Evaluating AUSC New Build and Retrofit Options for Existing Coal Plants

Robert Stevens

Clearwater Clean Energy Conference

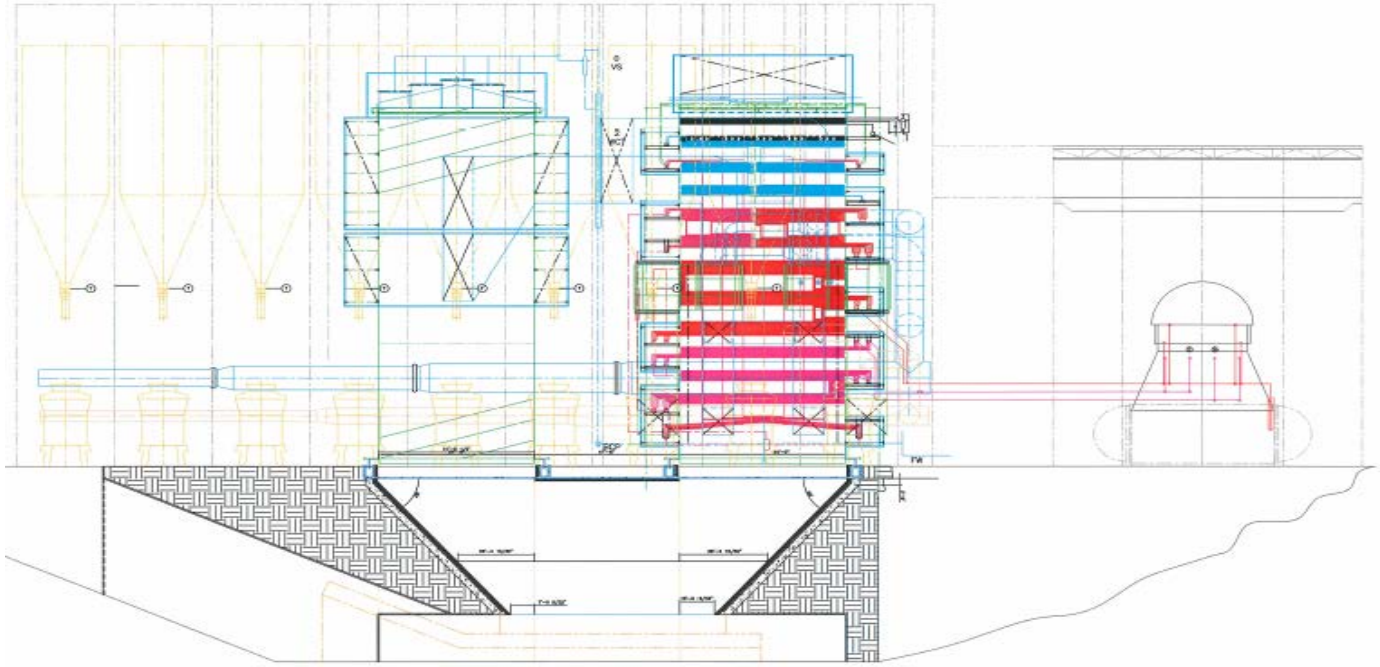
June 18, 2019

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL-PUB-22263

Advanced Ultra-Supercritical (AUSC) PC Plants – Objective

- **Develop Advanced Ultra-Supercritical (AUSC) pulverized coal (PC) reference cases**
  - Enabled by DOE/Ohio Coal Development Office (OCDO) AUSC Materials Consortia
    - Steam boilers (DE-FG26-01NT41175)
    - Steam turbines (DE-FE0000234)
  - Implement Inverted Tower Boiler Design (B&W)
  - Evaluate effects of steam pressure and CCS addition



Advanced Ultra-Supercritical (AUSC) PC Plants – Steam Conditions and Impact on Efficiency

	Temperature	Pressure (absolute)	Net Plant Efficiency (% HHV)**
Subcritical	540 - 565°C 1000 - 1050°F	16 - 22 MPa 2300 - 3200 psi	38.3 - 39.6%
Supercritical (SC)	565 - 600°C 1050 - 1112°F	22 - 27 MPa 3200 - 4000 psi	39.6 - 40.6%
Ultra-supercritical (USC)*	600 - 640°C 1112 - 1184°F	24 - 31 MPa 3500 - 4500 psi	41.3 - 42.0%
Advanced USC (AUSC) (DOE Program Goals)	700 - 760°C 1292 - 1400°F	24 - 35 MPa 3500 - 5000 psi	43.4 - 44.4%

*USC represents a broad range of steam conditions; criteria on what constitutes USC are not consistent (especially internationally). Commercially available USC technology results in efficiencies similar to or slightly above the state-of-the-art SCPC plant provided here.

**Net plant efficiencies above are based on an example plant operating on Bituminous coal, at ISO conditions, with 50°F reheat, wet flue gas desulfurization, and wet cooling towers. Other design parameters and site conditions will also impact the efficiency of a specific plant.

Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 3, 2015; and other internal assessments of AUSC steam conditions.

