission Expansion & BPA	Idaho Power	BPA point to point	BPA point to point
Maximum build-out (MW) as modeled	642	989	642	3840	3840

*ITC at 30% through year 2019, stepping down to 10% in 2022

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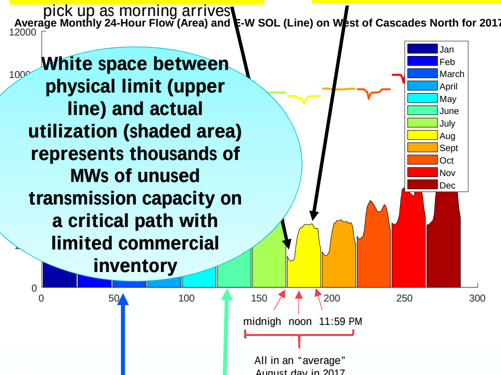
Detour! Eastern Washington into Puget Sound Area

'Average' August Morning in 2017:
Low night-time flows begin to pick up as morning arrives

'Average' August Evening in 2017:
Evening flows continue to be strong following the typical "single hump" summer peak



White space between physical limit (upper line) and actual utilization (shaded area) represents thousands of MWs of unused transmission capacity on a critical path with limited commercial inventory

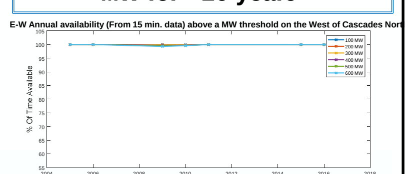
All in an "average" August day in 2017

March

June

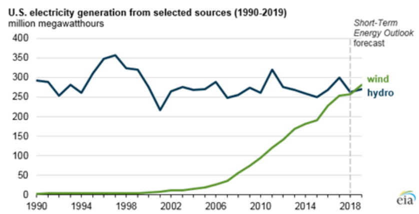
West of Cascades North

- Winter peaking path primarily serving Northwest Washington
- TTC: 10,250 MW
  - **LTF Inventory: 100's of MW for ~10 years**



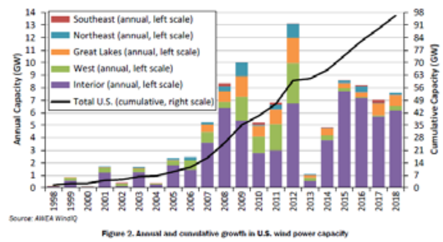
Back to Wind: Wind is the largest source of renewable energy in the U.S.

Wind surpasses hydro on MWh basis in 2018
(But is still less than 10% of US energy supply)



https://www.eia.gov/todayinenergy/detail.php?id=34652

Wind development is primarily in the U.S. Interior



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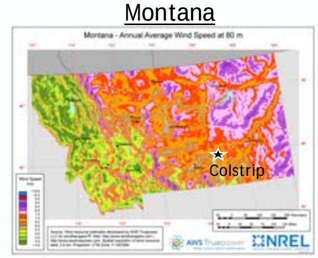
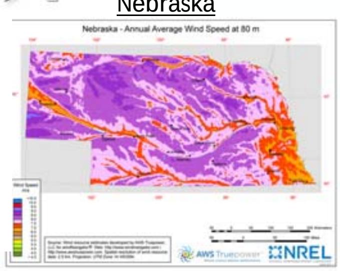
National Trend: The interior US is a world class wind resource

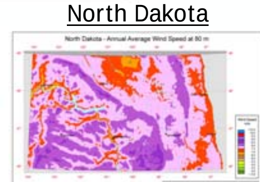
Montana



Nebraska



North Dakota



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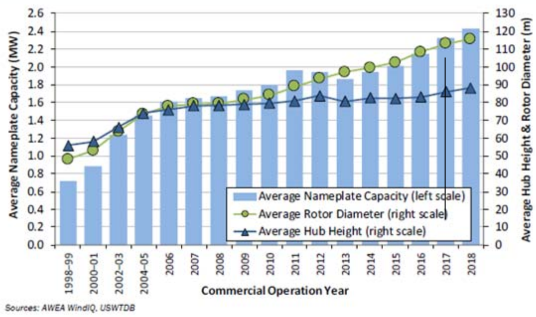
National Trends: Taller turbines, more powerful machines

