2019 IRP Technical Advisory Meeting: Electric Resource Costs

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July 26, 2018

Welcome

- Opening remarks
- Safety message

Updated IRP stakeholder participation process

PUGET SOUND ENERGY

July 26, 2018

Outcomes of stakeholder input from IRPAG kickoff meeting

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July 26, 2018

Outcomes from IRPAG meeting

- Improve PSE's stakeholder engagement process
- Incorporate the following elements into the IRP:
  - ✓ Greater carbon reduction scenarios
  - ✓ No new fossil fuel generation
  - ✓ No new fossil fuel generation in addition to retiring existing generation
  - ✓ No Liquefied Natural Gas (LNG) facility (no gas utility)
  - ✓ Reasonableness of temperature data

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Action items from IRPAG meeting

- Update charter
- Identify contact for PSE's carbon reduction goals
- Include carbon impact in scenarios or sensitivities
- Invite tribes to participate in IRP stakeholder process

Review agenda and meeting objectives

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Meeting objectives

- Members understand and provide feedback on the content of HDR's draft electric cost resource type report
- Members understand the new IRP stakeholder participation process and how PSE will use stakeholder feedback
- Members understand IRPAG input and how to use it

Today’s agenda

- √ Welcome and safety message
- √ Updated IRP stakeholder participation process
- √ Outcomes of stakeholder input from IRPAG kickoff meeting and action items
- √ Review agenda and meeting objectives
- Introductions

--BREAK--

- HDR presentation: Draft electric resource costs
- Next steps
- Adjourn and public meet and greet

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Introduction to HDR

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Feedback by Aug. 2

Energy portfolio modeling simulates how resources will be economically dispatched in the WECC-wide market.

Levelized costs are not used

- Can be helpful for some quick comparisons-with caution
- Average costs, not marginal costs
- Does not reflect the value of a resource, just the cost

Data on matrix is required

- Details the fixed costs so we can calculate how they will affect revenue requirement
- Details of variable costs are needed to fit into economic dispatch model
- Hourly shapes on non-dispatchable resources are essential to also fit into the economic dispatch model, to estimate the economic value of the resource