Thermodynamic Performance

- **ASPEN Plus models**
  - Based on NETL Bituminous Baseline supercritical PC (SC PC) cases B12A (no CCS) and B12B (with CCS)*
  - NETL supercritical steam conditions - 3500 psig/1100°F/1100°F
- **550MW net scale**
- **Reliant upon a notional downdraft inverted tower boiler (B&W)**
- **AUSC conditions for temperature/pressure**
  - T - HP: 1350°F, RH: 1400°F
  - P - HP: 3500, 4250, 5000 psig

* Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity Revision 3, DOE/NETL-2015/1723, 7/6/2015

Economics

- **Scaling from Bituminous Baseline SC PC cases B12A and B12B for commercial and post-combustion capture technology sections**
- **Components requiring advanced materials and/or novel designs**
  - Notional downdraft inverted tower boiler
    - Information/discussions with B&W
    - Previous NETL study
  - Main and reheat steam leads
    - Use of aforementioned boiler reduces lead lengths from ~450 ft found in conventional boiler designs to ~150 ft
    - Assumed $40/lb for Inconel 740H pipe
  - Steam turbine generator (STG) and accessories
    - AUSC Consortium data (EPRI/GE)

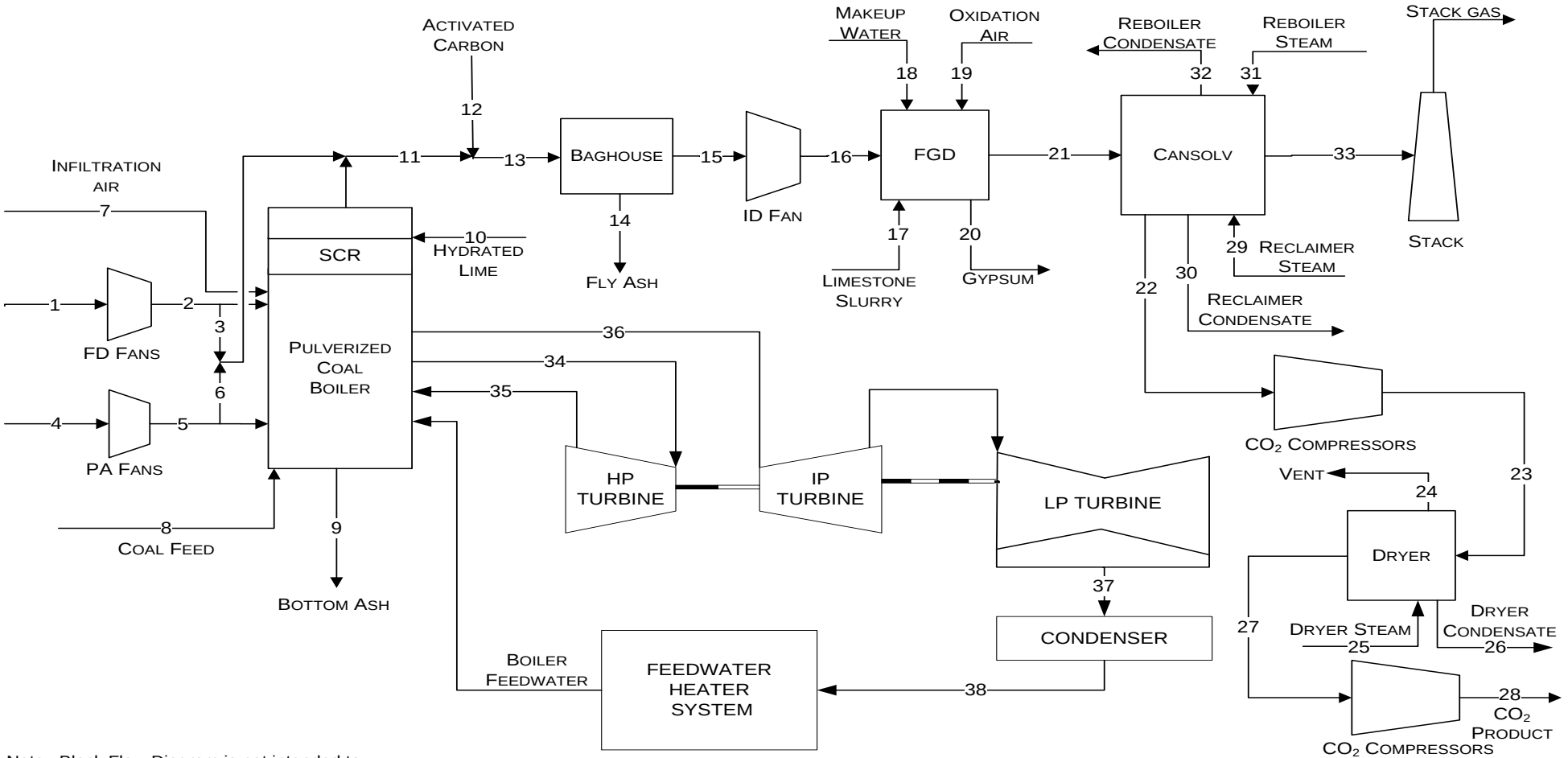
Advanced Ultra-Supercritical (AUSC) PC Plants - Steam Conditions

Case	Steam Conditions	Capacity (MW-net)	CO_2 Capture (Cansolv)	CO_2 Capture Heat Integration
1	3500 psig / 1350°F / 1400°F	550	0%	-
2	3500 psig / 1350°F / 1400°F	550	90%	No
3	4250 psig / 1350°F / 1400°F	550	0%	-
4	4250 psig / 1350°F / 1400°F	550	90%	No
5	5000 psig / 1350°F / 1400°F	550	0%	-
6	5000 psig / 1350°F / 1400°F	550	90%	No

