

Sixth Northwest Conservation & Electric Power Plan

## Rankine-cycle Coal-fired Power Plant Resource Assessment

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## Coal-fired power plant technologies

Rankine-cycle (a.k.a. "conventional", "pulverized coal", "PC" or "steam" technology)

Subcritical PC - Mature commercial

✓ **Supercritical PC - Emerging technology of choice**

Ultra-supercritical PC - Early commercial

Any of the above w/fluidized bed combustion - Commercial in smaller sizes

CO2 separation and sequestration (CSS) for any of the above - Not commercial and likely very expensive

Gasification

✓ **Integrated coal gasification combined-cycle (IGCC) - Very early commercial**

✓ **IGCC w/CSS - Components are commercial, complete plant not.**

✓ Alternatives to be characterized in detail for the portfolio analysis



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## Rankine-cycle coal-fired power plant considerations I

### Investment risk:

- Moderately high capital cost (currently \$3000 - 4000/kW)
- Moderately long development and construction lead time
- Proven ability to construct a completed plant on time
- Moderately-high fixed costs

### Fuel price risk

- Abundant and low-cost fuel supply
- Exposure to transportation fuel price risk for locations requiring rail haul

### Operational characteristics and risks:

- Mature, reliable technology (~90% availability)
- Inherent sustained peaking capability
- Limited regulation and load-following capability



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## Rankine-cycle coal-fired power plant considerations II

### Environmental risks and Catch-22

- Criteria air pollutants (SO<sub>x</sub>, NO<sub>x</sub>, particulates, etc.) controlled to "best available control technology" (BACT) levels with established technology.
- ~ 40% Hg control inherent w/wet FGD + SCR CAPcontrol, reduction to 90% possible at moderate cost using commercial activated C injection technology.
- Substantial CO<sub>2</sub> production unless equipped with CO<sub>2</sub> separation equipment and an accessible sequestration facility.
- WA, OR & MT state policies effectively prohibits utilities (IOUs in Montana) from executing long-term contracts for coal plants w/o CSS.
- Post-combustion CO<sub>2</sub> separation technology in very early pilot stage.
- Proven sequestration limited to enhanced oil recovery.

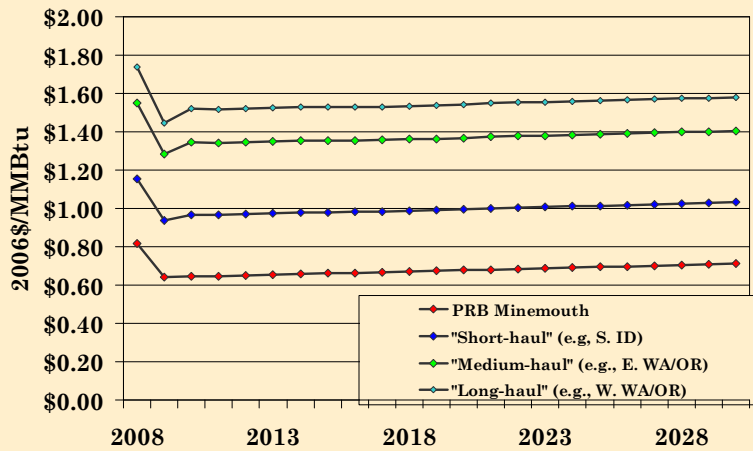
### Public perception:

- Recent Northwest proposals have been controversial
- Issues, here and elsewhere have been air emissions and CO<sub>2</sub> risk



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## Coal price forecast



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## Why Supercritical Technology?



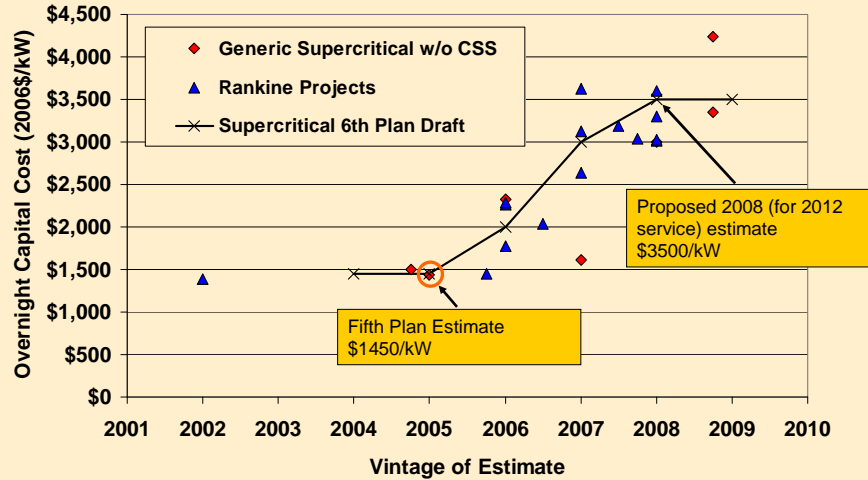
3500 psig/1050 F vs 2400/1000F psig steam conditions  
 Results in higher efficiency - 9000 vs 9800 Btu/kWh (38% vs 35%)  
 Proportionally lower (~ 8%):  
 Fuel consumption  
 Fuel cost  
 Criteria air emissions  
 CO<sub>2</sub> production