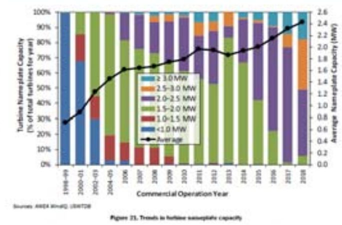
Turbines are getting taller & more powerful



Sources: AWEA WindIQ, USWTDB

Figure 20. Average turbine nameplate capacity, rotor diameter, and hub height for land-based wind projects[34]

By 2030, 3.X MW turbines are expected to be the norm



DOE/LBNL 2018 Wind Technologies Market Report

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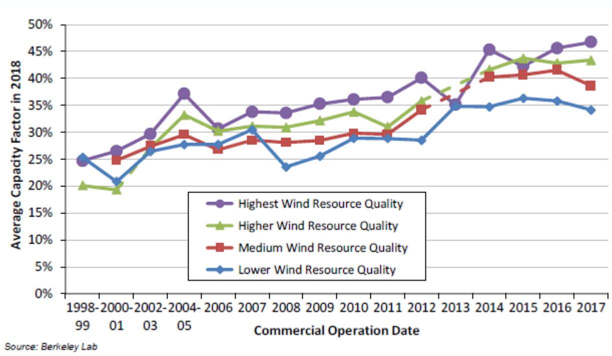
Capacity factors are going up everywhere owing to technology improvements



Source: Berkeley Lab

Figure 41. Calendar year 2018 capacity factors by commercial operation date and wind resource quality

DOE/LBNL 2018 Wind Technologies Market Report

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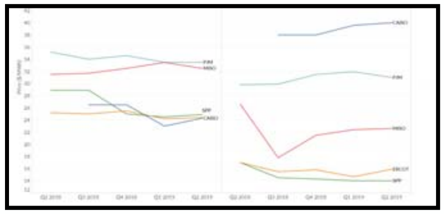
Declining capital costs, higher capacity factors, and the PTC have led to very, very low PPA prices

All PPAs

Corporate PPAs



Note: This data is focused on corporate PPAs which often have shorter contract lengths, allowing for flexibility on latter half of project life. Consider these numbers in context.

Level10 Q2 2019 PPA Price Index
https://cdn2.hubspot.net/hubfs/4108426/LevelTen%20Energy%20Q2%202019%20PPA%20Price%20Index.pdf?__hssc=83931014.1.1568923991351&__hstc=83931014.4281e5aab9bdc5c0f8bd3002b212f42d.1567961420011.1567961420011.1568923991351.2&__hsfp=979762834&hsCtaTracking=347b5e74-bf34-47d2-8fb8-4c2cf942ecac%7C4c5ce72d-25f1-47b6-910e-fcd8d47bf7c3

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PTC benefit coming to a close

- **Production Tax Credit**

Construction Start*	Percent of PTC	Value of PTC ($/MWh)
2015 and 2016	100%	$24.00
2017	80%	$19.20
2018	60%	$14.40
2019	40%	$9.60
2020 and on	0%	-

Reminder: PTC impacts LCOE/PPA price, but not overnight capital cost

***Construction Start:** Spending 5% of total cost of project or undertaking significant physical work (excavating turbine sites, building roads, *etc.*)

- Projects must then be operational on Dec. 31 four years after construction start to take safe harbor benefit

https://www.energy.gov/savings/renewable-electricity-production-tax-credit-ptc
https://www.taxequitytimes.com/2017/10/dramatic-arc-ptc/
https://www.windpowerengineering.com/business-news-projects/ptc-qualifies-start-construction-tax-equity-panel-advises/