- **Performance for all cases reflect the steam turbine stage efficiencies provided by the A-USC Consortium**
- **Boiler and steam piping costs reflect the conceptual B&W inverted tower boiler design**
  - Steam piping costs assume a reduced steam lead length to 150' from 450' for a conventional boiler

Advanced Ultra-Supercritical (AUSC) PC Plants – Block Flow Diagram

Study Cases 2, 4, and 6 (w/ CCS)



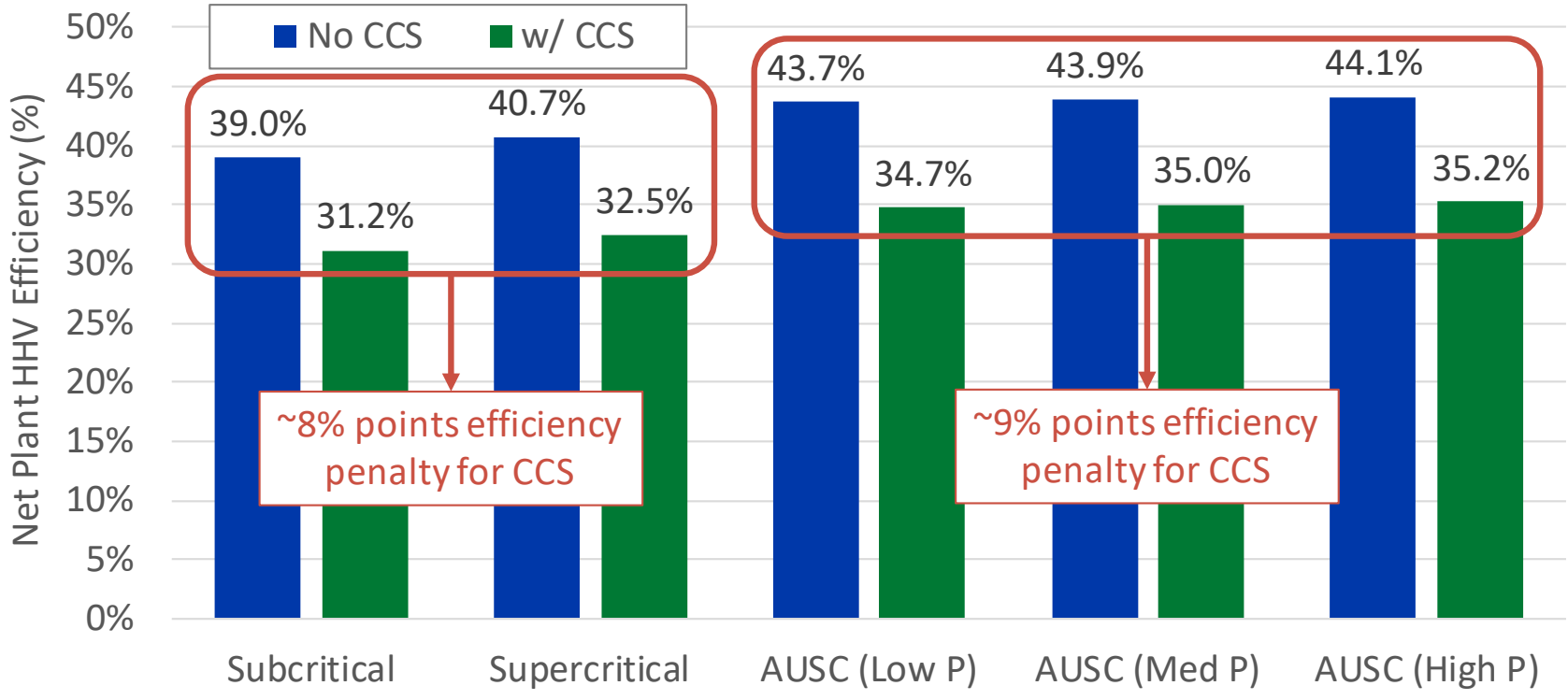
Note: Block Flow Diagram is not intended to represent a complete material balance. Only major process streams and equipment are shown.