PUGET SOUND ENERGY

HDR presentation: Draft electric resource costs

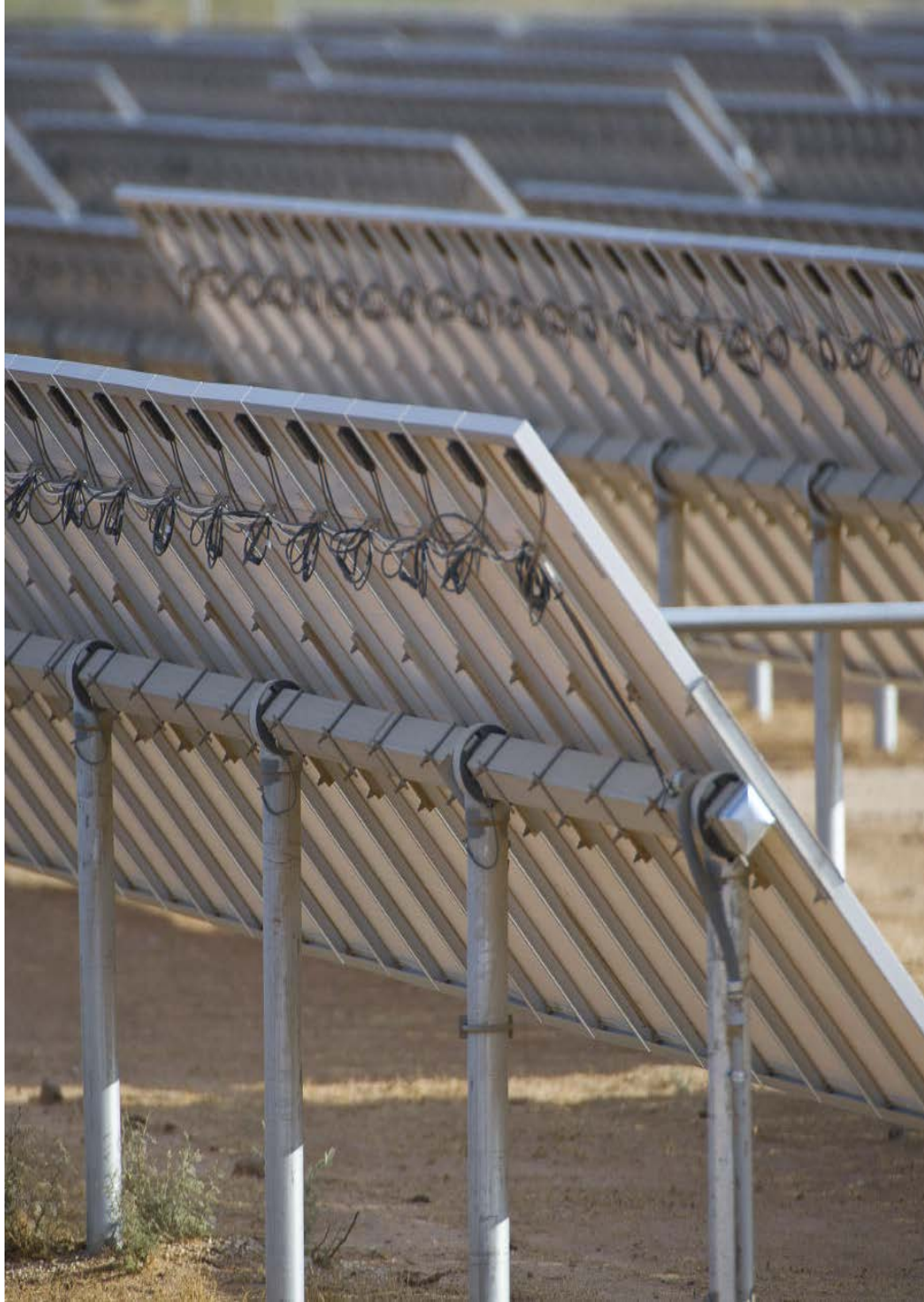
July 26, 2018

PSE 2019 IRP

Supply-Side Technology Characterizations

OVERVIEW

- 2019 IRP supply-side analysis
- HDR characterizing technology alternatives
- Discussion topics:
  - HDR overview
  - Approach/methodology
  - Technologies considered
  - Technology attributes
  - Summary and follow-up



HDR OVERVIEW

- 10,000+ employee owners, 225+ offices
- Founded in 1917 – domestic + international
- 1,000+ staff dedicated to energy
- Engineering Company Ratings

