

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS

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COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-
CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

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1 INTRODUCTION

The Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM) National Energy Technology Laboratory (NETL) previously released Revision 4a of the public report “Fossil Energy Baseline for Electricity Generating Units Volume 1: Coal and Natural Gas to Electricity” (“Rev4a”), which details greenfield cost and performance estimates for state-of-the-art natural gas power generation technologies [1]. Additionally, NETL has previously released the public report “Cost and Performance Projections for Coal- and Natural Gas-Fired Power Plants” (“C&P Projections”), which details greenfield and retrofit cost and performance projections for advanced natural gas power generation technologies [2].

NETL’s Rev4a included cases that used 2017 vintage H-Class combustion turbines in a 2×1 natural gas combined cycle (NGCC) configuration, where two combustion turbines (CT) paired with two heat recovery steam generators (HRSGs) are coupled to a single steam turbine (ST) bottoming cycle, and 2021 vintage CO₂ capture. The C&P Projections report modified Rev4a cases to reflect advanced X-Class CTs, which used more aggressive Brayton cycle conditions and a less energy-intensive CO₂ capture system, representative of future cost and performance improvements from commercial deployment of high-technology readiness level technologies and investments in targeted research, development, and deployment (RD&D) activities.

This study developed cost and performance estimates of NGCC cases analogous to NETL’s Rev4a using a state-of-the-art 2023 vintage H-Class CT in a 1×1 configuration, where a single CT and HRSG are coupled to a single ST on a common shaft. These 1×1 H-Class cases were then used to develop cost and performance estimates of X-Class 1×1 NGCC cases with advanced performance characteristics, analogous to NETL’s C&P Projections report.

2 METHODS

Cost and performance estimates of 14 cases were developed that are meant to be representative of

- Greenfield state-of-the-art 2023 H-Class 1×1 NGCC with 0, 90, 95, and 97 percent CO₂ capture using state-of-the-art 2021 solvent-based CO₂ capture technology.
- Greenfield X-Class 1×1 NGCC with 0, 90, 95, and 97 percent CO₂ capture using advanced solvent-based CO₂ capture technology.
- Retrofit state-of-the-art 2023 H-Class 1×1 NGCC with 90, 95, and 97 percent CO₂ capture using state-of-the-art 2021 solvent-based CO₂ capture technology.
- Retrofit state-of-the-art 2023 H-Class 1×1 NGCC with 90, 95, and 97 percent CO₂ capture using advanced solvent-based CO₂ capture technology.

The performance estimates of the H-Class NGCC cases were developed using vendor data and Aspen Plus® and are reflective of state-of-the-art commercial offerings^a (2023 for NGCC without CO₂ capture and 2021 for CANSOLV CO₂ capture system).

For H-Class cases, the cost estimates of accounts 6.1 (Combustion Turbine Generator), 7.1 (Heat Recovery Steam Generator), and 8.1 (Steam Turbine Generator & Accessories) were informed by vendor data. The balance of the plant's cost estimate was produced by scaling relevant capital and operating costs from the 2×1 reference B32 series from Rev4a to reflect changes in process flows [1].

The X-Class NGCC plant and advanced CO₂ capture technology are meant to be representative of advanced options that, with sufficiently aggressive investments in relevant RD&D, may be available for initial commercial operation in 2035.

The performance estimates of the X-Class NGCC cases were developed by modifying the H-Class cases to have a 3,100°F (notionally 2,800°F for the state-of-the-art 2023 H-Class 1×1 NGCC configuration) CT firing temperature, consistent with the 2023 C&P Projections report [2] (which were based on Rev4a's H-Class plants),^a and modifying the applicable Aspen Plus® models in a manner that reflects the relevant improvements for the advanced capture technology, described below.

It was assumed that the advantages of the CT used in the X-Class cases, relative to the H-Class CT, were achieved through no additional cost. Balance of plant cost estimates of the X-Class cases were then produced by scaling relevant capital and operating costs from the H-Class cases to reflect changes in process flows and making adjustments to capture direct cost reductions (e.g., cost reductions for CO₂ capture system capital components and consumables), described below.

^a Section 2.1 provides additional context on the differences between the H-Class NGCC cases reported in this technote and those reported in Rev4a.

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Retrofit NGCC cases are representative of H-class plants retrofit with either state-of-the-art capture or advanced capture.

A breakdown of case nomenclature and key assumptions used for this report is provided in Exhibit 2-1.

Exhibit 2-1. Case matrix

Case	CT Class	Steam Cycle, psia/°F/°F	Combustion Turbine	Boiler Technology	CO ₂ Separation	Capture Rate	Plant Type
B32A.1	H-Class NGCC	2516/1085 /1085	1× state-of-the-art 2023	HRSG	N/A	N/A	Greenfield
B32B.1.90					State-of-the-art 2021 Capture System	90%	
B32B.1.95						95%	
B32B.1.97						97%	
B3XA.1	X-Class NGCC		1× advanced with 3,100°F firing temperature		N/A	N/A	
B3XB.1.90					Advanced Capture System	90%	
B3XB.1.95						95%	
B3XB.1.97						97%	
B32A.1-BR.90	H-Class NGCC		1× state-of-the-art 2023		State-of-the-art 2021 Capture System	90%	Retrofit
B32A.1-BR.95						95%	
B32A.1-BR.97						97%	
Adv B32A.1-BR.90	H-Class NGCC		1× state-of-the-art 2023		Advanced Capture System	90%	
Adv B32A.1-BR.95						95%	
Adv B32A.1-BR.97						97%	

The advanced capture system reflects improvements in performance and reductions in cost beyond today's state-of-the-art solvent-based CO₂ capture system. Changes to process flows for BOP systems (e.g., steam cycle water flow reductions due to lower reboiler duty) were factored into capital cost scaling as well as relevant fixed and variable operating cost categories.

In total, the five parameters shown in Exhibit 2-2 were adjusted to reflect potential improvements of advanced CO₂ capture systems, where the percent reductions are relative to the current state-of-the-art 2021 CO₂ capture system.

Exhibit 2-2. Advanced capture system assumptions

Parameter	Reduction from Current State of the Art
Reboiler Duty, Btu/lb	30%
Capture System Auxiliary Load, kW/tph CO ₂	65%
Total Plant Cost for the Capture System, \$/kW	50%
Total Solvent Initial Fill Cost, \$MM/yr	50%
Total Solvent Makeup Cost, \$MM/yr	50%

The performance improvement estimates are informed by outcomes from individual relevant FECM-funded research and development projects, modeled as cumulative parameter adjustments without consideration for their interdependence (e.g., one project demonstrated a 30 percent reduction in reboiler duty and another project demonstrated a 65 percent reduction in auxiliary load, both reductions were applied in the advanced capture system); the modeling of integrated, process-level improvements is outside the scope of this effort. However, efficiency improvements in other process units are feasible (e.g., improved CO₂ reaction kinetics and solvent capacity could reduce solvent circulation rate and, thus, auxiliary load; advanced solvent regeneration configurations could reduce reboiler duty without auxiliary load impacts); the advanced capture system assumptions were assumed as overall net improvements to the aggregated system.

The capital cost reductions for the advanced capture system, including those for initial solvent fills, are only applied to the capture system components (e.g., the CO₂ removal system and solvent costs). Capital and operating costs for other affected processes (e.g., steam cycle water flow reductions due to lower reboiler duty) were scaled in accordance with NETL's, "Quality Guidelines for Energy System Studies: Capital Cost Scaling Methodology: Revision 4a Report," modified to reflect feedback provided by Black & Veatch during prior NETL studies [3]. All costs are presented in 2018 real dollars.

2.1 NOTE ON METHODS

The performance estimates reported in this technote were developed as part of the on-going Revision 4b update to the Fossil Energy Baseline ("Rev4b"). Vendor quotes were obtained for the H-Class CTs that represent 2023 state-of-the-art commercial offerings. Numerous differences exist between the H-Class NGCC design of Rev4a and those reported in this technote, beyond the CT vintage^b and use of a 1×1 configuration. These include, but are not limited to, air compressor pressure ratio, turbine inlet temperature, fuel temperature, fuel flow rate, air flow rate, exhaust temperature, stack temperature, rate of excess air, main steam pressure, HRSG pressure profile, HRSG temperature approaches, heat losses, leakage rates, CT efficiency, steam turbine efficiency, and uncontrolled NO_x emissions.

The methodology for developing the cost estimates provided in this technote is largely consistent with that used for Rev4a, as described in relevant NETL Quality Guidelines for Energy System Studies documents, but includes some modifications that better reflect the impact of

^b The H-Class CTs included in Rev4a are representative of 2017 state-of-the-art commercial offerings.

scaling from a 2×1 configuration to a 1×1 configuration. This methodology was informed by cost estimates developed by Black & Veatch under prior NETL studies, such as the “Cost and Performance Baseline for Fossil Energy Plants, Volume 5: Natural Gas Electricity Generating Units for Flexible Operation,” which includes both 2×1 and 1×1 H-Class cases.^c The relevant Quality Guidelines for Energy System Studies documents will be revised to reflect the cost estimating methodology used for the in-development Rev4b.^d

3 COST AND PERFORMANCE RESULTS

Cost and performance results for the 14 cases are summarized in Exhibit 3-1 through Exhibit 3-13, including the total overnight cost breakdown, fixed operating and maintenance costs, and variable operating and maintenance costs. Detailed tables showing capital costs, owner’s costs, and fixed and variable operating costs for all cases are included as an appendix to this report.

Except where otherwise noted, the design basis of this study is consistent with that of Rev4a, including ambient conditions, fuel specifications, and environmental design requirements [1]. All capture cases use the same CT as non-capture cases, resulting in the net plant output for plants equipped with CO₂ capture being lower than the cases without CO₂ capture. CO₂ capture retrofit cases maintain the same fuel feed rate as the base pre-retrofit plant and are derated to account for the steam diverted from the low-pressure section of the ST, and net output available for export to the grid is further decreased to account for the auxiliary load of the retrofitted capture system. A retrofit difficulty factor is applied at the total plant cost (TPC) level to account for the cost premium due to design, construction, and tie-in constraints imposed by the existing plant layout and operation. Performance and cost trends for higher capture rates are consistent with the analysis presented in Rev4a [1] and respective retrofit reports [4] [5].