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Summary of discussion so far

1. Wind capacity has grown substantially
2. Turbines are getting taller
3. Capacity factors are going up
4. Capital costs have been going down
5. The PTC has been important in achieving very low PPA prices and driving "last minute" development
    1. FYI, the utility solar ITC begins declining in 2020 but remains at 10% from 2022 and on

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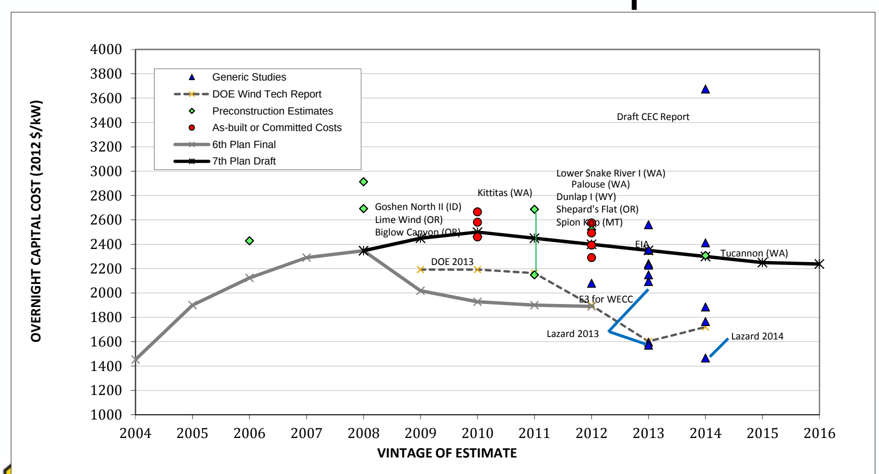
Back to the Region: Capital Costs in the 7th Plan Development



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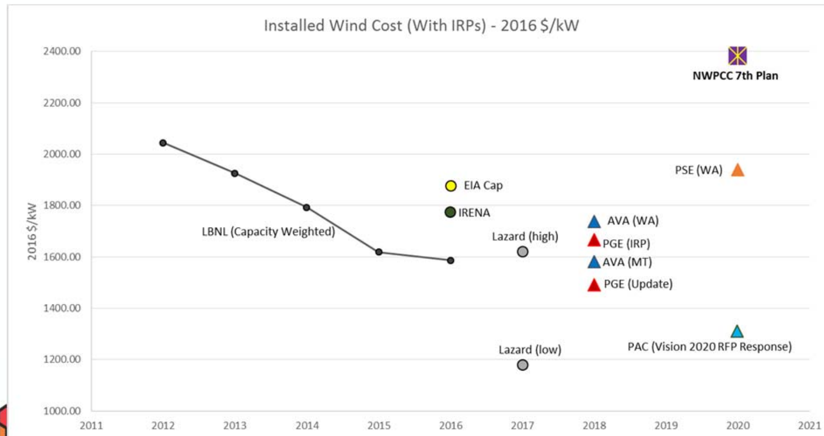
Back to the Region: Capital Costs in the 7th Plan Mid-Term



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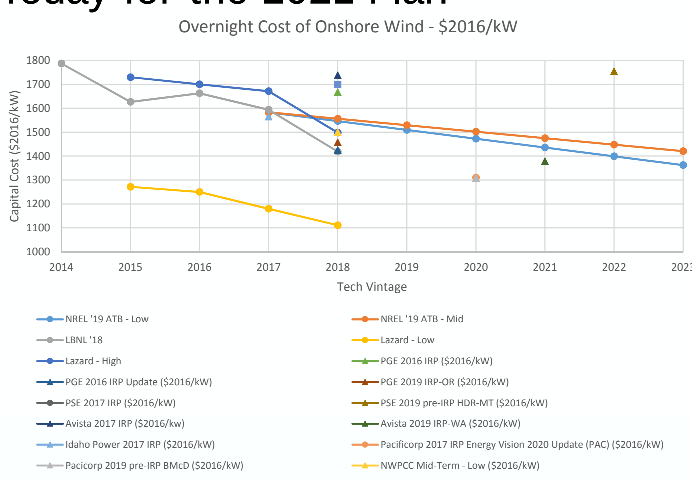
Back to the Region: A look at Capital Costs Today for the 2021 Plan