ENR Rankings

No. 6
Top 500 Design Firms

No. 10
Top 25 in Fossil Fuel

No. 5
Top 10 in Wind Power

No. 4
Top 10 in Solar Power

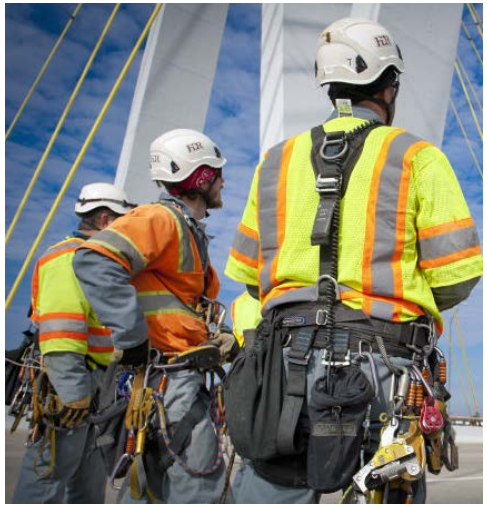
No. 2
Top 10 in Hydro Plants

No. 15
Top 20 in Power

No. 7
Top 25 in Transmission & Distribution

No. 22
Top 50 Designers in Global Markets

2018 ENR TOP 500 DESIGN FIRMS

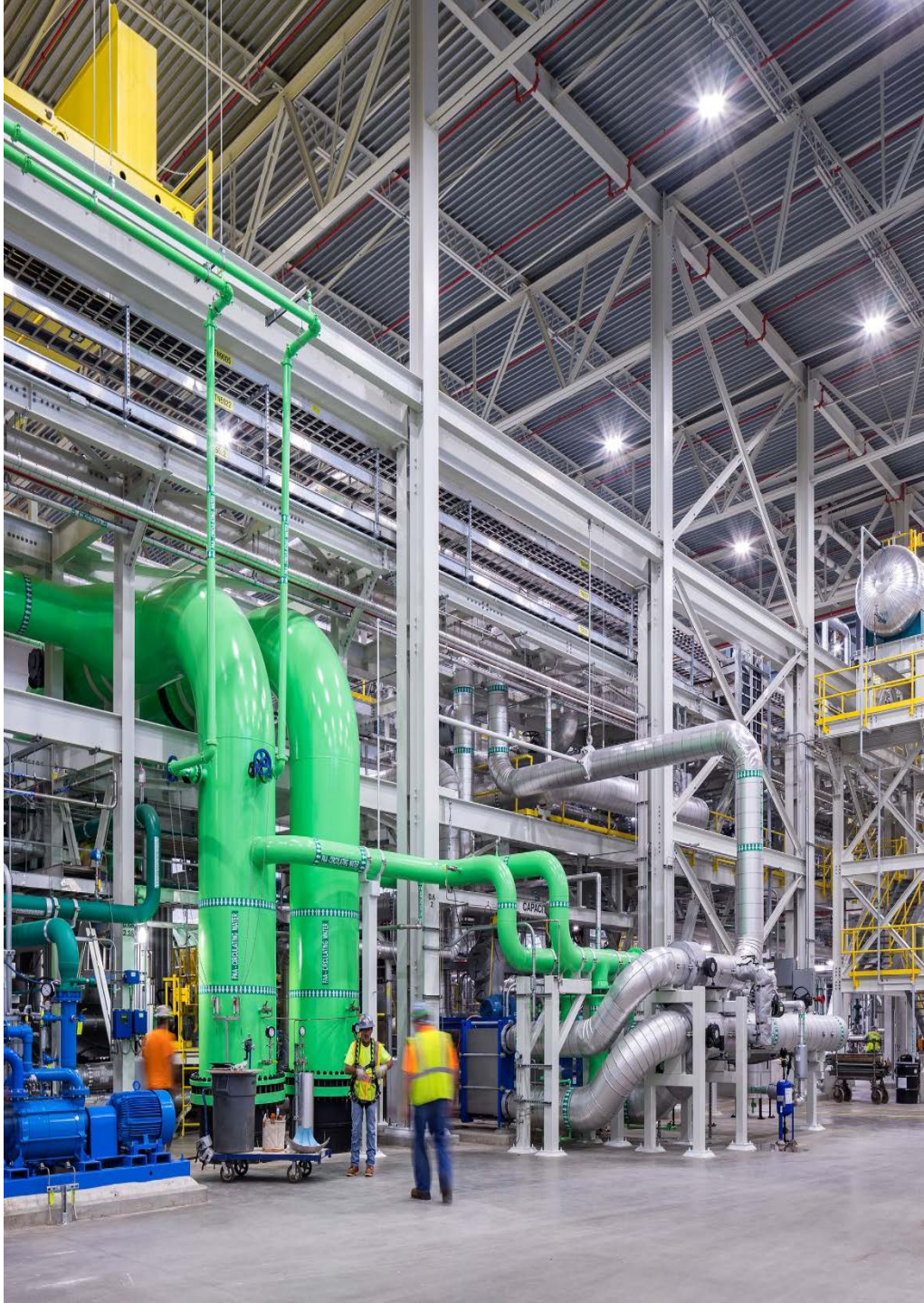


HDR ENERGY PROGRAM

- Generation
  - 73+ GW natural gas and coal
  - 35+ GW renewables and storage
  - 11+ GW hydroelectric and pumped storage
- Transmission & Distribution (T&D)
  - Planning and execution
- Regulatory & Permitting
  - Supply-side (thermal, hydro, renewables, and storage) and wires

HDR ENERGY PROGRAM

- Planning and development
- Owner’s engineering
- Conceptual and detailed design
- Support IRP across the US



METHODOLOGY

- Approach
  - Actual project developments
  - Executed projects
  - RFP/procurement resume
  - Other IRPs, publications
- Generic resource characterizations
  - Manufacturer and project agnostic
- Consideration of PSE and regional specific issues
- Market-based

PERFORMANCE BASIS

- Performance
  - Estimating software
  - Manufacturer data – normalized
  - Representative & regional site locations
  - Dispatch & auxiliary load estimates
  - Emission Profiles – thermal assets
- Operating Characteristics
  - Start times, ramping capability, etc.

COST BASIS

- Site and technology generic
- Resource size normalized
- Construction costs and allocations for:
  - Electrical interconnection
  - Fuel supply
- Construction + owner's costs
- Representative operating & dispatch profiles