^c The Volume 5 H-Class CTs are representative of 2021 state-of-the-art commercial offerings. Key design differences between the CTs included in Volume 5, Rev4a, and this technote, beyond the CT vintages, are that the plants are designed for flexible operation, rather than baseload, and are designed for 100 percent dry cooling, rather than 100 percent wet cooling. Additional differences between the H-Class NGCC design of Volume 5, Rev4a, and those reported in this technote include, but are not limited to, air compressor pressure ratio, fuel temperature, fuel flow rate, air flow rate, exhaust temperature, stack temperature, rate of excess air, main steam pressure, HRSG pressure profile, HRSG temperature approaches, heat losses, leakage rates, CT efficiency, and steam turbine efficiency.

^d As the cost estimates of the analogous H-Class cases of the in-development Rev4b are being developed by Black & Veatch using in-house data in addition to the vendor data used in this technote, there are likely to be additional methodology changes between Rev4a and Rev4b that are not accounted for in this technote.

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-1. Greenfield performance summary

Parameter	Greenfield H-Class NGCC				Greenfield X-Class NGCC			
	B32A.1	B32B.1.90	B32B.1.95	B32B.1.97	B3XA.1	B3XB.1.90	B3XB.1.95	B3XB.1.97
Nominal CO₂ Capture, %	0	90	95	97	0	90	95	97
CO ₂ Captured, ton/hr	0	210	222	226	0	249	262	268
Capacity Factor, %	85	85	85	85	85	85	85	85
Gross Power Output, MWe	660	619	617	615	793	759	757	756
Auxiliary Power Requirement, MWe	11	40	42	43	13	39	40	41
CO ₂ Capture, kWe	–	11,500	12,300	12,900	–	4,800	5,100	5,400
CO ₂ Compression, kWe	–	15,240	16,080	16,420	–	18,040	19,040	19,440
Balance of Plant, kWe	11,085	13,225	13,245	13,275	13,056	15,936	15,996	16,046
Net Power Output, MWe	649	579	575	572	780	720	717	715
Natural Gas Flow Rate, lb/hr	175,100	175,100	175,100	175,100	207,525	207,525	207,525	207,525
HHV Thermal Input, kW _t	1,153,739	1,153,739	1,153,739	1,153,739	1,367,387	1,367,387	1,367,387	1,367,387
Net Plant HHV Efficiency, %	56.2	50.2	49.8	49.6	57.1	52.7	52.4	52.3
Net Plant HHV Heat Rate, Btu/kWh	6,068	6,801	6,848	6,884	5,979	6,477	6,506	6,528
Raw Water Withdrawal, gpm/MW _{net}	3.6	6.5	6.6	6.6	3.5	6.4	6.5	6.5
Raw Water Consumption, gpm/MW _{net}	2.7	3.9	4.0	4.1	2.6	3.9	3.9	4.0

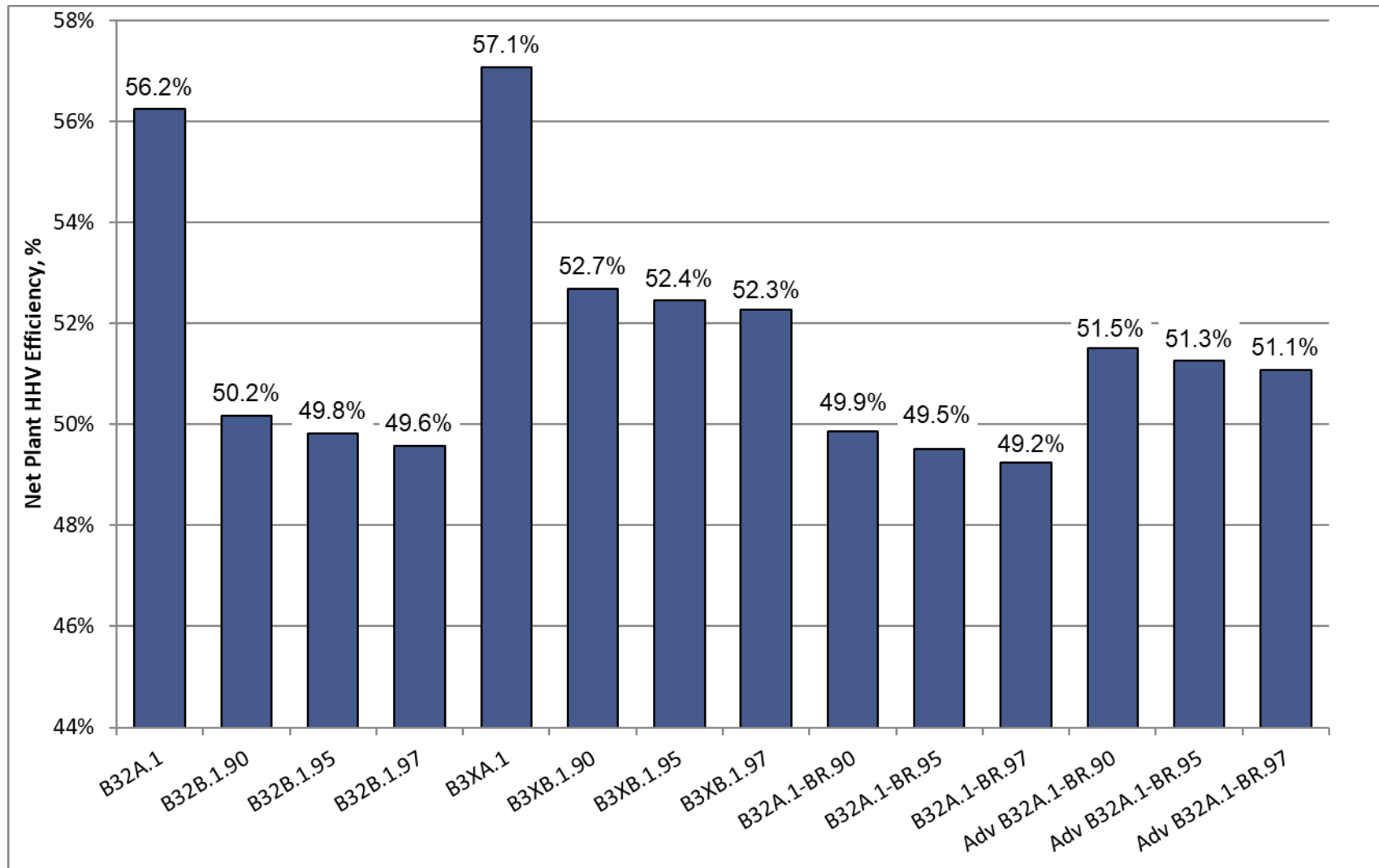
COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-2. Retrofit performance summary

Parameter	Retrofit H-Class NGCC			Advanced Retrofit H-Class NGCC		
	B32A.1- BR.90	B32A.1- BR.95	B32A.1- BR.97	Adv B32A.1- BR.90	Adv B32A.1- BR.95	Adv B32A.1- BR.97
Nominal CO₂ Capture, %	90	95	97	90	95	97
CO ₂ Captured, ton/hr	210	222	226	210	222	226
Capacity Factor, %	85	85	85	85	85	85
Gross Power Output, MWe	615	613	611	627	625	624
Auxiliary Power Requirement, MWe	40	42	43	33	34	35
CO ₂ Capture, kWe	11,500	12,300	12,900	4,000	4,300	4,500
CO ₂ Compression, kWe	15,240	16,080	16,420	15,240	16,080	16,420
Balance of Plant, kWe	13,215	13,235	13,265	13,505	13,575	13,625
Net Power Output, MWe	575	571	568	594	591	589
Natural Gas Flow Rate, lb/hr	175,100	175,100	175,100	175,100	175,100	175,100
HHV Thermal Input, kW _t	1,153,739	1,153,739	1,153,739	1,153,739	1,153,739	1,153,739
Net Plant HHV Efficiency, %	49.9	49.5	49.2	51.5	51.3	51.1
Net Plant HHV Heat Rate, Btu/kWh	6,844	6,892	6,931	6,624	6,657	6,681
Raw Water Withdrawal, gpm/MW _{net}	6.5	6.6	6.7	6.6	6.7	6.7
Raw Water Consumption, gpm/MW _{net}	4.0	4.0	4.1	4.1	4.2	4.2

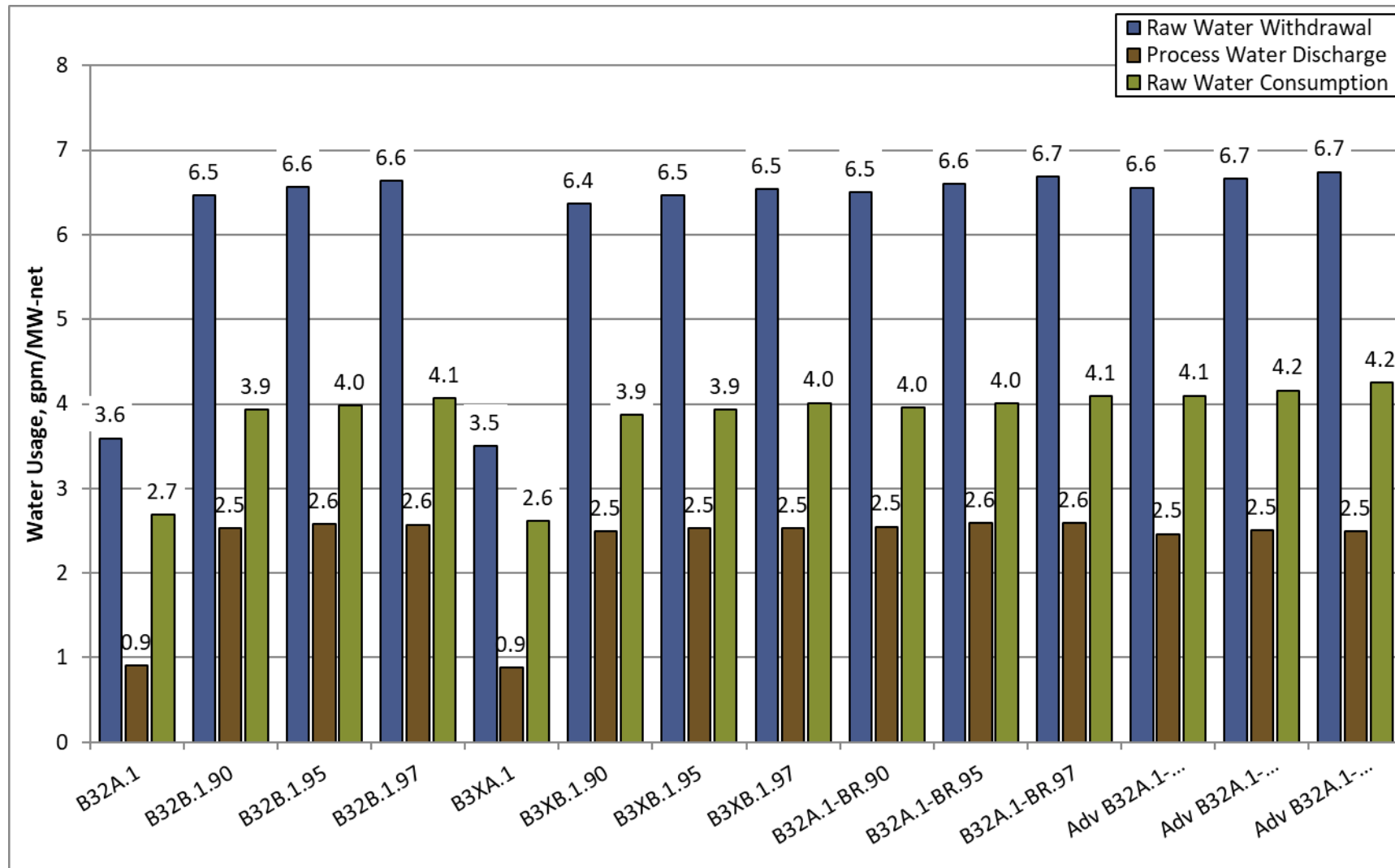
COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-3. Net plant efficiency (HHV basis)



COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-4. Raw water withdrawal, discharge, and consumption



COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-5. Greenfield H-class carbon balance

Carbon In, kg/hr (lb/hr)					Carbon Out, kg/hr (lb/hr)				
	B32A.1	B32B.1.90	B32B.1.95	B32B.1.97		B32A.1	B32B.1.90	B32B.1.95	B32B.1.97
Natural Gas	57,366 (126,471)	57,366 (126,471)	57,366 (126,471)	57,366 (126,471)	Stack Gas	57,757 (127,332)	5,786 (12,756)	2,899 (6,391)	1,744 (3,845)
Air (CO ₂)	390 (861)	390 (861)	390 (861)	390 (861)	CO ₂ Product	– (–)	51,970 (114,575)	54,858 (120,940)	56,013 (123,487)
					CO ₂ Knockout	– (–)	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)	Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)

Exhibit 3-6. Greenfield X-class carbon balance

Carbon In, kg/hr (lb/hr)					Carbon Out, kg/hr (lb/hr)				
	B3XA.1	B3XB.1.90	B3XB.1.95	B3XB.1.97		B3XA.1	B3XB.1.90	B3XB.1.95	B3XB.1.97
Natural Gas	67,989 (149,891)	67,989 (149,891)	67,989 (149,891)	67,989 (149,891)	Stack Gas	68,380 (150,752)	6,850 (15,103)	3,432 (7,567)	2,065 (4,552)
Air (CO ₂)	390 (861)	390 (861)	390 (861)	390 (861)	CO ₂ Product	– (–)	61,529 (135,649)	64,947 (143,185)	66,315 (146,199)
					CO ₂ Knockout	– (–)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
Total	68,380 (150,752)	68,380 (150,752)	68,380 (150,752)	68,380 (150,752)	Total	68,380 (150,752)	68,380 (150,752)	68,380 (150,752)	68,380 (150,752)

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-7. Retrofit H-class carbon balance

Carbon In, kg/hr (lb/hr)				Carbon Out, kg/hr (lb/hr)			
	B32A.1-BR.90	B32A.1-BR.95	B32A.1-BR.97		B32A.1-BR.90	B32A.1-BR.95	B32A.1-BR.97
Natural Gas	57,366 (126,471)	57,366 (126,471)	57,366 (126,471)	Stack Gas	5,786 (12,756)	2,899 (6,391)	1,744 (3,845)
Air (CO ₂)	390 (861)	390 (861)	390 (861)	CO ₂ Product	51,970 (114,575)	54,858 (120,940)	56,013 (123,487)
				CO ₂ Knockout	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)	Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)

Exhibit 3-8. Advanced retrofit H-class carbon balance

Carbon In, kg/hr (lb/hr)				Carbon Out, kg/hr (lb/hr)			
	Adv B32A.1- BR.90	Adv B32A.1-BR.95	Adv B32A.1- BR.97		Adv B32A.1- BR.90	Adv B32A.1- BR.95	Adv B32A.1- BR.97
Natural Gas	57,366 (126,471)	57,366 (126,471)	57,366 (126,471)	Stack Gas	5,786 (12,756)	2,899 (6,391)	1,744 (3,845)
Air (CO ₂)	390 (861)	390 (861)	390 (861)	CO ₂ Product	51,970 (114,575)	54,858 (120,940)	56,013 (123,487)
				CO ₂ Knockout	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)
Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)	Total	57,757 (127,332)	57,757 (127,332)	57,757 (127,332)

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-9. Greenfield air emissions in lb/MMBtu input (HHV)

Emission (lb/MMBtu)	Greenfield H-Class				Greenfield X-Class			
	B32A.1	B32B.1.90	B32B.1.95	B32B.1.97	B3XA.1	B3XB.1.90	B3XB.1.95	B3XB.1.97
SO ₂	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
NO _x	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002
PM	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Hg	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
CO	0.020	0.000	0.000	0.000	0.020	0.000	0.000	0.000
CO ₂	119	12	6	4	118	12	6	4

Exhibit 3-10. Retrofit air emissions in lb/MMBtu input (HHV)

Emission (lb/MMBtu)	Retrofit H-Class			Advanced Retrofit H-Class		
	B32A.1-BR.90	B32A.1-BR.95	B32A.1-BR.97	Adv B32A.1-BR.90	Adv B32A.1-BR.95	Adv B32A.1-BR.97
SO ₂	0.000	0.000	0.000	0.000	0.000	0.000
NO _x	0.003	0.003	0.003	0.003	0.003	0.003
PM	0.000	0.000	0.000	0.000	0.000	0.000
Hg	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
CO	0.000	0.000	0.000	0.000	0.000	0.000
CO ₂	12	6	4	12	6	4

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-11. Greenfield cost summary

Cost	Greenfield H-Class				Greenfield X-Class			
	B32A.1	B32B.1.90	B32B.1.95	B32B.1.97	B3XA.1	B3XB.1.90	B3XB.1.95	B3XB.1.97
Total Plant Cost, 2018\$/kW	924	1,877	1,921	1,949	834	1,365	1,387	1,401
Bare Erected Cost	665	1,273	1,301	1,319	600	945	960	969
Home Office Expenses	133	255	260	264	120	189	192	194
Project Contingency	126	279	286	291	114	198	202	204
Process Contingency	0	70	74	76	0	32	34	34
Total Overnight Cost, 2018\$/kW	1,125	2,279	2,332	2,366	1,015	1,659	1,686	1,703
Owner's Costs	201	402	411	417	182	294	299	302
Total As-Spent Cost, 2018\$/kW	1,229	2,490	2,548	2,585	1,110	1,812	1,842	1,860
Fixed Operating Costs, \$/kW-net	30.6	60.4	61.7	62.6	27.4	44.3	45.0	45.4
Variable Operating Costs, \$/MWh-net	2.0	4.2	4.3	4.3	1.8	3.1	3.2	3.2
Levelized Cost of Electricity (Excluding T&S), \$/MWh	44.6	66.0	67.0	67.7	42.5	54.9	55.5	55.9
Capital Costs	11.7	23.7	24.2	24.6	10.5	17.2	17.5	17.7
Fixed Costs	4.1	8.1	8.3	8.4	3.7	6.0	6.0	6.1
Variable Costs	2.0	4.2	4.3	4.3	1.8	3.1	3.2	3.2
Fuel Costs	26.8	30.1	30.3	30.4	26.4	28.6	28.8	28.9
Levelized Cost of Electricity (Including T&S), \$/MWh	44.6	69.3	70.5	71.3	42.5	58.1	58.8	59.3
CO ₂ T&S Costs	0.0	3.3	3.5	3.6	0.0	3.1	3.3	3.4

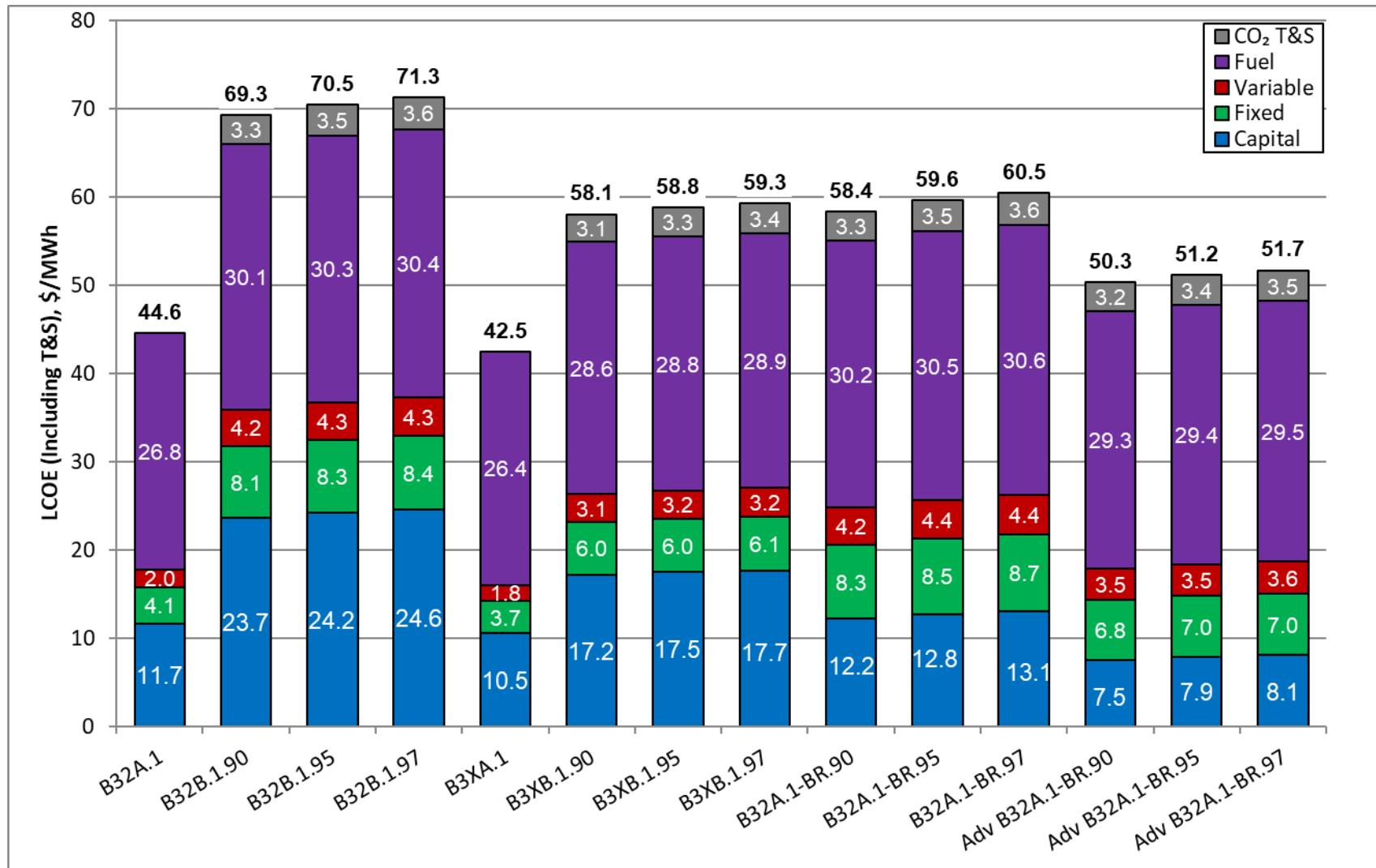
COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-12. Retrofit cost summary