Source: NETL

Advanced Ultra-Supercritical (AUSC) PC Plants – Performance Results

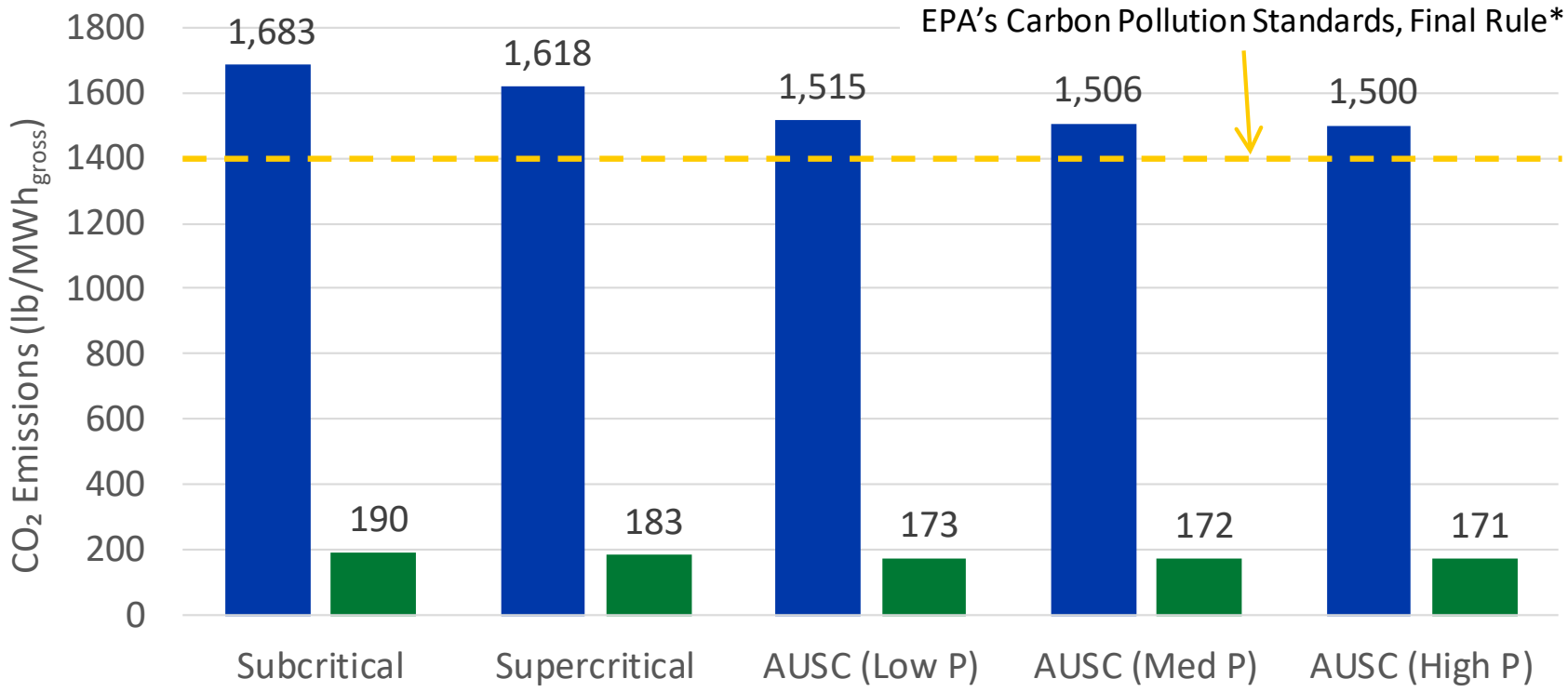
	PC Subcritical		PC Supercritical		PC A-USC					
	Case B11A	Case B11B	Case B12A	Case B12B	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Nominal CO_2 Capture	0%	90%	0%	90%	0%	90%	0%	90%	0%	90%
Gross Power Output (MWe)	581	644	580	642	578	635	578	634	578	633
Auxiliary Power Requirement (MWe)	31	94	30	91	27	85	27	84	27	84
Net Power Output (MWe)	550	550	550	550	550	550	550	550	550	550
HHV Thermal Input (MW_{th})	1,409	1,765	1,351	1,694	1,260	1,583	1,253	1,569	1,247	1,559
Efficiency (%) Net Plant HHV	**39.0%**	**31.2%**	**40.7%**	**32.5%**	**43.7%**	**34.7%**	**43.9%**	**35.0%**	**44.1%**	**35.2%**
Raw Water Withdrawal, gpm	5,538	8,441	5,105	7,882	4,508	7,124	4,461	7,025	4,422	6,960
Process Water Discharge, gpm	1,137	1,920	1,059	1,813	930	1,638	919	1,615	911	1,600
Raw Water Consumption, gpm	4,401	6,521	4,045	6,069	3,578	5,486	3,541	5,410	3,511	5,360
CO_2 Emissions (lb/MWhgross)	1,683	190	1,618	183	1,515	173	1,506	172	1,500	171

Advanced Ultra-Supercritical (AUSC) PC Plants – Efficiency Summary



Case	B11A/B*	B12A/B*	1 & 2	3 & 4	5 & 6
Pressure (psig)	2400	3500	3500	4250	5000
Main Steam (°F)	1050	1100	1350	1350	1350
Reheat (°F)	1050	1100	1400	1400	1400

Advanced Ultra-Supercritical (AUSC) PC Plants – CO_2 Emissions



Case	B11A/B	B12A/B	1 & 2	3 & 4	5 & 6
Pressure (psig)	2400	3500	3500	4250	5000
Main Steam (°F)	1050	1100	1350	1350	1350
Reheat (°F)	1050	1100	1400	1400	1400