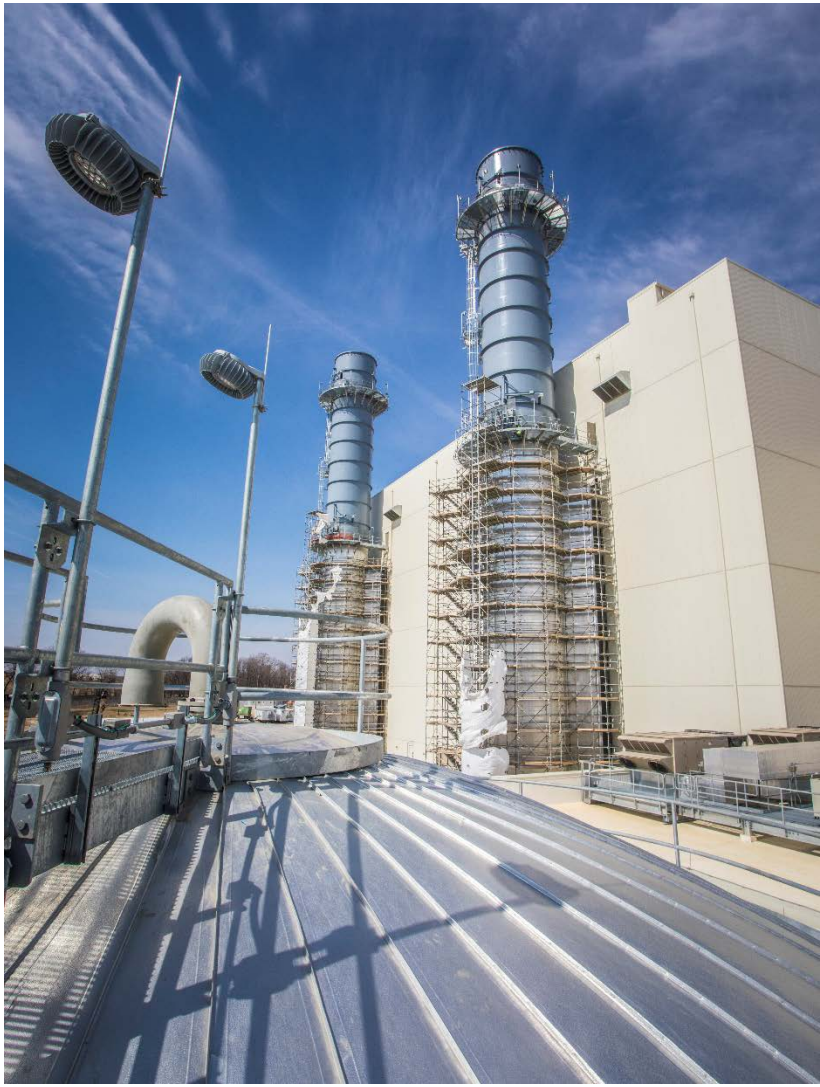
SUPPLY-SIDE RESOURCES

- Thermal – Single and Dual Fuel
  - Simple and combined cycle CT
  - Simple cycle RICE
- Renewable
  - Wind – Montana and Washington
  - Solar – Washington
  - Biomass
- Energy Storage
  - Pumped hydro
  - Battery
    - Li-Ion
    - Vanadium Flow

THERMAL RESOURCES

- Simple cycle combustion turbine
- Combined cycle combustion turbine
- Reciprocating internal combustion engine
- Representative site conditions
- Estimated air emissions

Estimated Emissions	Heat Input	Net Output	NOx	PM	SO2	CO	VOC	CO2
	mmbtu/hr	MW	lb/mmbtu	lb/mmbtu	lb/mmbtu	lb/mmbtu	lb/mmbtu	lb/mmbtu
1x0 F-Class CT (NG)	2,316	237	0.0081	0.0057	0.0014	0.0049	0.0014	118
1x0 F-Class CT (FO)	2,266	229	0.0203	0.0057	0.0082	0.0049	0.0043	160
1x1 F-Class CC (Fired)	2,480	367	0.0081	0.0057	0.0014	0.0049	0.0014	118
1x1 F-Class CC (Unfired)	2,315	348	0.0081	0.0057	0.0014	0.0049	0.0014	118
12x0 18 MW RICE SC (NG Only)	1,846	219	0.0203	0.0057	0.0014	0.0370	0.0351	118
12x0 18 MW Dual Fuel RICE (NG)	1,726	201	0.0251	0.0057	0.0019	0.0370	0.0576	122
12x0 18 MW Dual Fuel RICE (FO)	1,520	173	0.1418	0.0057	0.0082	0.0493	0.0604	160
15 MW Biomass	216	15	0.0290	0.0540	0.0320	0.3000	0.0014	213