Cost	Retrofit H-Class NGCC			Advanced Retrofit H-Class NGCC		
	B32A.1-BR.90	B32A.1-BR.95	B32A.1-BR.97	Adv B32A.1-BR.90	Adv B32A.1-BR.95	Adv B32A.1-BR.97
Total Plant Cost (2018\$/kW)	973	1,017	1,045	600	626	642
Bare Erected Cost	565	590	606	357	372	381
Home Office Expenses	113	118	121	71	74	76
Project Contingency	145	151	155	88	92	94
Process Contingency	70	73	75	34	36	37
Total Overnight Cost (2018\$/kW)	1,097	1,145	1,177	677	706	723
Owner's Costs	123	129	132	76	80	82
Total As-Spent Cost (2018\$/kW)	1,286	1,343	1,380	794	828	848
Fixed Operating Costs (\$/kW-net)	62.2	63.6	64.6	50.9	51.8	52.3
Variable Operating Costs (\$/MWh-net)	4.2	4.4	4.4	3.5	3.5	3.6
Levelized Cost of Electricity (Excluding T&S), \$/MWh	55.1	56.1	56.8	47.1	47.8	48.2
Capital Costs	12.2	12.8	13.1	7.5	7.9	8.1
Fixed Costs	8.3	8.5	8.7	6.8	7.0	7.0
Variable Costs	4.2	4.4	4.4	3.5	3.5	3.6
Fuel Costs	30.2	30.5	30.6	29.3	29.4	29.5
Levelized Cost of Electricity (Including T&S), \$/MWh	58.4	59.6	60.5	50.3	51.2	51.7
CO ₂ T&S Costs	3.3	3.5	3.6	3.2	3.4	3.5

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit 3-13. Levelized Cost of Electricity



4 SUMMARY

Cost and performance estimates of 2023 state-of-the-art 1×1 H-Class NGCC power plants are presented for greenfield and retrofit applications with state-of-the-art CO₂ capture and retrofit applications with advanced CO₂ capture.

Cost and performance projections of greenfield NGCC plants configured with advanced high-firing temperature (X-Class) CT technologies and advanced CO₂ capture are also presented.

The advanced plant and capture options are representative of technology that, with sufficiently aggressive investments in relevant RD&D, may be available for initial commercial operation in 2035.

Performance and cost trends for higher capture rates are consistent with the analysis presented in Rev4a [1] and respective retrofit reports [4] [5].

5 REFERENCES

- [1] National Energy Technology Laboratory, "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 4a," U.S. Department of Energy, Pittsburgh, PA, 2022.
- [2] National Energy Technology Laboratory, "Cost and Performance Projections for Coal- and Natural Gas-Fired Power Plants," U.S. Department of Energy, Pittsburgh, 2023.
- [3] National Energy Technology Laboratory, "Quality Guidelines for Energy System Studies: Capital Cost Scaling Methodology: Revision 4a Report," U.S. Department of Energy, Pittsburgh, PA, 2022.
- [4] K. Buchheit, A. Zoelle, E. Lewis, T. Fout and G. Hackett, "Eliminating the Derate of Carbon Capture Retrofits - Revision 2," National Energy Technology Laboratory, Pittsburgh, PA, March 31, 2023.
- [5] T. Schmitt, S. Homsy, M. Woods, T. Shultz, T. Fout and G. Hackett, "Cost and Performance of Retrofitting NGCC Units for Carbon Capture – Revision 3," National Energy Technology Laboratory, Pittsburgh, PA, March 17, 2023.

APPENDIX: COST ESTIMATING

A.1 H-CLASS COST ESTIMATING

Exhibit A-1. Case B32A.1 total plant cost details

Case:		B32A.1 – NGCC H-Class (1×1) – Natural Gas w/o CO ₂ Capture						Estimate Type:		Conceptual	
Plant Size (MW, net):		649						Cost Base:		Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,538	\$2,636	\$1,318	\$0	\$5,492	\$1,098	\$0	\$989	\$7,579	\$12
3.2	Water Makeup & Pretreating	\$3,229	\$323	\$1,830	\$0	\$5,382	\$1,076	\$0	\$1,292	\$7,749	\$12
3.3	Other Feedwater Subsystems	\$875	\$287	\$272	\$0	\$1,434	\$287	\$0	\$258	\$1,979	\$3
3.4	Service Water Systems	\$982	\$1,875	\$6,072	\$0	\$8,929	\$1,786	\$0	\$2,143	\$12,858	\$20
3.5	Other Boiler Plant Systems	\$232	\$84	\$211	\$0	\$527	\$105	\$0	\$95	\$728	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$21
3.7	Waste Water Treatment Equipment	\$4,607	\$0	\$2,824	\$0	\$7,431	\$1,486	\$0	\$1,784	\$10,701	\$16
3.9	Miscellaneous Plant Equipment	\$13,470	\$1,767	\$6,845	\$0	\$22,082	\$4,416	\$0	\$5,300	\$31,797	\$49
	Subtotal	\$33,989	\$7,361	\$19,664	\$0	\$61,015	\$12,203	\$0	\$13,612	\$86,830	\$134
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$240
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$6
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$4
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$252
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$44,458	\$0	\$11,114	\$0	\$55,572	\$11,114	\$0	\$10,003	\$76,690	\$118
7.2	Heat Recovery Steam Generator Accessories	\$15,395	\$0	\$2,849	\$0	\$18,244	\$3,649	\$0	\$3,284	\$25,177	\$39
7.3	Ductwork	\$0	\$827	\$575	\$0	\$1,401	\$280	\$0	\$252	\$1,934	\$3
7.4	Stack	\$7,908	\$0	\$1,463	\$0	\$9,371	\$1,874	\$0	\$1,687	\$12,933	\$20
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$617	\$578	\$0	\$1,195	\$239	\$0	\$287	\$1,721	\$3
7.6	Selective Catalytic Reduction System	\$1,306	\$549	\$765	\$0	\$2,620	\$524	\$0	\$472	\$3,615	\$6
	Subtotal	\$69,067	\$1,992	\$17,345	\$0	\$88,404	\$17,681	\$0	\$15,984	\$122,070	\$188
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$36,497	\$0	\$5,345	\$0	\$41,842	\$8,368	\$0	\$7,532	\$57,742	\$89
8.2	Steam Turbine Plant Auxiliaries	\$127	\$0	\$291	\$0	\$418	\$84	\$0	\$75	\$577	\$1
8.3	Condenser & Auxiliaries	\$5,859	\$0	\$2,811	\$0	\$8,670	\$1,734	\$0	\$1,561	\$11,965	\$18
8.4	Steam Piping	\$8,638	\$0	\$3,500	\$0	\$12,138	\$2,428	\$0	\$2,185	\$16,751	\$26
8.5	Turbine Generator Foundations	\$0	\$1,094	\$1,807	\$0	\$2,900	\$580	\$0	\$696	\$4,176	\$6