Tech Vintage	Average Price from Source Data ($2016/kW)
2017	$1524
2018	$1525
2020	$1398
2021	$1378
2022	$1533



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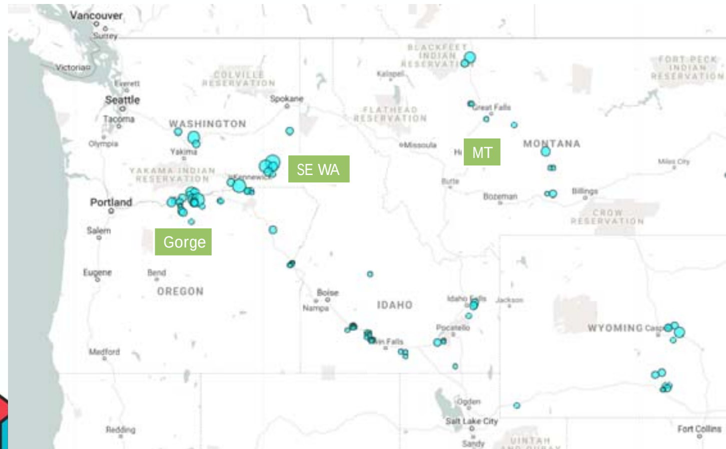
Resource Locations



https://www.nwcouncil.org/energy/energy-topics/power-supply/map-of-power-generation-in-the-northwest

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A look at capacity factors for reference plats in IRPs

Oregon Capacity Factors	
PGE '16: Ione, OR, 2.0 MW	34.0%
PGE '16: Ione, OR, 2.0 MW	35.0%
PGE '19: Ione, OR, 3.6 MW	32.7%
PAC '19: OR, 3.5 MW	37.1%

Gorge Capacity Factors	
PGE '19: Gorge, 3.6 MW (Similar shape to Ione, OR)	40.8%
NWPCC 2021P Draft Gorge, 3.6 MW	39.8%

Washington Capacity Factors	
PGE '19: SE WA, 3.6 MW	42.9%
PSE '19: SE WA, ?? MW	31.9%
Avista '19: Off System, WA, 2.2 MW	37.0%
PAC '19: WA, 3.5 MW	37.1%
NWPCC 2021P Draft SE WA, 3.6 MW	41.2%

Montana Capacity Factors	
PGE '19: Loco Mtn MT, 3.6 MW	42.9%
PSE '19: Near CTS MT, ?? MW	35.5%
PSE '19: Great Falls MT, ?? MW	42.4%
Avista '19: MT, 2.2 MW	48.0%
NWPCC 2021P Draft MT, 3.6 MW	45.5%

Other Capacity Factors	
PAC '19: WY, 3.5 MW	43.6%
PAC '19: ID, 3.5 MW	37.1%

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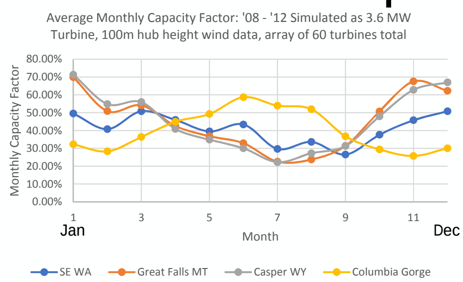
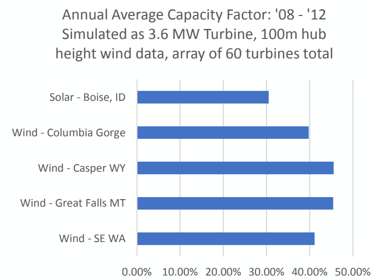
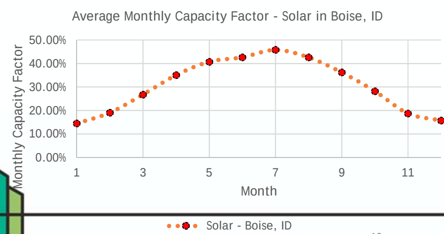
Back to the Region: A look at shape