THERMAL RESOURCES

Puget Sound Energy 2019 IRP	Fuel	Winter Peak Net Output	Winter Peak Net Heat Rate (HHV)	EPC Cost	Owner's Cost	Total Cost	Capacity Factor	First Year Fixed O&M	First Year Variable O&M	Gas + Electric interconnent	Total with Interconnect
Unit Type	**Type**	**MW**	**Btu/kWh**	**$/kW**	**$/kW**	**$/kW**	**%**	**$/kW-yr**	**$/MWh**	**$/kW**	**$/kW**
Simple Cycle (SC) Combustion Turbine (CT)											
1x0 F-Class Dual Fuel CT (NG / FO)	NG	237	9,774	$554	$131	$686	4%	$3.93	$6.56	$139	$825
1x0 F-Class Dual Fuel CT (NG / FO)	FO	229	9,900								
Combined Cycle (CC) CT - Wet Cooling											
1x1 F-Class CC (Unfired)	NG	348	6,649	$898	$232	$1,131	85%	$14.16	$2.52	$99	$1,229
1x1 F-Class CC (Fired)	NG	367	6,761	$853	$221	$1,073	85%	$13.44	$2.45	$94	$1,167
Reciprocating Internal Combustion Engine (RICE)											
12x0 18 MW Class RICE (NG Only)	NG	219	8,428	$842	$201	$1,043	15%	$3.74	$5.30	$148	$1,192
12x0 18 MW Class Dual Fuel RICE (NG / FO)	NG	201	8,565	$965	$230	$1,196	15%	$4.12	$5.80	$161	$1,357
12x0 18 MW Class Dual Fuel RICE (NG / FO)	FO	173	8,763								

RENEWABLE RESOURCES

- On-shore wind
  - Montana
  - Washington
- Off-shore wind
  - Washington
- Solar
  - Washington
- Biomass

RENEWABLE RESOURCES

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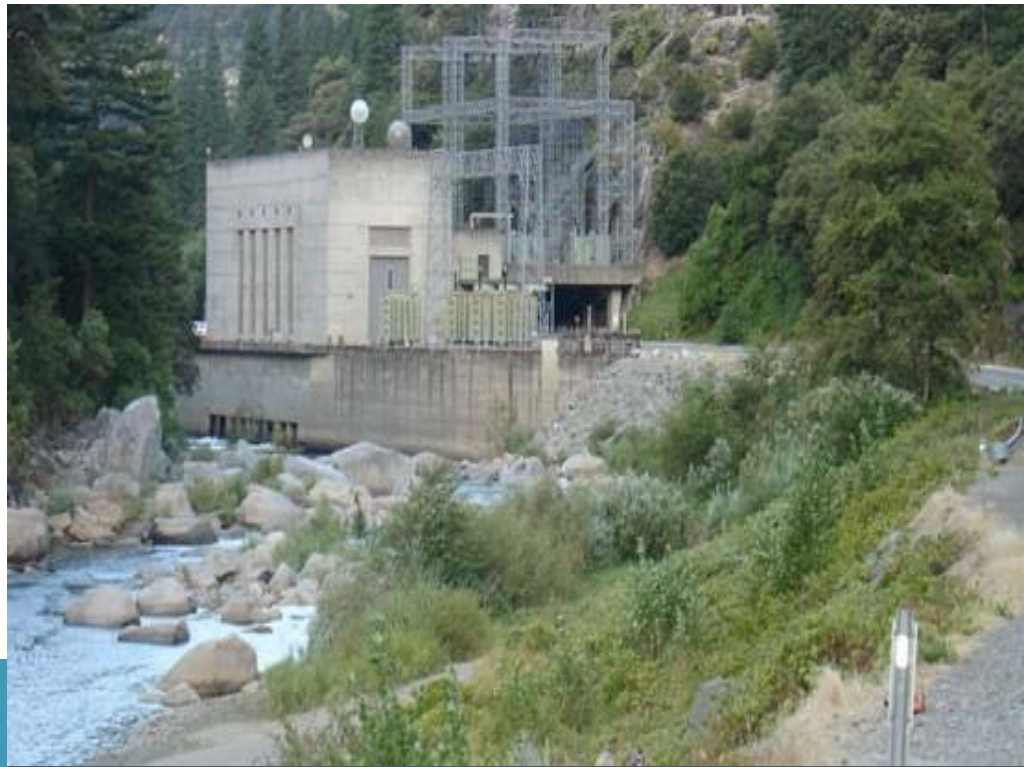
On-Shore Wind											
100 MW Wind Farm - Central Montana (Site #1)	-	100	-	$1,633	$280	$1,913	36%	$37.00	-	$103	$2,016
100 MW Wind Farm - Central Montana (Site #2)	-	100	-	$1,633	$280	$1,913	42%	$37.00	-	$831	$2,744
100 MW Wind Farm - Southeastern Washington	-	100	-	$1,656	$283	$1,939	32%	$37.00	-	$103	$2,042
Off-Shore Wind											
300 MW Wind Farm - Washington Coast	-	300	-	$5,000	$1,480	$6,480	31-35%	$120.00	-	$67	$6,547
Solar Photovoltaic (PV)											
25 MW Solar PV (Washington) - Single Axis Tracking	-	25	-	$1,352	$191	$1,543	19%	$27.19	-	$380	$1,922
Biomass											
15 MW Biomass	Wood	15	14,154	$7,036	$2,031	$9,067	85%	$345.20	$6.60	$628	$9,695