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32A.1 – NGCC H-Class (1×1) – Natural Gas w/o CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		649						Cost Base:			Dec 2018
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
	Subtotal	\$51,121	\$1,094	\$13,753	\$0	\$65,968	\$13,194	\$0	\$12,048	\$91,210	\$141
9 Cooling Water System											
9.1	Cooling Towers	\$7,048	\$0	\$2,150	\$0	\$9,199	\$1,840	\$0	\$1,656	\$12,694	\$20
9.2	Circulating Water Pumps	\$919	\$0	\$54	\$0	\$973	\$195	\$0	\$175	\$1,343	\$2
9.3	Circulating Water System Auxiliaries	\$7,355	\$0	\$970	\$0	\$8,325	\$1,665	\$0	\$1,498	\$11,488	\$18
9.4	Circulating Water Piping	\$0	\$2,027	\$1,836	\$0	\$3,863	\$773	\$0	\$695	\$5,331	\$8
9.5	Make-Up Water System	\$277	\$0	\$356	\$0	\$634	\$127	\$0	\$114	\$875	\$1
9.6	Component Cooling Water System	\$299	\$0	\$229	\$0	\$528	\$106	\$0	\$95	\$729	\$1
9.7	Circulating Water System Foundations	\$0	\$469	\$779	\$0	\$1,248	\$250	\$0	\$299	\$1,797	\$3
	Subtotal	\$15,898	\$2,496	\$6,375	\$0	\$24,769	\$4,954	\$0	\$4,533	\$34,257	\$53
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,410	\$0	\$1,818	\$0	\$4,228	\$846	\$0	\$761	\$5,834	\$9
11.2	Station Service Equipment	\$2,587	\$0	\$222	\$0	\$2,809	\$562	\$0	\$506	\$3,877	\$6
11.3	Switchgear & Motor Control	\$3,694	\$0	\$641	\$0	\$4,335	\$867	\$0	\$780	\$5,982	\$9
11.4	Conduit & Cable Tray	\$0	\$893	\$2,573	\$0	\$3,465	\$693	\$0	\$624	\$4,782	\$7
11.5	Wire & Cable	\$0	\$1,333	\$2,382	\$0	\$3,715	\$743	\$0	\$669	\$5,126	\$8
11.6	Protective Equipment	\$101	\$0	\$351	\$0	\$452	\$90	\$0	\$81	\$623	\$1
11.7	Standby Equipment	\$617	\$0	\$569	\$0	\$1,186	\$237	\$0	\$214	\$1,637	\$3
11.8	Main Power Transformers	\$8,127	\$0	\$166	\$0	\$8,292	\$1,658	\$0	\$1,493	\$11,443	\$18
11.9	Electrical Foundations	\$0	\$87	\$220	\$0	\$307	\$61	\$0	\$74	\$442	\$1
	Subtotal	\$17,535	\$2,312	\$8,941	\$0	\$28,788	\$5,758	\$0	\$5,200	\$39,746	\$61
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$164	\$0	\$105	\$0	\$269	\$54	\$0	\$48	\$371	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$263	\$0	\$168	\$0	\$431	\$86	\$0	\$78	\$595	\$1
12.4	Other Major Component Control Equipment	\$445	\$0	\$283	\$0	\$728	\$146	\$0	\$131	\$1,004	\$2
12.5	Signal Processing Equipment	\$368	\$0	\$11	\$0	\$380	\$76	\$0	\$68	\$524	\$1
12.6	Control Boards, Panels & Racks	\$98	\$0	\$60	\$0	\$158	\$32	\$0	\$28	\$218	\$0
12.7	Distributed Control System Equipment	\$5,449	\$0	\$166	\$0	\$5,615	\$1,123	\$0	\$1,011	\$7,749	\$12
12.8	Instrument Wiring & Tubing	\$450	\$360	\$1,439	\$0	\$2,249	\$450	\$0	\$405	\$3,104	\$5
12.9	Other Instrumentation & Controls Equipment	\$312	\$0	\$722	\$0	\$1,033	\$207	\$0	\$186	\$1,426	\$2
	Subtotal	\$7,931	\$360	\$3,196	\$0	\$11,487	\$2,297	\$0	\$2,068	\$15,852	\$24
13 Improvements to Site											
13.1	Site Preparation	\$0	\$543	\$11,525	\$0	\$12,068	\$2,414	\$0	\$2,896	\$17,378	\$27
13.2	Site Improvements	\$0	\$1,747	\$2,306	\$0	\$4,053	\$811	\$0	\$973	\$5,836	\$9
13.3	Site Facilities	\$1,676	\$0	\$1,758	\$0	\$3,434	\$687	\$0	\$824	\$4,944	\$8
	Subtotal	\$1,676	\$2,290	\$15,590	\$0	\$19,555	\$3,911	\$0	\$4,693	\$28,159	\$43
14 Buildings & Structures											

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32A.1 – NGCC H-Class (1×1) – Natural Gas w/o CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		649					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$3,119	\$4,149	\$0	\$7,269	\$1,454	\$0	\$1,308	\$10,031	\$15
14.4	Administration Building	\$0	\$355	\$241	\$0	\$596	\$119	\$0	\$107	\$822	\$1
14.5	Circulation Water Pumphouse	\$0	\$47	\$23	\$0	\$70	\$14	\$0	\$13	\$96	\$0
14.6	Water Treatment Buildings	\$0	\$270	\$246	\$0	\$516	\$103	\$0	\$93	\$713	\$1
14.7	Machine Shop	\$0	\$533	\$341	\$0	\$874	\$175	\$0	\$157	\$1,205	\$2
14.8	Warehouse	\$0	\$412	\$249	\$0	\$660	\$132	\$0	\$119	\$911	\$1
14.9	Other Buildings & Structures	\$0	\$293	\$213	\$0	\$506	\$101	\$0	\$91	\$698	\$1
14.10	Waste Treating Building & Structures	\$0	\$633	\$1,128	\$0	\$1,761	\$352	\$0	\$317	\$2,430	\$4
	Subtotal	\$0	\$6,055	\$6,797	\$0	\$12,852	\$2,570	\$0	\$2,313	\$17,736	\$27
	Total	\$306,059	\$25,760	\$99,510	\$0	\$431,329	\$86,266	\$0	\$81,900	\$599,495	\$924

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-2. Case B32A.1 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$3,944	\$6
1 Month Maintenance Materials	\$670	\$1
1 Month Non-fuel Consumables	\$263	\$0
1 Month Waste Disposal	\$0	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,176	\$5
2% of TPC	\$11,990	\$18
Total	\$20,043	\$31
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$333	\$1
0.5% of TPC (spare parts)	\$2,997	\$5
Total	\$3,330	\$5
Other Costs		
Initial Cost for Catalyst and Chemicals	\$638	\$1
Land	\$300	\$0
Other Owner's Costs	\$89,924	\$139
Financing Costs	\$16,186	\$25
Total Overnight Costs (TOC)	\$729,917	\$1,125
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$797,541	\$1,229

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-3. Case B32A.1 initial and annual operating and maintenance costs

Case:	B32A.1 – NGCC H-Class (1×1) – Natural Gas w/o CO ₂ capture			Cost Base:	Dec 2018
Plant Size (MW, net):	649	Heat Rate-net (Btu/kWh):	6,068	Capacity Factor (%):	85
Operating & Maintenance Labor					
Operating Labor			Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0
Operating Labor Burden:		30.00	% of base	Operator:	1.0
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0
				Lab Techs, etc.:	1.0
				Total:	4.0
Fixed Operating Costs					
				Annual Cost	
				(\$)	(\$/kW-net)
Annual Operating Labor:				\$1,753,752	\$2.703
Maintenance Labor:				\$4,556,165	\$7.022
Administrative & Support Labor:				\$1,577,479	\$2.431
Property Taxes and Insurance:				\$11,989,907	\$18.480
Total:				\$19,877,303	\$30.636
Variable Operating Costs					
				(\$)	(\$/MWh-net)
Maintenance Material:				\$6,834,247	\$1.415
Consumables					
	Initial Fill	Per Day	Per Unit	Initial Fill	
Water (/1000 gallons):	0	1,678	\$1.90	\$0	\$989,375
Makeup and Waste Water Treatment Chemicals (ton):	0	5.00	\$550	\$0	\$853,139
Ammonia (19 wt%, ton):	0	7.89	\$300	\$0	\$734,727
SCR Catalyst (ft³):	4,252	2.33	\$150	\$637,811	\$108,428
Subtotal:				\$637,811	\$2,685,668
Waste Disposal					
SCR Catalyst (ft³):	0	2.33	\$2.50	\$0	\$1,807
Subtotal:				\$0	\$1,807
Variable Operating Costs Total:				\$637,811	\$9,521,722
Fuel Cost					
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562
Total:				\$0	\$129,568,562

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-4. Case B32B.1.90 total plant cost details

Case:		B32B.1.90	– NGCC H-Class (1×1) – Natural Gas with 90% CO ₂				Estimate Type:			Conceptual	
Plant Size (MW, net):		579	Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,539	\$2,638	\$1,319	\$0	\$5,496	\$1,099	\$0	\$989	\$7,584	\$13
3.2	Water Makeup & Pretreating	\$4,519	\$452	\$2,561	\$0	\$7,531	\$1,506	\$0	\$1,807	\$10,845	\$19
3.3	Other Feedwater Subsystems	\$875	\$287	\$273	\$0	\$1,435	\$287	\$0	\$258	\$1,980	\$3
3.4	Service Water Systems	\$1,355	\$2,587	\$8,375	\$0	\$12,317	\$2,463	\$0	\$2,956	\$17,736	\$31
3.5	Other Boiler Plant Systems	\$232	\$84	\$211	\$0	\$528	\$106	\$0	\$95	\$728	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$23
3.7	Waste Water Treatment Equipment	\$8,836	\$0	\$5,416	\$0	\$14,251	\$2,850	\$0	\$3,420	\$20,522	\$35
3.9	Miscellaneous Plant Equipment	\$13,470	\$1,767	\$6,845	\$0	\$22,082	\$4,416	\$0	\$5,300	\$31,797	\$55
	Subtotal	\$39,882	\$8,204	\$25,292	\$0	\$73,378	\$14,676	\$0	\$16,579	\$104,632	\$181
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$89,060	\$42,276	\$88,780	\$0	\$220,116	\$44,023	\$39,621	\$60,752	\$364,513	\$630
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,266	\$3,790	\$10,482	\$0	\$39,538	\$7,908	\$0	\$9,489	\$56,935	\$98
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$196	\$31	\$84	\$0	\$312	\$62	\$0	\$75	\$449	\$1
5.12	Gas Cleanup Foundations	\$0	\$336	\$363	\$0	\$700	\$140	\$0	\$168	\$1,008	\$2
	Subtotal	\$114,522	\$46,434	\$99,710	\$0	\$260,666	\$52,133	\$39,621	\$70,484	\$422,905	\$731
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$269
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$6
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$5
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$283
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$43,655	\$0	\$10,914	\$0	\$54,569	\$10,914	\$0	\$9,822	\$75,305	\$130
7.2	Heat Recovery Steam Generator Accessories	\$15,117	\$0	\$2,797	\$0	\$17,915	\$3,583	\$0	\$3,225	\$24,722	\$43
7.3	Ductwork	\$0	\$712	\$495	\$0	\$1,207	\$241	\$0	\$217	\$1,666	\$3
7.4	Stack	\$6,811	\$0	\$1,260	\$0	\$8,071	\$1,614	\$0	\$1,453	\$11,138	\$19
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$531	\$498	\$0	\$1,029	\$206	\$0	\$247	\$1,482	\$3
7.6	Selective Catalytic Reduction System	\$1,306	\$549	\$765	\$0	\$2,620	\$524	\$0	\$472	\$3,615	\$6
	Subtotal	\$66,889	\$1,792	\$16,730	\$0	\$85,411	\$17,082	\$0	\$15,436	\$117,928	\$204
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$30,891	\$0	\$4,524	\$0	\$35,414	\$7,083	\$0	\$6,375	\$48,872	\$84
8.2	Steam Turbine Plant Auxiliaries	\$109	\$0	\$250	\$0	\$359	\$72	\$0	\$65	\$495	\$1
8.3	Condenser & Auxiliaries	\$3,833	\$0	\$1,839	\$0	\$5,672	\$1,134	\$0	\$1,021	\$7,827	\$14
8.4	Steam Piping	\$8,638	\$0	\$3,500	\$0	\$12,138	\$2,428	\$0	\$2,185	\$16,751	\$29