Early reliability problems discouraged use of technology in U.S  
 Established technology in Europe and Japan (higher fuel costs)  
 Technology shift appears underway in North America, beginning with Genesee 3 in Alberta (completed in 2005)  
 Emerging strategy is new supercritical plant + biomass co-firing + BACT retrofit to adjacent existing project(s)



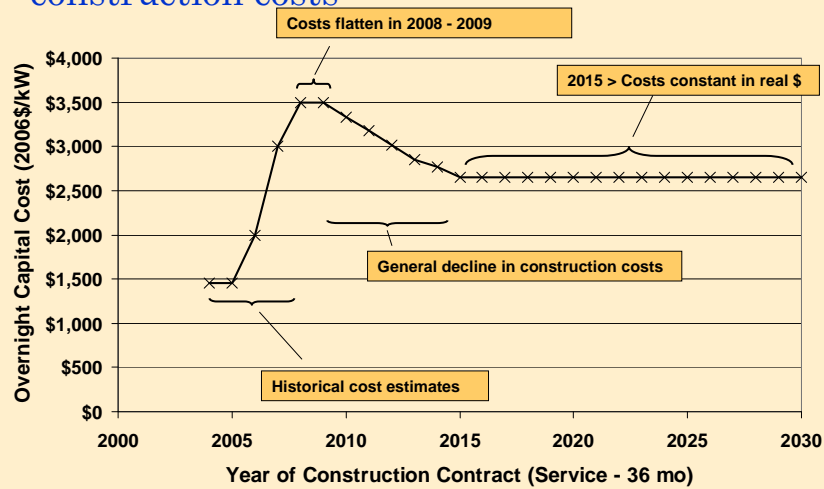
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## Capital cost estimate: Supercritical PC coal plant (no CSS)



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## Forecast supercritical PC coal plant construction costs



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## Supercritical PC coal-fired power plant assumptions

### Configuration:

- Single unit; 450 MW supercritical (>3500+ psig) steam cycle
- 90 % availability; 85% capacity factor (for levelized cost of energy estimates)
- Heat rate 8900 - 9000 Btu/kWh (Use 9000; 38%)

### Development and construction cost (overnight):

- \$3500/kW (2008 cost, 2011 service)

### Operating costs:

- Fixed O&M - \$60.00/kW/yr
- Variable O&M - \$2.75/MWh
- System Integration - None (Fully dispatchable)

### Schedule and cash flow

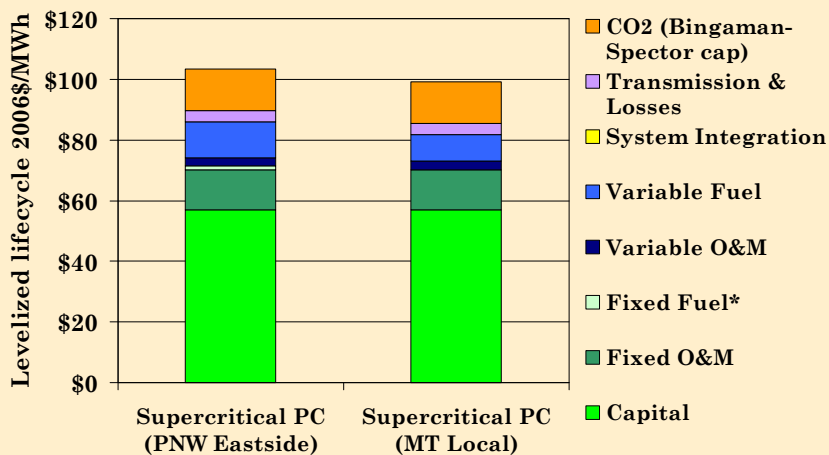
- Development - 36 mo; 3% of total plant cost
- Optional construction - 8 mo; 27% of total plant cost
- Committed construction - 27 mo; 70% of total plant cost

Earliest service for new project available to the Northwest ~ 2015



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## Supercritical PC plant cost elements