ENERGY STORAGE

- Pumped hydro energy storage
  - Slice of PNW project
- Battery energy storage systems
  - Lithium ion
  - Vanadium flow
  - 25 MW capability and 2 daily cycles
  - 2, 4, and 6 hour

SUMMARY

- HDR focus was on supply-side evaluation
- Generic characterization and representation of generation and storage resources
- Thermal, renewable, storage – 13 total
- Representative of current market and forecast trends



APPENDIX

Puget Sound Energy 2019 IRP	Fuel	Winter Peak Net Output	Winter Peak Net Heat Rate (HHV)	EPC Cost	Owner's Cost	Total Cost	Capacity Factor	First Year Fixed O&M	First Year Variable O&M	EPC Schedule	Gas + Electric interconnent	Total with Interconnect
Unit Type	**Type**	**MW**	**Btu/kWh**	**$/kW**	**$/kW**	**$/kW**	**%**	**$/kW-yr**	**$/MWh**	**Months**	**$/kW**	**$/kW**
Simple Cycle (SC) Combustion Turbine (CT)												
1x0 F-Class Dual Fuel CT (NG / FO)	NG	237	9,774	$554	$131	$686	4%	$3.93	$6.56	20 - 22	$139	$825
1x0 F-Class Dual Fuel CT (NG / FO)	FO	229	9,900									
Combined Cycle (CC) CT - Wet Cooling												
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Reciprocating Internal Combustion Engine (RICE)												
12x0 18 MW Class RICE (NG Only)	NG	219	8,428	$842	$201	$1,043	15%	$3.74	$5.30	26 - 28	$148	$1,192
12x0 18 MW Class Dual Fuel RICE (NG / FO)	NG	201	8,565	$965	$230	$1,196	15%	$4.12	$5.80	26 - 28	$161	$1,357
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100 MW Wind Farm - Southeastern Washington	-	100	-	$1,656	$283	$1,939	32%	$37.00	-	20 - 24	$103	$2,042
Off-Shore Wind												
300 MW Wind Farm - Washington Coast	-	300	-	$5,000	$1,480	$6,480	31-35%	$120.00	-	33 - 40	$67	$6,547
Solar Photovoltaic (PV)												
25 MW Solar PV (Washington) - Single Axis Tracking	-	25	-	$1,352	$191	$1,543	19%	$27.19	-	10 - 12	$380	$1,922
Biomass												
15 MW Biomass	Wood	15	14,154	$7,036	$2,031	$9,067	85%	$345.20	$6.60	38 - 40	$628	$9,695
Pumped Hydro Energy Storage (PHES)												
PHES - 500 MW Closed Loop (8 Hour)	Elec. Grid	500	-	$1,800	$812	$2,612	-	$14.55	$0.90	60 - 96	$49	$2,661
PHES - 300 MW Closed Loop (8 Hour)	Elec. Grid	300	-	$1,800	$812	$2,612	-	$17.40	$1.50	60 - 96	$67	$2,679
Battery Energy Storage System (BESS)												
BESS - 25 MW Lithium Ion (2 Hour / 2 Cycles Daily)	Elec. Grid	25	-	$1,331	$219	$1,550	-	$20.54	-	10 - 12	$380	$1,930
BESS - 25 MW Lithium Ion (4 Hour / 2 Cycles Daily)	Elec. Grid	25	-	$2,346	$334	$2,680	-	$32.16	-	10 - 12	$380	$3,059
BESS - 25 MW Vandium Flow (4 Hour / 2 Cycles Daily)	Elec. Grid	25	-	$1,493	$239	$1,732	-	$30.80	-	10 - 12	$380	$2,111
BESS - 25 MW Vandium Flow (6 Hour / 2 Cycles Daily)	Elec. Grid	25	-	$2,050	$328	$2,378	-	$40.27	-	10 - 12	$380	$2,758