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.90 – NGCC H-Class (1×1) – Natural Gas with 90% CO ₂					Estimate Type:		Conceptual		
Plant Size (MW, net):		579	Capture				Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$939	\$1,552	\$0	\$2,491	\$498	\$0	\$598	\$3,587	\$6
	Subtotal	\$43,470	\$939	\$11,664	\$0	\$56,074	\$11,215	\$0	\$10,243	\$77,531	\$134
9 Cooling Water System											
9.1	Cooling Towers	\$9,722	\$0	\$2,966	\$0	\$12,688	\$2,538	\$0	\$2,284	\$17,510	\$30
9.2	Circulating Water Pumps	\$1,274	\$0	\$75	\$0	\$1,348	\$270	\$0	\$243	\$1,861	\$3
9.3	Circulating Water System Auxiliaries	\$9,182	\$0	\$1,211	\$0	\$10,394	\$2,079	\$0	\$1,871	\$14,343	\$25
9.4	Circulating Water Piping	\$0	\$2,660	\$2,409	\$0	\$5,070	\$1,014	\$0	\$913	\$6,996	\$12
9.5	Make-Up Water System	\$335	\$0	\$430	\$0	\$766	\$153	\$0	\$138	\$1,057	\$2
9.6	Component Cooling Water System	\$392	\$0	\$301	\$0	\$693	\$139	\$0	\$125	\$957	\$2
9.7	Circulating Water System Foundations	\$0	\$616	\$1,022	\$0	\$1,637	\$327	\$0	\$393	\$2,358	\$4
	Subtotal	\$20,905	\$3,276	\$8,415	\$0	\$32,596	\$6,519	\$0	\$5,966	\$45,081	\$78
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,320	\$0	\$1,750	\$0	\$4,070	\$814	\$0	\$733	\$5,617	\$10
11.2	Station Service Equipment	\$5,878	\$0	\$504	\$0	\$6,383	\$1,277	\$0	\$1,149	\$8,808	\$15
11.3	Switchgear & Motor Control	\$8,393	\$0	\$1,456	\$0	\$9,850	\$1,970	\$0	\$1,773	\$13,593	\$23
11.4	Conduit & Cable Tray	\$0	\$2,028	\$5,845	\$0	\$7,874	\$1,575	\$0	\$1,417	\$10,865	\$19
11.5	Wire & Cable	\$0	\$3,028	\$5,412	\$0	\$8,441	\$1,688	\$0	\$1,519	\$11,648	\$20
11.6	Protective Equipment	\$229	\$0	\$797	\$0	\$1,027	\$205	\$0	\$185	\$1,417	\$2
11.7	Standby Equipment	\$598	\$0	\$552	\$0	\$1,150	\$230	\$0	\$207	\$1,587	\$3
11.8	Main Power Transformers	\$7,755	\$0	\$158	\$0	\$7,914	\$1,583	\$0	\$1,424	\$10,921	\$19
11.9	Electrical Foundations	\$0	\$83	\$210	\$0	\$293	\$59	\$0	\$70	\$422	\$1
	Subtotal	\$25,175	\$5,139	\$16,686	\$0	\$47,000	\$9,400	\$0	\$8,478	\$64,878	\$112
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$355	\$0	\$226	\$0	\$581	\$116	\$0	\$104	\$801	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$568	\$0	\$362	\$0	\$930	\$186	\$0	\$167	\$1,284	\$2
12.4	Other Major Component Control Equipment	\$960	\$0	\$611	\$0	\$1,571	\$314	\$79	\$295	\$2,258	\$4
12.5	Signal Processing Equipment	\$795	\$0	\$24	\$0	\$819	\$164	\$0	\$147	\$1,131	\$2
12.6	Control Boards, Panels & Racks	\$212	\$0	\$129	\$0	\$341	\$68	\$17	\$64	\$491	\$1
12.7	Distributed Control System Equipment	\$11,762	\$0	\$358	\$0	\$12,120	\$2,424	\$606	\$2,273	\$17,423	\$30
12.8	Instrument Wiring & Tubing	\$971	\$777	\$3,107	\$0	\$4,855	\$971	\$243	\$910	\$6,979	\$12
12.9	Other Instrumentation & Controls Equipment	\$672	\$0	\$1,558	\$0	\$2,230	\$446	\$111	\$418	\$3,206	\$6
	Subtotal	\$16,677	\$777	\$6,618	\$0	\$24,072	\$4,814	\$1,056	\$4,491	\$34,434	\$59
13 Improvements to Site											
13.1	Site Preparation	\$0	\$702	\$14,905	\$0	\$15,607	\$3,121	\$0	\$3,746	\$22,474	\$39
13.2	Site Improvements	\$0	\$2,259	\$2,983	\$0	\$5,241	\$1,048	\$0	\$1,258	\$7,548	\$13
13.3	Site Facilities	\$2,167	\$0	\$2,273	\$0	\$4,440	\$888	\$0	\$1,066	\$6,394	\$11
	Subtotal	\$2,167	\$2,961	\$20,161	\$0	\$25,289	\$5,058	\$0	\$6,069	\$36,416	\$63

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.90	– NGCC H-Class (1×1) – Natural Gas with 90% CO ₂				Estimate Type:			Conceptual	
Plant Size (MW, net):		579	Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$2,753	\$3,662	\$0	\$6,414	\$1,283	\$0	\$1,155	\$8,851	\$15
14.4	Administration Building	\$0	\$347	\$235	\$0	\$583	\$117	\$0	\$105	\$804	\$1
14.5	Circulation Water Pumphouse	\$0	\$67	\$33	\$0	\$101	\$20	\$0	\$18	\$139	\$0
14.6	Water Treatment Buildings	\$0	\$369	\$337	\$0	\$706	\$141	\$0	\$127	\$974	\$2
14.7	Machine Shop	\$0	\$521	\$333	\$0	\$855	\$171	\$0	\$154	\$1,179	\$2
14.8	Warehouse	\$0	\$403	\$243	\$0	\$646	\$129	\$0	\$116	\$892	\$2
14.9	Other Buildings & Structures	\$0	\$286	\$208	\$0	\$495	\$99	\$0	\$89	\$683	\$1
14.10	Waste Treating Building & Structures	\$0	\$1,214	\$2,164	\$0	\$3,377	\$675	\$0	\$608	\$4,660	\$8
	Subtotal	\$0	\$6,354	\$7,423	\$0	\$13,777	\$2,755	\$0	\$2,480	\$19,013	\$33
	Total	\$438,530	\$77,676	\$220,547	\$0	\$736,753	\$147,351	\$40,677	\$161,673	\$1,086,453	\$1,877

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-5. Case B32B.1.90 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,622	\$11
1 Month Maintenance Materials	\$1,214	\$2
1 Month Non-fuel Consumables	\$538	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,176	\$5
2% of TPC	\$21,729	\$38
Total	\$33,281	\$57
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$765	\$1
0.5% of TPC (spare parts)	\$5,432	\$9
Total	\$6,197	\$11
Other Costs		
Initial Cost for Catalyst and Chemicals	\$638	\$1
Land	\$300	\$1
Other Owner's Costs	\$162,968	\$282
Financing Costs	\$29,334	\$51
Total Overnight Costs (TOC)	\$1,319,171	\$2,279
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,441,389	\$2,490

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-6. Case B32B.1.90 initial and annual operating and maintenance costs

Case:	B32B.1.90	– NGCC H-Class (1×1) – Natural Gas with 90% CO2 Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	579	Heat Rate-net (Btu/kWh):	6,801		Capacity Factor (%):	85
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0	
Operating Labor Burden:		30.00	% of base	Operator:	2.3	
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0	
				Lab Techs, etc.:	1.0	
				Total:	5.3	
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$4.039
Maintenance Labor:					\$8,257,046	\$14.265
Administrative & Support Labor:					\$2,648,809	\$4.576
Property Taxes and Insurance:					\$21,729,068	\$37.539
Total:					\$34,973,112	\$60.420
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$12,385,569	\$2.874
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,694	\$1.90	\$0	\$1,588,299	\$0.369
Makeup and Waste Water Treatment Chemicals (ton):	0	8.03	\$550	\$0	\$1,369,592	\$0.318
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,408	\$0.171
SCR Catalyst (ft³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO2 Capture System Chemicals^:	Proprietary				\$1,675,586	\$0.389
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$7,969	\$0.002
Subtotal:				\$637,811	\$5,488,282	\$1.273
Waste Disposal						
SCR Catalyst (ft³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$410	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.49	\$38.0	\$0	\$17,562	\$0.004
Subtotal:				\$0	\$19,779	\$0.005
Variable Operating Costs Total:				\$637,811	\$17,893,630	\$4.152
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$30.062
Total:				\$0	\$129,568,562	\$30.062

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-7. Case B32B.1.95 total plant cost details