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## Impact of steam conditions and CO2 capture<sup>1</sup> on power plant cost and performance

	Steam Conditions (typical)	Total Plant Cost	Operation & Maintenance Cost	Heat Rate
Subcritical PC	2400 psig 1000°F	96	100	112
Subcritical PC w/Amine CS	""	168	213	153
<b>Supercritical PC</b>	3500+ psig 1050°F	<b>100</b>	<b>100</b>	<b>100</b>
Supercritical PC w/Amine CS	""	161	213	132
Ultrasupercritical PC	4600+ psig 1100+°F	102	100	89
Ultrasupercritical PC w/Amine CS	""	157	213	113

1) 90% CO2 separation and compression; excluding transportation, injection & monitoring. From MIT *The Future of Coal* (2007)  
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## Technology variants scaled to supercritical PC assumptions

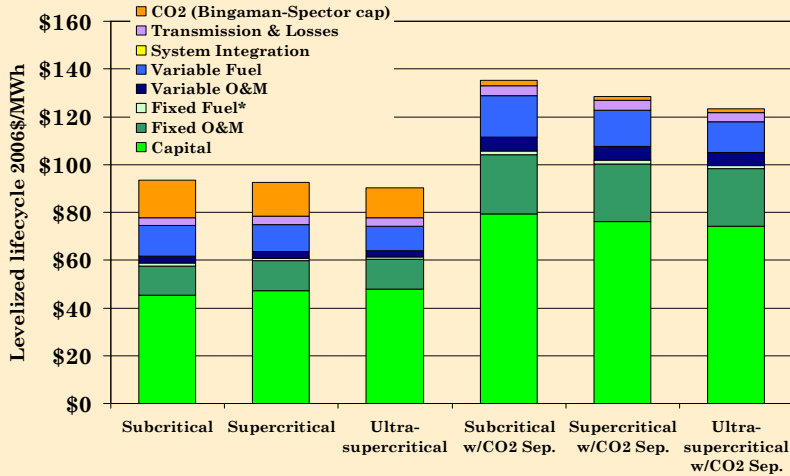
	Total Plant Cost (\$/kW)	Fixed O&M (\$/kW/yr)	Variable O&M (\$/MWh)	Heat Rate (Btu/kWh)
Subcritical PC	\$3360	\$60	\$2.75	10080
Subcritical PC w/Amine CS	\$5880	\$130	\$5.85	13770
<b>Supercritical PC</b>	<b>\$3500</b>	<b>\$60</b>	<b>\$2.75</b>	<b>9000</b>
Supercritical PC w/Amine CS	\$5640	\$130	\$5.85	11880
Ultrasupercritical PC	\$3570	\$60	\$2.75	8010
Ultrasupercritical PC w/Amine CS	\$5500	\$130	\$5.85	10170



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## Comparison of technology variants

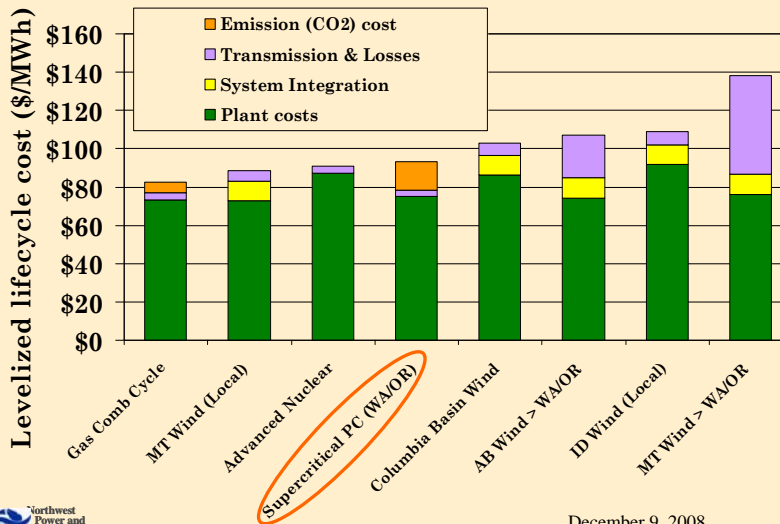
IOU financing  
 2020 service  
 85% CF  
 Estimates exclude the cost of CO2 transportation, injection and monitoring



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## Resource options, early 2020s

Transmission cost & losses to point of LSE wholesale delivery  
 No federal investment or production tax credits  
 Baseload operation (CC - 85%CF, Nuc 87.5% CF, SPCP 85%)  
 Medium NG and coal price forecast (Proposed 6th Plan)  
 Bingaman/Spector safety valve CO2 cost



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