2019 IRP Electric Supply-Side Resources - Thermal

2018 $	Units	1x0 F-Class Dual Fuel CT (NG)	1x0 F-Class Dual Fuel CT (FO)	1x1 F-Class CC (NG Only)	12x0 18 MW Class RICE (NG Only)	12x0 18 MW Dual Fuel RICE (NG)	12x0 18 MW Dual Fuel RICE (FO)
ISO Capacity Primary	MW	225	217	336	219	201	173
Winter Capacity Primary (23 degrees F)	MW	237	229	348	219	201	173
Capacity DF (At ISO)	MW			355			
Capital Cost + Duct Fire*	$/KW	$686		$1,073	$1,043	$1,196	
O&M Fixed	$/KW-yr	$3.93		$13.44	$3.74	$4.12	
Flexibility	$/KW-yr						
O&M Variable	$/MWh	$0.69		$1.97	$5.30	$5.80	
Start Up Costs	$/Start	$6,502		$6,566	$0.46	$0.48	
Capacity Credit	%						
Operating Reserves	%						
Forced Outage Rate		2.38%	2.38%	3.88%	3.30%	3.30%	3.30%
ISO Heat Rate – Baseload (HHV)	Btu/KWh	9,904	10,985	6,624	8,445	8,582	8,780
ISO Heat Rate – Turndown (HHV)	Btu/KWh	15,794	12,856	7,988	11,288	11,471	11,736
Heat Rate – DF	Btu/KWh			6,724			
Min Capacity	%	30%	50%	38%	30%	30%	30%
Start Time (hot)	minutes	21	21	45	5	5	5
Start Time (warm)	minutes	21	21	60	5	5	5
Start Time (cold)	minutes	21	21	150	5	5	5
Start up fuel (hot)	mmBtu	366	338	839	69	69	57
Start up fuel (warm)	mmBtu	366	338	1,119	69	69	57
Start up fuel (cold)	mmBtu	366	338	2,797	69	69	57
Location							
Fixed Gas Transport	$/Dth/Day						
Fixed Gas Transport	$/KW-yr						
Variable Gas Transport	$/MMBtu						
Fixed Transmission	$/KW-yr						
Variable Transmission	$/MWh						
Emissions:							
CO_2 - Natural Gas	lbs/MMBtu	118		118	118	122	
CO_2 - Distillate Fuel Oil	lbs/MMBtu		160				160
NOx - Natural Gas	lbs/MMBtu	0.004		0.008	0.029	0.037	
NOx - Distillate Fuel Oil	lbs/MMBtu		0.014				0.130
First Year Available							
Economic Life	Years	30	30	30	30	30	30
Greenfield Dev. & Const. Lead-time	years	1.8	1.8	2.7	2.3	2.3	2.3

2019 IRP Electric Supply-Side Resources - Renewables

2018 $	Units	On-Shore Wind - MT (Site #1)	On-Shore Wind - MT (Site #2)	On-Shore Wind - SE Wash.	Offshore Wind - WA Coast	Solar PV - WA	Biomass
ISO Capacity Primary	MW	100	100	100	300	25	15
Winter Capacity Primary	MW	100	100	100	300	25	15
Capacity Credit	%						
Operating Reserves	%						
Capacity Factor	%	35.5%	42.4%	31.9%	29.3%	24.2%	85%
Capital Cost	$/KW	$1,913	$1,913	$1,939	$6,480	$1,543	$9,067
O&M Fixed	$/KW-yr	$37.00	$37.00	$37.00	$120.00	$27.19	$345.20
O&M Variable	$/MWh	$0.00	$0.00	$0.00	$0.00	$0.00	$6.60
Land Area	acres/MW	48.2	48.2	48.2		5 - 7	6 - 8
Degradation	%/year	0	0	0	0	0.50%	N/A
Location	-						
Fixed Transmission	$/KW-yr						
Variable Transmission	$/MWh						
Loss Factor to PSE	%						
Heat Rate – Baseload (HHV)	Btu/KWh						14,972
Emissions:							
NO_x	lbs/MMBtu						0.03
SO_2	lbs/MMBtu						0.03
CO_2	lbs/MMBtu						0.30
First Year Available							
Economic Life	Years	25	25	25	25	20	30
Greenfield Dev. & Const. Leadtime	years	2.0	2.0	2.0	3.2	1.0	3.3