Case:		B32B.1.95	– NGCC H-Class (1×1) – Natural Gas with 95% CO ₂				Estimate Type:			Conceptual	
Plant Size (MW, net):		575	Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,539	\$2,638	\$1,319	\$0	\$5,496	\$1,099	\$0	\$989	\$7,584	\$13
3.2	Water Makeup & Pretreating	\$4,544	\$454	\$2,575	\$0	\$7,574	\$1,515	\$0	\$1,818	\$10,906	\$19
3.3	Other Feedwater Subsystems	\$875	\$287	\$273	\$0	\$1,435	\$287	\$0	\$258	\$1,980	\$3
3.4	Service Water Systems	\$1,362	\$2,599	\$8,417	\$0	\$12,377	\$2,475	\$0	\$2,971	\$17,823	\$31
3.5	Other Boiler Plant Systems	\$232	\$84	\$211	\$0	\$528	\$106	\$0	\$95	\$728	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$23
3.7	Waste Water Treatment Equipment	\$8,904	\$0	\$5,457	\$0	\$14,362	\$2,872	\$0	\$3,447	\$20,681	\$36
3.9	Miscellaneous Plant Equipment	\$13,470	\$1,767	\$6,845	\$0	\$22,082	\$4,416	\$0	\$5,300	\$31,797	\$55
	Subtotal	\$39,983	\$8,219	\$25,389	\$0	\$73,591	\$14,718	\$0	\$16,630	\$104,939	\$183
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$92,966	\$43,833	\$92,049	\$0	\$228,848	\$45,770	\$41,193	\$63,162	\$378,972	\$659
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,828	\$3,874	\$10,715	\$0	\$40,418	\$8,084	\$0	\$9,700	\$58,202	\$101
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$205	\$33	\$88	\$0	\$326	\$65	\$0	\$78	\$469	\$1
5.12	Gas Cleanup Foundations	\$0	\$351	\$379	\$0	\$730	\$146	\$0	\$175	\$1,052	\$2
	Subtotal	\$119,000	\$48,091	\$103,231	\$0	\$270,322	\$54,064	\$41,193	\$73,116	\$438,695	\$763
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$271
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$7
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$5
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$285
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$43,611	\$0	\$10,903	\$0	\$54,514	\$10,903	\$0	\$9,813	\$75,230	\$131
7.2	Heat Recovery Steam Generator Accessories	\$15,102	\$0	\$2,795	\$0	\$17,897	\$3,579	\$0	\$3,221	\$24,697	\$43
7.3	Ductwork	\$0	\$711	\$494	\$0	\$1,205	\$241	\$0	\$217	\$1,662	\$3
7.4	Stack	\$6,798	\$0	\$1,258	\$0	\$8,056	\$1,611	\$0	\$1,450	\$11,117	\$19
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$530	\$497	\$0	\$1,027	\$205	\$0	\$247	\$1,479	\$3
7.6	Selective Catalytic Reduction System	\$1,306	\$549	\$765	\$0	\$2,620	\$524	\$0	\$472	\$3,615	\$6
	Subtotal	\$66,817	\$1,789	\$16,712	\$0	\$85,319	\$17,064	\$0	\$15,419	\$117,802	\$205
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$30,570	\$0	\$4,477	\$0	\$35,046	\$7,009	\$0	\$6,308	\$48,364	\$84
8.2	Steam Turbine Plant Auxiliaries	\$108	\$0	\$247	\$0	\$356	\$71	\$0	\$64	\$491	\$1
8.3	Condenser & Auxiliaries	\$3,714	\$0	\$1,782	\$0	\$5,496	\$1,099	\$0	\$989	\$7,585	\$13
8.4	Steam Piping	\$8,638	\$0	\$3,500	\$0	\$12,138	\$2,428	\$0	\$2,185	\$16,751	\$29

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.95 – NGCC H-Class (1×1) – Natural Gas with 95% CO ₂					Estimate Type:		Conceptual		
Plant Size (MW, net):		575	Capture				Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$930	\$1,537	\$0	\$2,467	\$493	\$0	\$592	\$3,553	\$6
	Subtotal	\$43,030	\$930	\$11,543	\$0	\$55,503	\$11,101	\$0	\$10,139	\$76,743	\$133
9											
Cooling Water System											
9.1	Cooling Towers	\$9,770	\$0	\$2,981	\$0	\$12,751	\$2,550	\$0	\$2,295	\$17,596	\$31
9.2	Circulating Water Pumps	\$1,280	\$0	\$75	\$0	\$1,355	\$271	\$0	\$244	\$1,870	\$3
9.3	Circulating Water System Auxiliaries	\$9,213	\$0	\$1,216	\$0	\$10,429	\$2,086	\$0	\$1,877	\$14,392	\$25
9.4	Circulating Water Piping	\$0	\$2,671	\$2,419	\$0	\$5,091	\$1,018	\$0	\$916	\$7,025	\$12
9.5	Make-Up Water System	\$336	\$0	\$432	\$0	\$768	\$154	\$0	\$138	\$1,060	\$2
9.6	Component Cooling Water System	\$394	\$0	\$302	\$0	\$696	\$139	\$0	\$125	\$961	\$2
9.7	Circulating Water System Foundations	\$0	\$618	\$1,026	\$0	\$1,644	\$329	\$0	\$395	\$2,368	\$4
	Subtotal	\$20,993	\$3,290	\$8,451	\$0	\$32,734	\$6,547	\$0	\$5,991	\$45,271	\$79
11											
Accessory Electric Plant											
11.1	Generator Equipment	\$2,315	\$0	\$1,746	\$0	\$4,061	\$812	\$0	\$731	\$5,605	\$10
11.2	Station Service Equipment	\$6,034	\$0	\$518	\$0	\$6,551	\$1,310	\$0	\$1,179	\$9,041	\$16
11.3	Switchgear & Motor Control	\$8,615	\$0	\$1,495	\$0	\$10,110	\$2,022	\$0	\$1,820	\$13,951	\$24
11.4	Conduit & Cable Tray	\$0	\$2,082	\$5,999	\$0	\$8,081	\$1,616	\$0	\$1,455	\$11,152	\$19
11.5	Wire & Cable	\$0	\$3,108	\$5,555	\$0	\$8,663	\$1,733	\$0	\$1,559	\$11,955	\$21
11.6	Protective Equipment	\$236	\$0	\$818	\$0	\$1,054	\$211	\$0	\$190	\$1,454	\$3
11.7	Standby Equipment	\$597	\$0	\$551	\$0	\$1,148	\$230	\$0	\$207	\$1,584	\$3
11.8	Main Power Transformers	\$7,735	\$0	\$158	\$0	\$7,893	\$1,579	\$0	\$1,421	\$10,892	\$19
11.9	Electrical Foundations	\$0	\$83	\$210	\$0	\$292	\$58	\$0	\$70	\$421	\$1
	Subtotal	\$25,531	\$5,272	\$17,050	\$0	\$47,853	\$9,571	\$0	\$8,631	\$66,055	\$115
12											
Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$363	\$0	\$231	\$0	\$595	\$119	\$0	\$107	\$821	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$582	\$0	\$371	\$0	\$953	\$191	\$0	\$172	\$1,315	\$2
12.4	Other Major Component Control Equipment	\$984	\$0	\$626	\$0	\$1,610	\$322	\$80	\$302	\$2,314	\$4
12.5	Signal Processing Equipment	\$815	\$0	\$25	\$0	\$839	\$168	\$0	\$151	\$1,158	\$2
12.6	Control Boards, Panels & Racks	\$217	\$0	\$132	\$0	\$350	\$70	\$17	\$66	\$503	\$1
12.7	Distributed Control System Equipment	\$12,053	\$0	\$367	\$0	\$12,420	\$2,484	\$621	\$2,329	\$17,854	\$31
12.8	Instrument Wiring & Tubing	\$995	\$796	\$3,184	\$0	\$4,975	\$995	\$249	\$933	\$7,152	\$12
12.9	Other Instrumentation & Controls Equipment	\$689	\$0	\$1,596	\$0	\$2,285	\$457	\$114	\$428	\$3,285	\$6
	Subtotal	\$17,080	\$796	\$6,776	\$0	\$24,652	\$4,930	\$1,082	\$4,600	\$35,264	\$61
13											
Improvements to Site											
13.1	Site Preparation	\$0	\$707	\$15,010	\$0	\$15,718	\$3,144	\$0	\$3,772	\$22,633	\$39
13.2	Site Improvements	\$0	\$2,275	\$3,004	\$0	\$5,279	\$1,056	\$0	\$1,267	\$7,601	\$13
13.3	Site Facilities	\$2,182	\$0	\$2,290	\$0	\$4,472	\$894	\$0	\$1,073	\$6,439	\$11
	Subtotal	\$2,182	\$2,982	\$20,304	\$0	\$25,468	\$5,094	\$0	\$6,112	\$36,674	\$64

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.95	– NGCC H-Class (1×1) – Natural Gas with 95% CO ₂				Estimate Type:			Conceptual		
Plant Size (MW, net):		575	Capture					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost		
				Direct	Indirect			Process	Project	\$/1,000	\$/kW	
14		Buildings & Structures										
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1	
14.3	Steam Turbine Building	\$0	\$2,731	\$3,633	\$0	\$6,364	\$1,273	\$0	\$1,146	\$8,782	\$15	
14.4	Administration Building	\$0	\$347	\$235	\$0	\$582	\$116	\$0	\$105	\$803	\$1	
14.5	Circulation Water Pumphouse	\$0	\$68	\$34	\$0	\$101	\$20	\$0	\$18	\$140	\$0	
14.6	Water Treatment Buildings	\$0	\$371	\$338	\$0	\$710	\$142	\$0	\$128	\$979	\$2	
14.7	Machine Shop	\$0	\$521	\$333	\$0	\$854	\$171	\$0	\$154	\$1,178	\$2	
14.8	Warehouse	\$0	\$402	\$243	\$0	\$645	\$129	\$0	\$116	\$890	\$2	
14.9	Other Buildings & Structures	\$0	\$286	\$208	\$0	\$494	\$99	\$0	\$89	\$682	\$1	
14.10	Waste Treating Building & Structures	\$0	\$1,223	\$2,180	\$0	\$3,403	\$681	\$0	\$613	\$4,697	\$8	
	Subtotal	\$0	\$6,343	\$7,412	\$0	\$13,754	\$2,751	\$0	\$2,476	\$18,981	\$33	
	Total	\$443,458	\$79,512	\$224,716	\$0	\$747,686	\$149,537	\$42,275	\$164,561	\$1,104,059	\$1,921	

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-8. Case B32B.1.95 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,706	\$12
1 Month Maintenance Materials	\$1,234	\$2
1 Month Non-fuel Consumables	\$548	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,176	\$6
2% of TPC	\$22,081	\$38
Total	\$33,746	\$59
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$781	\$1
0.5% of TPC (spare parts)	\$5,520	\$10
Total	\$6,302	\$11
Other Costs		
Initial Cost for Catalyst and Chemicals	\$638	\$1
Land	\$300	\$1
Other Owner's Costs	\$165,609	\$288
Financing Costs	\$29,810	\$52
Total Overnight Costs (TOC)	\$1,340,462	\$2,332
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,464,652	\$2,548

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-9. Case B32B.1.95 initial and annual operating and maintenance costs