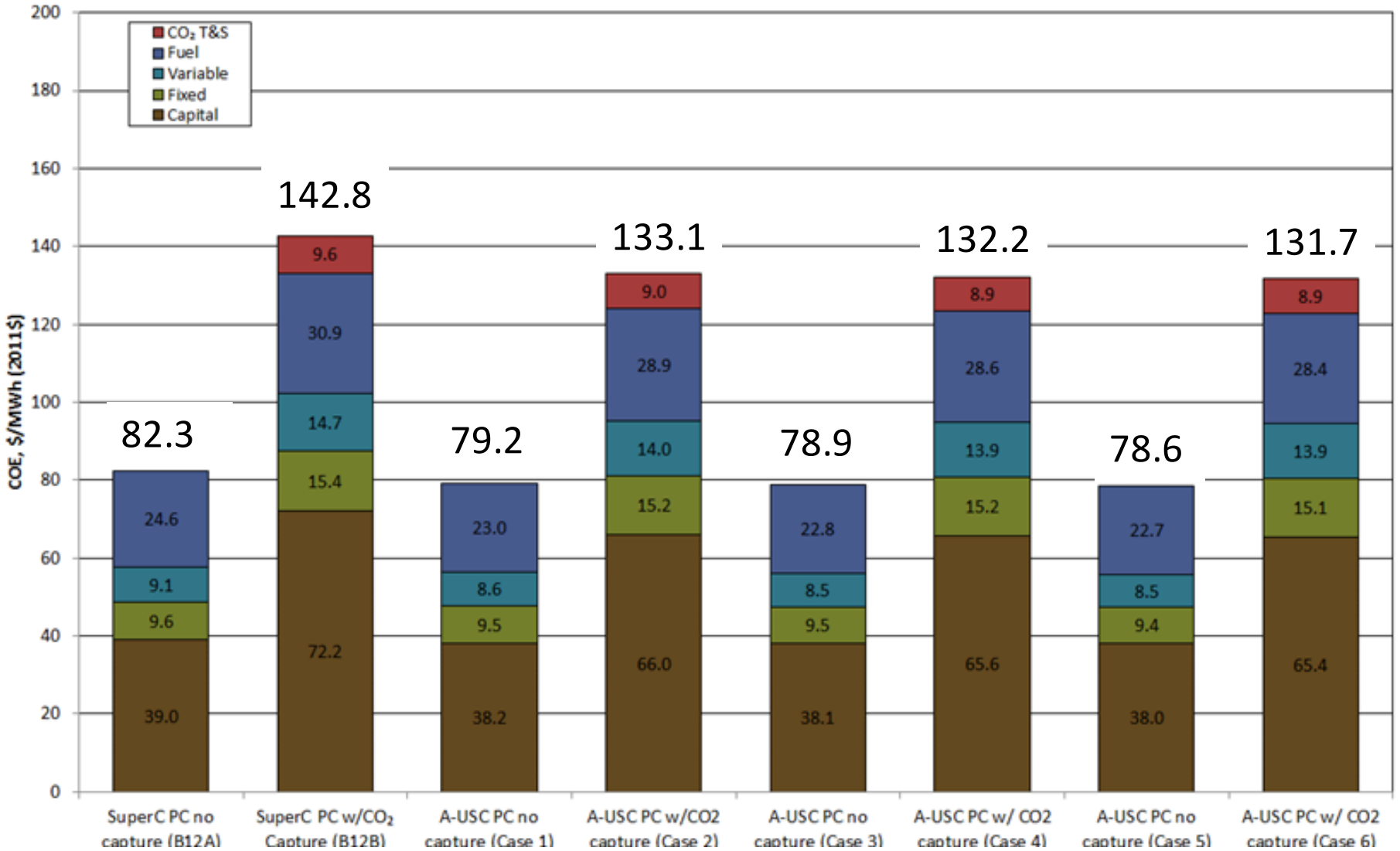
- Small reduction in CO_2 from SC to AUSC (~ 6%)
- Minimal change when P increases for AUSC cases
- Cases would require partial CO_2 capture to meet EPA limits:
  - 13-15% for Sub/SC
  - ~ 7% for AUSC

* On 12/20/2018, the EPA proposed amendments to the rulemaking titled "Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units (EGUs)," which the EPA promulgated 10/23/15. The EPA proposes to amend its previous determination that the best system of emission reduction (BSER) for newly constructed coal-fired generating units is partial carbon capture and storage (CCS). Instead, the EPA proposes to find that the BSER is the most efficient demonstrated steam cycle (e.g., supercritical steam conditions for large units and subcritical steam conditions for small units) in combination with the best operating practices. If finalized, the 1,400 lb CO_2/MWh gross emissions limit will no longer be in effect.

Advanced Ultra-Supercritical (AUSC) PC Plants – Cost Summary

	PC Supercritical		PC A-USC					
Case Name	B12A	B12B	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
COST								
Total Plant Cost (2011$/kW)	2,026	3,524	1,986	3,447	1,977	3,429	1,972	3,417
Bare Erected Cost	1,646	2,716	1,614	2,660	1,607	2,646	1,603	2,636
Home Office Expenses	165	263	161	258	161	256	160	256
Project Contingency	216	430	210	419	209	417	209	416
Process Contingency	0	115	0	111	0	110	0	110
Total Overnight Cost (2011$MM)	1,379	2,384	1,350	2,329	1,345	2,316	1,341	2,308
Total Overnight Cost (2011$/kW)	2,507	4,333	2,455	4,236	2,444	4,214	2,437	4,199
Owner's Costs	480	809	469	789	467	785	465	782
Total As-Spent Cost (2011$/kW)	2,842	4,940	2,784	4,829	2,772	4,804	2,764	4,787
COE ($/MWh) (excluding T&S)	82.3	133.2	79.2	124.1	78.9	123.3	78.6	122.8
Capital Costs	39.0	72.2	38.2	66.0	38.1	65.6	38.0	65.4
Fixed Costs	9.6	15.4	9.5	15.2	9.5	15.2	9.4	15.1
Variable Costs	9.1	14.7	8.6	14.0	8.5	13.9	8.5	13.9
Fuel Costs	24.6	30.9	23.0	28.9	22.8	28.6	22.7	28.4
COE ($/MWh) (including T&S)	82.3	142.8	79.2	133.1	78.9	132.2	78.6	131.7
CO_2 T&S Costs	0.0	9.6	0.0	9.0	0.0	8.9	0.0	8.9
CO_2 Captured Cost (excluding T&S), $/tonne	N/A	58.2	N/A	51.1	N/A	50.7	N/A	50.4
CO_2 Avoided Cost (including T&S), $/tonne	N/A	89.4	N/A	74.3	N/A	73.0	N/A	72.2