FYI



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2021 Plan Reference Plant: Wind

	Onshore Wind - Columbia Gorge	Onshore Wind - SE Washington	Onshore Wind - Montana
Configuration	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height
Location	OR/WA	WA	MT
Technology Vintage	2019	2019	2019
Development Period (Years)	2	2	2
Construction Period (Years)	1	1	1
Capacity (MW)	216	216	216
Capacity Factor (%)	39.8%	41.2%	45.5%
Overnight Capital Cost ($/kW)	1,450	1,450	1,450
Fixed O&M Cost ($/kW-yr)	30	30	30
Variable O&M ($/MWh)	0	0	0
Economic Life (years)	25	25	25
Financial Sponsor	IPP	IPP	IPP
Transmission	BPA P2P	BPA P2P	PSE CTS + MT Int + BPA P2P
Max Build Out	TBD, substantial	TBD, substantial	TBD, substantial

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Example Impact of Transmission

- Example of exporting Montana Wind
  - Source: Commercial & Policy group of the "Montana Renewable Resource Development Action Plan"

Transmission Systems	Trans Rate ($/kw-mo)	Losses	Total Cost* ($/MWh)
BPA	$1.79	1.9%	$6.02
PSE CTS + MT Int + BPA	$4.95	4.6%**	$16.45
NWE + BPA	$5.12	5.9%	$17.36
NWE + AVA + BPA	$7.12	8.9%	$24.34

* Total cost based on 45% capacity factor and losses valued at $30/MWh

** Does not include 5% MT Intertie losses for third party use

[1]https://www.nwcouncil.org/energy/grac/meetings/2018_02_gracwebinar/
https://www.bpa.gov/Projects/Initiatives/Montana-Renewable-Energy/Pages/Montana-Renewable-Energy.aspx

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Summary and discussion

- Staff has worked with GRAC to develop draft onshore wind reference plants
- Staff is proposing three Wind reference plants:
  - Gorge
  - SE Washington
  - Montana
- Each location has the same cost, but different capacity factors and transmission charges

Discussion and feedback?

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Additional Background Information and Backup Slides

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A detailed look at Capital Costs for the 2021 Plan

Source	Tech Vintage	$2016/kW
Lazard - High	2017	1671
LBNL '18	2017	1594
IPC '17 IRP	2017	1565
NREL '19 ATB	2017	1610
Lazard - Low	2017	1180

Source	Tech Vintage	$2016/kW
Avista '17 IRP	2018	1737
NWPCC Mid-Term - High	2018	1700
PGE '16 IRP	2018	1667
NREL '19 ATB - Mid	2018	1583
NREL '19 ATB - Low	2018	1573
Lazard - High	2018	1550
NWPCC Mid-Term - Low	2018	1500
PGE '19 IRP	2018	1457
PGE '16 IRP Update	2018	1425
LBNL '18	2018	1468
Lazard - Low	2018	1111

Source	Tech Vintage	$2016/kW
NREL '19 ATB - Mid	2020	1502
NREL '19 ATB - Low	2020	1473
PAC '17 IRP Update Vision 2020	2020	1310
PAC '19 IRP	2020	1308

Source	Tech Vintage	$2016/kW
Avista '19 IRP	2021	1378

Source	Tech Vintage	$2016/kW
PSE '19 IRP-MT	2022	1754
NREL '19 ATB - Mid	2022	1448
NREL '19 ATB - Low	2022	1399