2019 IRP Electric Supply-Side Resources - Energy Storage

2018 $	Units	PHES - Closed Loop (8 Hour)	PHES Closed Loop (8 Hour)	BESS - 25 MW Li-Ion (2 Hour / 2 Cycles Daily)	BESS - 25 MW Li-Ion (4 Hour / 2 Cycles Daily)	BESS - 25 MW Flow (4 Hours / 2 Cycles Daily)	BESS - 25 MW Flow (6 Hours / 2 Cycles Daily)
Nameplate Capacity	MW	500	300	25	25	25	25
Winter Capacity	MW	500	300	25	25	25	25
Capacity Credit	%						
Operating Reserves	%						
Capital Cost	$/KW	$2,612	$2,612	$1,550	$2,680	$1,732	$2,378
O&M Fixed	$/KW-yr	$14.55	$17.40	$20.54	$32.16	$30.80	$40.27
O&M Variable	$/MWh	$0.90	$1.50	$0.00	$0.00	$0.00	$0.00
Forced Outage Rate	%	1%	1%	<2%	<2%	<5%	<5%
Degredation	%/year	(a)	(a)	(d)	(d)	(d)	(d)
Operating Range (e)	%	147-500 MW (b)	112.5-300 MW (c)	2.0%	2.0%	2.0%	2.0%
R/T Efficiency	%	80%	80%	82%	87%	73%	73%
Discharge at Nominal Power	Hours	8	8	2	4	4	6
Location							
Fixed Transmission	$/KW-yr						
Variable Transmission	$/MWh						
Flexbility Benefit	$/KW-yr						
First Year Available							
Economic Life	Years	30+	30+	20	20	20	20
Greenfield Dev. & Const. Leadtime	years	5 - 8	5 - 8	1	1	1	1

Transmission Costs

July 26, 2018

Transmission Costs – Montana Wind

Transmission Path from Montana

	$/kW-Year	Losses
Colstrip/Broadview – Townsend (PSEI)	$12.56[2]	2.7%
Townsend – Garrison (BPA)	$7.18	5%
Garrison – PSE (BPA)	$21.52	1.9%
Estimated Wind Integration Costs (NWE)[1]	$12.12	
Total	$53.38	9.6%

[1]BPA Balancing Service Rates

[2]New tariff rate waiting for approval at FERC is $11/kw-yr. Old tariff rate is $27/kw-yr

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Transmission Costs – Washington Wind

Transmission Path from Eastern Washington or Offshore Wind

	$/kW-Year	Losses
Substation – PSEI (BPA)	$21.52	1.9%
Spin/Supp Reserve Requirement	$0.0219	
Balancing Services	$12.12	
Generation Imbalance and Intentional Deviation Penalty (Band 1&2)	Variable	
Total	$33.66	1.9%

Transmission Costs – Washington Solar

Transmission Path from Eastern Washington

	$/kW-Year	Losses
Substation – PSEI (BPA)	$21.52	1.9%
Spin/Supp Reserve Requirement	$0.0219	
Balancing Services	$2.52	
Generation Imbalance and Intentional Deviation Penalty (Band 1&2)	Variable	
Total	$24.06	1.9%

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Next steps

July 26, 2018

Next steps

- IRPAG meeting on August 28
- Second TAG meeting on September 25

PUGET SOUND ENERGY


THANK
YOU

Appendix

July 26, 2018

Comparison of generic resource costs

	2017 IRP			2019 IRP			Change in costs from 2019 IRP to 2017 IRP		
2018 $/kW	EPC Cost	Owner's Costs + Interconnection	Total Costs	EPC Cost	Owner's Costs + Interconnection	Total Costs	EPC Cost	Owner's Costs + Interconnection	All in Costs
CCCT	$1,020	$358	$1,378	$898	$269	$1,167	($122)	($89)	($211)
Frame Peaker (Fuel Fuel)	$526	$172	$698	$554	$271	$825	$28	$99	$127
Recip Engine (NG only)	$1,030	$312	$1,341	$842	$350	$1,192	($188)	$38	($149)
WA Wind	$1,548	$656	$2,204	$1,656	$386	$2,042	$108	($270)	($162)
MT Wind	$1,471	$1,312	$2,783	$1,633	$1,111	$2,744	$162	($201)	($39)
Solar	$1,497	$874	$2,371	$1,352	$570	$1,922	($145)	($304)	($449)
Biomass	$4,084	$207	$4,291	$7,036	$2,659	$9,695	$2,952	$2,452	$5,404
Offshore Wind	$5,717	$1,795	$7,512	$5,000	$1,547	$6,547	($717)	($248)	($965)
Li-Ion Battery 2-hr	$1,313	$342	$1,655	$1,331	$599	$1,930	$18	$257	$275
Li-Ion Battery 4-hr	$2,116	$552	$2,668	$2,346	$708	$3,054	$230	$156	$386
Flow Battery 4-hr	$1,870	$674	$2,544	$1,493	$618	$2,111	($377)	($56)	($433)
Flow Battery 6-hr	$2,447	$882	$3,329	$2,050	$708	$2,758	($397)	($174)	($571)
Pumped Storage	$2,503	$127	$2,630	$1,800	$879	$2,679	($703)	$752	$49

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