Advanced Ultra-Supercritical (AUSC) PC Plants – COE Summary



- COE shows ~4% decrease for non-capture and ~7% decrease for capture plants as T increases from SC to AUSC conditions at 3500 psig
- Further reductions in total COE are small as the main steam P increase for all AUSC cases
- For AUSC cases, the COE penalty for including CO_2 capture is ~ 68%

Advanced Ultra-Supercritical (AUSC) PC Plants – Summary

- **AUSC PC plants without CCS gain 3.0% points; with CCS, 2.2% points**
  - SC (3500 psig/1100°F/1100°F) to AUSC (3500 psig/1350°F/1400°F)
  - Further slight improvement with increased main steam pressure
- **AUSC PC plants without CCS show a 3.8% decrease in COE; with CCS, 6.8%**
  - SC (3500 psig/1100°F/1100°F) to AUSC (3500 psig/1350°F/1400°F)
  - Further slight decreases with increased main steam pressure
- **Primary uncertainty is downdraft inverted tower boiler**
  - Cost estimation, particularly as configured for AUSC steam conditions

Steam Conditions Retrofits – Objective

- **Develop performance and cost estimates to evaluate the feasibility and potential benefits of retrofitting existing subcritical pulverized coal (PC) plants to operate at either supercritical (SC) or advanced ultrasupercritical (AUSC) steam conditions.**
- **Cases**
  - B11A – Reference subcritical plant from "Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity, Revision 3" (Bituminous Baseline).
  - B12A – Reference supercritical plant from the Bituminous Baseline.
  - 1 – Reference advanced ultrasupercritical plant from "Development of Advanced Ultra-Supercritical (AUSC) Pulverized Coal (PC) Plants".
  - Ret-SC – Retrofitted supercritical plant.
  - Ret-AUSC – Retrofitted advanced ultrasupercritical plant.

Steam Conditions Retrofits – Assumptions

Converted Plant		
Case	**Ret-SC**	**Ret-AUSC**
Replacement Rankine Technology	Supercritical	Advanced Ultrasupercritical
Reference Case	Case B12A	Case 1
Main Steam Pressure	3,500 psig	3,500 psig
Main Steam Temperature	1,100°F	1,350°F
Reheat Temperature	1,100°F	1,400°F
External Superheater/Reheater	No	
Topping Cycle	No	
Double Reheat	No	
Additional Feedwater Heater	No	
Normalization Basis	Power Output	
Considerations for Off-Design Operation	No	
Scrap Material Revenue	No	
Retrofit Difficulty Factor	Yes	
Deconstruction Costs	Yes	
Existing Plant		
Reference Rankine Technology	Subcritical	
Triggers New Source Review	Yes	
Existing Plant Includes Best Available Control Technology	Yes	
Includes CO_2 Capture	No	
Retrofit Costs Include Emission Control Technology	No	
Located Within Attainment Area	Yes	
Existing New Construction Space Available	No	

Steam Conditions Retrofits – Systems to be Replaced

- **NETL consulted with Babcock and Wilcox (B&W)**
- **Sub-to-supercritical (SC) plant:**
  - Access to subcritical units will be a serious challenge as space is significantly limited
  - It would be unlikely that sufficient space would be available to install a topping cycle
  - The fireside of the boiler would need to be demolished to make room for other pressure vessels, bypass valves, flash tanks, etc.
  - Nearly the entire boiler and steam turbine would need to be demolished and replaced, with some exceptions:
    - Some top steel for support
    - Fuel prep system
    - Fans, flues, and ducts
    - Foundation

Steam Conditions Retrofits – Systems to be Replaced (cont'd)

- **The inverted tower utilized in the Ret-AUSC case requires the following additional equipment to be replaced:**
  - Steam Generator Foundation
  - Coal Conveyors
  - Ash Transport and Feed Equipment (bottom ash only)
- **An additional 25 percent contingency was added to the demolition costs of the AUSC boiler, compared to an SC boiler, to account for the additional equipment.**