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Impacts of PTC

- **Impact of Production Tax Credit:** Drives current capital structure

Tax Equity – ~50% of total capital structure at 7-10% cost

Access to PTC + Depreciation (MACRS + Bonus)

Debt

Sponsor Equity

7th Plan used 50/50 debt-to-equity (IOU) and 60/40 (IPP) based on the assumption that Wind projects in region would begin construction post-PTC

https://www.nrel.gov/docs/fy17osti/68227.pdf & summary at https://www.taxequitytimes.com/2017/09/nrels-wind-finance-report-highlights

http://www.nortonrosefulbright.com/knowledge/publications/150031/new-trends-in-financing-wind-farms

Note: Lazard's LCOE v. 11 assumed 15% debt at 8.0% interest, 70% tax equity at 10.0% cost, 15% common equity at 12.0% cost

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Impacts of PTC

10 year tax benefit (Prior to 2017 Tax Reform)

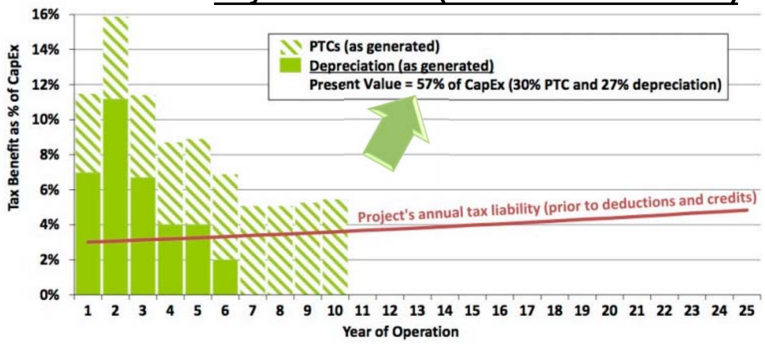

Figure 2. Timing of the federal tax benefits generated by a wind project[14]

Source: Bolinger 2014

https://www.nrel.gov/docs/fy17osti/68227.pdf

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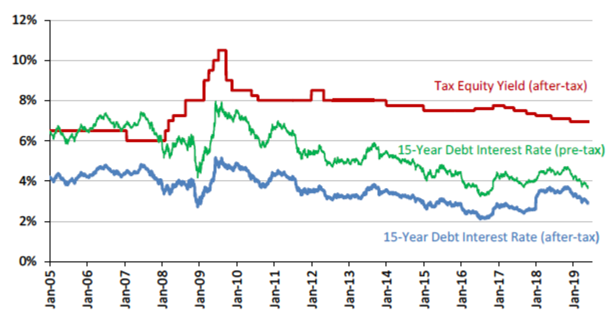
PTC benefit was substantial, but opportunities for lower cost financing may offset the impact somewhat in PPA pricing



Sources: Intercontinental Exchange Benchmark Administration (https://www.theice.com/iba), BNEF (2017), Norton Rose Fulbright (2019)

Figure 17. Cost of 15-year debt and tax equity for utility-scale wind projects over time

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Summary of wind pricing

- Capital costs are a component of PPA pricing
- Financing is also a component of PPA pricing
- The PTC impacts PPA pricing
- All else equal, losing the PTC will drive up PPA prices
- But, tax equity was a relatively expensive form of capital (due to a limited number of investors)
- The loss of the PTC may be offset somewhat in PPA price by lower cost financing due to more competition in the capital markets

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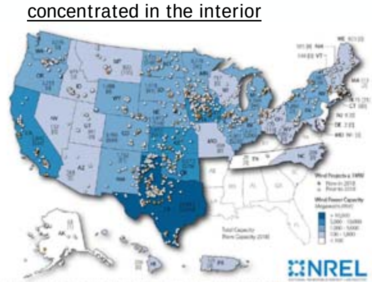
National Trend: The interior US is a world class wind resource

Wind continues to be developed across the US, but is most concentrated in the interior