Steam Conditions Retrofits – Ret-SC Cost Results

Total Plant Cost Summary													
Case:		Ret-SC – Subcritical to Supercritical PC w/o CO_2					Cost Base:			Jun 2011			
Plant Size (MW, net):		550					Cost Base ($x1,000):			Jun 2011			
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost		Retrofit Factor	
				Direct	Indirect			Process	Project	$/1000	$/kW	Equipment	Labor
Miscellaneous		Miscellaneous Costs											
	Demolition Costs	$0	$0	$0	$0	$25,000	$2,500	$0	$2,750	$30,250	$55	N/A	
Subtotal		$0	$0	$0	$0	$25,000	$2,500	$0	$2,750	$30,250	$55		
3		Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	$19,086	$0	$6,740	$0	$25,825	$2,583	$0	$4,261	$32,669	$59	1.05	1.15
3.3	Other Feedwater Subsystems	$6,004	$0	$2,699	$0	$8,703	$870	$0	$1,436	$11,010	$20	1.05	1.15
3.5	Other Boiler Plant Systems	$7,283	$0	$7,542	$0	$14,825	$1,482	$0	$2,446	$18,753	$34	1.05	1.15
Subtotal		$32,373	$0	$16,981	$0	$49,353	$4,935	$0	$8,143	$62,432	$114		
4		Boiler & Accessories											
4.1	PC Boiler & Accessories	$160,019	$0	$95,142	$0	$255,160	$25,516	$0	$28,068	$308,744	$561	1.15	1.20
Subtotal		$160,019	$0	$95,142	$0	$255,160	$25,516	$0	$28,068	$308,744	$561		
8		Steam Turbine Generator											
8.1	Steam TG & Accessories	$85,459	$0	$9,724	$0	$95,183	$9,518	$0	$10,470	$115,172	$209	1.15	1.20
8.2	Turbine Plant Auxiliaries	$475	$0	$1,053	$0	$1,528	$153	$0	$168	$1,849	$3	1.15	1.20
8.4	Steam Piping	$30,104	$0	$12,731	$0	$42,835	$4,284	$0	$7,068	$54,187	$99	1.15	1.20
Subtotal		$116,037	$0	$23,509	$0	$139,546	$13,955	$0	$17,706	$171,207	$311		
14		Buildings & Structures											
14.1	Boiler Building	$0	$2,479	$2,178	$0	$4,657	$466	$0	$768	$5,892	$11	N/A	
14.2	Turbine Building	$0	$3,540	$3,297	$0	$6,837	$684	$0	$1,128	$8,649	$16	N/A	
14.8	Other Buildings & Structures	$0	$256	$239	$0	$495	$49	$0	$82	$626	$1	1.05	1.15
Subtotal		$0	$6,275	$5,714	$0	$11,990	$1,199	$0	$1,978	$15,167	$28		
Total		$308,428	$6,275	$141,346	$0	$481,050	$48,105	$0	$58,645	$587,800	$1,069		

Steam Conditions Retrofits – Ret-SC Cost Results (cont'd)

Owner's Costs		
Description	**$/1,000**	**$/kW**
Pre-Production Costs		
6 Months All Labor	$8,752	$16
1 Month Maintenance Materials	$1,129	$2
1 Month Non-fuel Consumables	$0	$0
1 Month Waste Disposal	$429	$1
25% of 1 Months Fuel Cost at 100% CF	$0	$0
2% of TPC	$11,756	$21
Total	**$22,066**	**$40**
Inventory Capital		
60 day supply of fuel and consumables at 100% CF	$0	$0
0.5% of TPC (spare parts)	$2,939	$5
Total	**$2,939**	**$5**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$88,170	$160
Financing Costs	$15,871	$29
Total Overnight Costs (TOC)	**$716,846**	**$1,303**
TASC Multiplier (IOU, low-risk, 32 year)	1.042	
Total As-Spent Cost (TASC)	**$746,953**	**$1,358**

Steam Conditions Retrofits – Ret-AUSC Cost Results

Total Plant Cost Summary													
Case:		Ret-AUSC – Supercritical to AUSC PC w/o CO_2					Cost Base:			Jun 2011			
Plant Size (MW, net):		550					Cost Base ($x1,000):			Jun 2011			
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O.& Fee	Contingencies		Total Plant Cost		Retrofit Factor	
				Direct	Indirect			Process	Project	$/1000	$/kW	Equipment	Labor
Miscellaneous		**Miscellaneous Costs**											
	Demolition Costs	$0	$0	$0	$0	$31,250	$3,125	$0	$3,438	$37,813	$69	N/A	
	Subtotal	**$0**	**$0**	**$0**	**$0**	**$31,250**	**$3,125**	**$0**	**$3,438**	**$37,813**	**$69**		
1		**Coal & Sorbent Handling**											
1.3	Coal Conveyors	$4,831	$0	$1,258	$0	$6,089	$609	$0	$1,005	$7,703	$14	1.05	1.15
	Subtotal	**$4,831**	**$0**	**$1,258**	**$0**	**$6,089**	**$609**	**$0**	**$1,005**	**$7,703**	**$14**		
3		**Feedwater & Miscellaneous BOP Systems**											
3.1	Feedwater System	$19,124	$0	$6,753	$0	$25,878	$2,588	$0	$4,270	$32,735	$60	1.05	1.15
3.3	Other Feedwater Subsystems	$6,016	$0	$2,705	$0	$8,721	$872	$0	$1,439	$11,032	$20	1.05	1.15
3.5	Other Boiler Plant Systems	$7,179	$0	$7,434	$0	$14,614	$1,461	$0	$2,411	$18,486	$34	1.05	1.15
	Subtotal	**$32,320**	**$0**	**$16,892**	**$0**	**$49,212**	**$4,921**	**$0**	**$8,120**	**$62,253**	**$113**		
4		**Boiler & Accessories**											
4.1	PC Boiler & Accessories	$186,418	$0	$110,838	$0	$297,256	$29,726	$0	$32,698	$359,680	$654	1.15	1.20
	Subtotal	**$186,418**	**$0**	**$110,838**	**$0**	**$297,256**	**$29,726**	**$0**	**$32,698**	**$359,680**	**$654**		
8		**Steam Turbine Generator**											
8.1	Steam TG & Accessories	$99,283	$0	$9,740	$0	$109,023	$10,902	$0	$11,993	$131,918	$240	1.15	1.20
8.2	Turbine Plant Auxiliaries	$475	$0	$1,055	$0	$1,530	$153	$0	$168	$1,852	$3	1.15	1.20
8.4	Steam Piping	$30,155	$0	$9,988	$0	$40,142	$4,014	$0	$6,623	$50,780	$92	1.15	1.20
	Subtotal	**$129,913**	**$0**	**$20,782**	**$0**	**$150,696**	**$15,070**	**$0**	**$18,784**	**$184,550**	**$335**		
10		**Ash & Spent Sorbent Handling Systems**											
10.7	Ash Transport & Feed Equipment	$1,897	$0	$2,060	$0	$3,957	$396	$0	$435	$4,788	$9	1.05	1.15
		$1,897	**$0**	**$2,060**	**$0**	**$3,957**	**$396**	**$0**	**$435**	**$4,788**	**$9**		
14		**Buildings & Structures**											
14.1	Boiler Building	$0	$2,430	$2,135	$0	$4,565	$456	$0	$753	$5,774	$10	N/A	
14.2	Turbine Building	$0	$3,446	$3,210	$0	$6,656	$666	$0	$1,098	$8,420	$15	N/A	
14.8	Other Buildings & Structures	$0	$254	$237	$0	$491	$49	$0	$81	$622	$1	1.05	1.15
	Subtotal	**$0**	**$6,130**	**$5,582**	**$0**	**$11,712**	**$1,171**	**$0**	**$1,933**	**$14,816**	**$27**		
	Total	**$355,379**	**$6,130**	**$157,413**	**$0**	**$550,172**	**$55,017**	**$0**	**$66,413**	**$671,602**	**$1,221**		

Steam Conditions Retrofits – Ret-AUSC Cost Results (cont'd)

Owner's Costs		
Description	**$/1,000**	**$/kW**
Pre-Production Costs		
6 Months All Labor	$8,840	$16
1 Month Maintenance Materials	$1,149	$2
1 Month Non-fuel Consumables	$0	$0
1 Month Waste Disposal	$400	$1
25% of 1 Months Fuel Cost at 100% CF	$0	$0
2% of TPC	$13,432	$24
Total	**$23,821**	**$43**
Inventory Capital		
60 day supply of fuel and consumables at 100% CF	$0	$0
0.5% of TPC (spare parts)	$3,358	$6
Total	**$3,358**	**$6**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$0	$0
Other Owner's Costs	$100,740	$183
Financing Costs	$18,133	$33
Total Overnight Costs (TOC)	**$817,655**	**$1,486**
TASC Multiplier (IOU, low-risk, 32 year)	1.042	
Total As-Spent Cost (TASC)	**$851,996**	**$1,549**

Steam Conditions Retrofits – Performance Results Summary

Case	Ret-SC*	B12A	Ret-AUSC**	1
Performance				
Heat Rate, Btu/kWh	8,379	8,379	7,814	7,814
Net Plant Efficiency, %	40.7	40.7	43.7	43.7
Total Gross Power, MWe	580	580	578	578
Total Auxiliaries, MWe	30	30	27	27
Total Net Power, MWe	550	550	550	550
As Received Coal Feed Rate, lb/hr	395,053	395,053	368,475	368,475
Cost				
Total Plant Cost, $/kW	1,069	2,026	1,221	1,986
Total Plant Cost, $/1,000	587,800	1,114,361	671,602	1,092,444
Total Overnight Cost, $/kW	1,303	2,507	1,486	2,455
Total Overnight Cost, $/1,000	716,846	1,378,634	817,655	1,350,301
Total As-Spent Cost, $/kW	1,358	2,842	1,549	2,784
Total As-Spent Cost, $/1,000	746,953	1,563,371	851,996	1,531,241

* Performance for Case Ret-SC is identical to that of Case B12A.

** Performance for Case Ret-AUSC is identical to that of Case 1.

Steam Conditions Retrofits – Cost Results Summary

Case	B11A*	Ret-SC	B12A	Ret-AUSC	1
Cost of Electricity					
Capital, $/MWh	0.0	17.9	39.0	23.2	38.2
Fixed, $/MWh	13.5	10.1	9.6	10.3	9.5
Variable, $/MWh	10.4	9.2	9.1	8.7	8.6
Fuel, $/MWh	25.7	24.6	24.6	23.0	23.0
Total (w/o Loss of Revenue), $/MWh	**49.6**	**61.8**	**82.3**	**65.1**	**79.2**
Loss of Revenue, $/MWh	N/A	6.4	N/A	6.4	N/A
Total (w/ Loss of Revenue), $/MWh	**N/A**	**68.2**	**N/A**	**71.6**	**N/A**

*The costs reported are for a case equivalent to Case B11A from the Bituminous Baseline with no remaining capital costs operating at a capacity factor of 58.4 percent.

Steam Conditions Retrofits – Conclusions

- New Source Review would be applicable for retrofitting a subcritical PC plant to either a supercritical or AUSC steam conditions.
- Loss of revenue can be a potentially significant contributor to the cost of retrofit, representing a 10 percent increase in the cost of electricity (2 year shutdown).
- The duration of the retrofit has the greatest impact on the loss of revenue, with costs ranging from $65 million to $520 million (0.5 – 4 year shutdown).
- The estimated total plant cost for a supercritical/AUSC retrofit is approximately 50/60 percent of the cost for greenfield construction.
- The boiler replacement along with its respective retrofit difficulty factor have the greatest potential impact on the capital costs.

Questions?

Robert.Stevens@NETL.DOE.GOV

304.285.4305

Authors

NETL: Dale Keairns, Eric Lewis, Richard Newby, Walter Shelton, Travis Shultz, Marc Turner, Charles White, Mark Woods

Retired: David Gray, John Plunkett