Wind makes up a substantial (but not majority) portion of the generation and sales in many states

Table 2. U.S. Wind Power Rankings: The Top 20 States

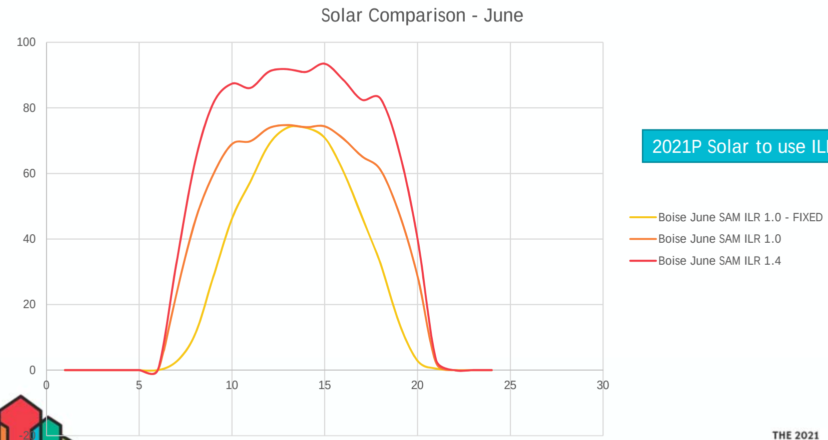
Installed Capacity (MW)				2018 Wind Generation as a Percentage of:			
Annual (2018)		Cumulative (end of 2018)		In-State Generation		In-State Sales	
Texas	2,359	Texas	24,895	Kansas	36.4%	North Dakota	53.5%
Iowa	1,120	Iowa	8,421	Iowa	33.7%	Kansas	47.1%
Colorado	600	Oklahoma	8,072	Oklahoma	31.7%	Oklahoma	43.4%
Oklahoma	576	California	5,840	North Dakota	25.8%	Iowa	43.2%
Nebraska	558	Kansas	5,653	South Dakota	24.4%	New Mexico	25.6%
Kansas	543	Illinois	4,861	Maine	21.0%	Wyoming	24.9%
Illinois	529	Minnesota	3,778	New Mexico	18.7%	South Dakota	21.7%
California	330	Colorado	3,703	Minnesota	17.9%	Maine	21.0%
Indiana	200	Oregon	3,213	Colorado	17.3%	Texas	18.6%
New York	158	North Dakota	3,155	Texas	15.9%	Colorado	17.5%
North Dakota	148	Washington	3,076	Vermont	15.8%	Minnesota	17.0%
Ohio	113	Indiana	2,317	Idaho	14.7%	Nebraska	16.9%
Montana	105	New York	1,987	Nebraska	14.1%	Oregon	15.0%
Minnesota	90	Nebraska	1,972	Oregon	11.0%	Montana	14.9%
New Mexico	51	Michigan	1,904	Wyoming	9.0%	Idaho	10.8%
Michigan	44	New Mexico	1,732	Montana	7.9%	Illinois	9.1%
South Dakota	41	Wyoming	1,488	Illinois	6.8%	Washington	8.2%
Rhode Island	21	Pennsylvania	1,369	California	6.5%	Vermont	7.1%
Massachusetts	2	South Dakota	1,019	Washington	6.3%	Hawaii	5.8%
Alaska	1	Idaho	973	Indiana	5.0%	Indiana	5.6%
Rest of U.S.	0	*Rest of U.S.*	7,006	*Rest of U.S.*	1.1%	*Rest of U.S.*	1.5%
TOTAL	7,588	TOTAL	96,433	TOTAL	6.5%	TOTAL	7.3%

Note: Based on 2018 wind and total generation and retail sales by state from EIA's Electric Power Monthly.

Sources: AWEA WindIQ, EIA

THE 2021 NORTHWEST POWER PLAN

Solar Profile with 2021P Tech



2021P Solar to use ILR 1.4

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