Case:	B32B.1.95	– NGCC H-Class (1×1) – Natural Gas with 95% CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	575	Heat Rate-net (Btu/kWh):	6,848		Capacity Factor (%):	85
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0	
Operating Labor Burden:		30.00	% of base	Operator:	2.3	
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0	
				Lab Techs, etc.:	1.0	
				Total:	5.3	
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$4.067
Maintenance Labor:					\$8,390,846	\$14.596
Administrative & Support Labor:					\$2,682,259	\$4.666
Property Taxes and Insurance:					\$22,081,173	\$38.410
Total:					\$35,492,467	\$61.739
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$12,586,269	\$2.940
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,716	\$1.90	\$0	\$1,600,897	\$0.374
Makeup and Waste Water Treatment Chemicals (ton):	0	8.09	\$550	\$0	\$1,380,455	\$0.322
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,509	\$0.173
SCR Catalyst (ft³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO ₂ Capture System Chemicals^:	Proprietary				\$1,748,781	\$0.409
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,411	\$0.002
Subtotal:				\$637,811	\$5,585,481	\$1.305
Waste Disposal						
SCR Catalyst (ft³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$433	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.56	\$38.0	\$0	\$18,361	\$0.004
Subtotal:				\$0	\$20,601	\$0.005
Variable Operating Costs Total:				\$637,811	\$18,192,351	\$4.250
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$30.269
Total:				\$0	\$129,568,562	\$30.269

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-10. Case B32B.1.97 total plant cost details

Case:		B32B.1.97	– NGCC H-Class (1×1) – Natural Gas with 97% CO ₂				Estimate Type:			Conceptual	
Plant Size (MW, net):		572	Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,539	\$2,638	\$1,319	\$0	\$5,496	\$1,099	\$0	\$989	\$7,584	\$13
3.2	Water Makeup & Pretreating	\$4,565	\$456	\$2,587	\$0	\$7,608	\$1,522	\$0	\$1,826	\$10,955	\$19
3.3	Other Feedwater Subsystems	\$875	\$287	\$273	\$0	\$1,435	\$287	\$0	\$258	\$1,980	\$3
3.4	Service Water Systems	\$1,367	\$2,609	\$8,449	\$0	\$12,425	\$2,485	\$0	\$2,982	\$17,892	\$31
3.5	Other Boiler Plant Systems	\$232	\$84	\$211	\$0	\$528	\$106	\$0	\$95	\$728	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$23
3.7	Waste Water Treatment Equipment	\$8,854	\$0	\$5,426	\$0	\$14,280	\$2,856	\$0	\$3,427	\$20,563	\$36
3.9	Miscellaneous Plant Equipment	\$13,470	\$1,767	\$6,845	\$0	\$22,082	\$4,416	\$0	\$5,300	\$31,797	\$56
	Subtotal	\$39,958	\$8,231	\$25,402	\$0	\$73,591	\$14,718	\$0	\$16,630	\$104,940	\$183
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$95,217	\$44,913	\$94,317	\$0	\$234,446	\$46,889	\$42,200	\$64,707	\$388,243	\$679
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$26,051	\$3,908	\$10,807	\$0	\$40,766	\$8,153	\$0	\$9,784	\$58,703	\$103
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$209	\$33	\$90	\$0	\$332	\$66	\$0	\$80	\$478	\$1
5.12	Gas Cleanup Foundations	\$0	\$357	\$386	\$0	\$742	\$148	\$0	\$178	\$1,069	\$2
	Subtotal	\$121,476	\$49,211	\$105,599	\$0	\$276,286	\$55,257	\$42,200	\$74,749	\$448,493	\$784
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$272
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$7
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$5
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$286
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$43,572	\$0	\$10,893	\$0	\$54,465	\$10,893	\$0	\$9,804	\$75,161	\$131
7.2	Heat Recovery Steam Generator Accessories	\$15,088	\$0	\$2,792	\$0	\$17,881	\$3,576	\$0	\$3,218	\$24,675	\$43
7.3	Ductwork	\$0	\$714	\$496	\$0	\$1,209	\$242	\$0	\$218	\$1,669	\$3
7.4	Stack	\$6,824	\$0	\$1,263	\$0	\$8,087	\$1,617	\$0	\$1,456	\$11,160	\$20
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$532	\$499	\$0	\$1,031	\$206	\$0	\$247	\$1,485	\$3
7.6	Selective Catalytic Reduction System	\$1,306	\$549	\$765	\$0	\$2,620	\$524	\$0	\$472	\$3,615	\$6
	Subtotal	\$66,790	\$1,794	\$16,708	\$0	\$85,293	\$17,059	\$0	\$15,415	\$117,766	\$206
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$30,290	\$0	\$4,436	\$0	\$34,725	\$6,945	\$0	\$6,251	\$47,921	\$84
8.2	Steam Turbine Plant Auxiliaries	\$107	\$0	\$245	\$0	\$353	\$71	\$0	\$63	\$487	\$1
8.3	Condenser & Auxiliaries	\$3,606	\$0	\$1,730	\$0	\$5,336	\$1,067	\$0	\$961	\$7,364	\$13
8.4	Steam Piping	\$8,638	\$0	\$3,500	\$0	\$12,138	\$2,428	\$0	\$2,185	\$16,751	\$29

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.97 – NGCC H-Class (1×1) – Natural Gas with 97% CO ₂					Estimate Type:		Conceptual		
Plant Size (MW, net):		572	Capture				Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$923	\$1,524	\$0	\$2,447	\$489	\$0	\$587	\$3,523	\$6
	Subtotal	\$42,641	\$923	\$11,435	\$0	\$54,999	\$11,000	\$0	\$10,047	\$76,045	\$133
9											
Cooling Water System											
9.1	Cooling Towers	\$9,808	\$0	\$2,992	\$0	\$12,800	\$2,560	\$0	\$2,304	\$17,664	\$31
9.2	Circulating Water Pumps	\$1,285	\$0	\$76	\$0	\$1,360	\$272	\$0	\$245	\$1,877	\$3
9.3	Circulating Water System Auxiliaries	\$9,238	\$0	\$1,219	\$0	\$10,457	\$2,091	\$0	\$1,882	\$14,430	\$25
9.4	Circulating Water Piping	\$0	\$2,680	\$2,427	\$0	\$5,107	\$1,021	\$0	\$919	\$7,048	\$12
9.5	Make-Up Water System	\$337	\$0	\$433	\$0	\$770	\$154	\$0	\$139	\$1,063	\$2
9.6	Component Cooling Water System	\$395	\$0	\$303	\$0	\$698	\$140	\$0	\$126	\$964	\$2
9.7	Circulating Water System Foundations	\$0	\$620	\$1,030	\$0	\$1,650	\$330	\$0	\$396	\$2,376	\$4
	Subtotal	\$21,063	\$3,300	\$8,479	\$0	\$32,843	\$6,569	\$0	\$6,011	\$45,422	\$79
11											
Accessory Electric Plant											
11.1	Generator Equipment	\$2,311	\$0	\$1,743	\$0	\$4,054	\$811	\$0	\$730	\$5,594	\$10
11.2	Station Service Equipment	\$6,123	\$0	\$525	\$0	\$6,648	\$1,330	\$0	\$1,197	\$9,175	\$16
11.3	Switchgear & Motor Control	\$8,743	\$0	\$1,517	\$0	\$10,260	\$2,052	\$0	\$1,847	\$14,158	\$25
11.4	Conduit & Cable Tray	\$0	\$2,113	\$6,089	\$0	\$8,201	\$1,640	\$0	\$1,476	\$11,318	\$20
11.5	Wire & Cable	\$0	\$3,154	\$5,638	\$0	\$8,792	\$1,758	\$0	\$1,583	\$12,133	\$21
11.6	Protective Equipment	\$239	\$0	\$830	\$0	\$1,069	\$214	\$0	\$192	\$1,476	\$3
11.7	Standby Equipment	\$596	\$0	\$550	\$0	\$1,146	\$229	\$0	\$206	\$1,582	\$3
11.8	Main Power Transformers	\$7,716	\$0	\$157	\$0	\$7,874	\$1,575	\$0	\$1,417	\$10,866	\$19
11.9	Electrical Foundations	\$0	\$82	\$209	\$0	\$292	\$58	\$0	\$70	\$420	\$1
	Subtotal	\$25,728	\$5,349	\$17,259	\$0	\$48,336	\$9,667	\$0	\$8,718	\$66,721	\$117
12											
Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$369	\$0	\$235	\$0	\$603	\$121	\$0	\$109	\$832	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$2
12.3	Steam Turbine Control Equipment	\$590	\$0	\$376	\$0	\$966	\$193	\$0	\$174	\$1,334	\$2
12.4	Other Major Component Control Equipment	\$997	\$0	\$635	\$0	\$1,632	\$326	\$82	\$306	\$2,346	\$4
12.5	Signal Processing Equipment	\$826	\$0	\$25	\$0	\$851	\$170	\$0	\$153	\$1,175	\$2
12.6	Control Boards, Panels & Racks	\$220	\$0	\$134	\$0	\$355	\$71	\$18	\$66	\$510	\$1
12.7	Distributed Control System Equipment	\$12,221	\$0	\$372	\$0	\$12,593	\$2,519	\$630	\$2,361	\$18,102	\$32
12.8	Instrument Wiring & Tubing	\$1,009	\$807	\$3,228	\$0	\$5,044	\$1,009	\$252	\$946	\$7,251	\$13
12.9	Other Instrumentation & Controls Equipment	\$699	\$0	\$1,618	\$0	\$2,317	\$463	\$116	\$434	\$3,331	\$6
	Subtotal	\$17,313	\$807	\$6,867	\$0	\$24,986	\$4,997	\$1,097	\$4,662	\$35,743	\$62
13											
Improvements to Site											
13.1	Site Preparation	\$0	\$710	\$15,072	\$0	\$15,782	\$3,156	\$0	\$3,788	\$22,726	\$40
13.2	Site Improvements	\$0	\$2,284	\$3,016	\$0	\$5,300	\$1,060	\$0	\$1,272	\$7,632	\$13
13.3	Site Facilities	\$2,191	\$0	\$2,299	\$0	\$4,490	\$898	\$0	\$1,078	\$6,466	\$11
	Subtotal	\$2,191	\$2,994	\$20,387	\$0	\$25,573	\$5,115	\$0	\$6,137	\$36,825	\$64

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32B.1.97	– NGCC H-Class (1×1) – Natural Gas with 97% CO ₂				Estimate Type:			Conceptual		
Plant Size (MW, net):		572	Capture					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost		
				Direct	Indirect			Process	Project	\$/1,000	\$/kW	
14		Buildings & Structures										
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1	
14.3	Steam Turbine Building	\$0	\$2,712	\$3,608	\$0	\$6,320	\$1,264	\$0	\$1,138	\$8,722	\$15	
14.4	Administration Building	\$0	\$346	\$235	\$0	\$581	\$116	\$0	\$105	\$802	\$1	
14.5	Circulation Water Pumphouse	\$0	\$68	\$34	\$0	\$102	\$20	\$0	\$18	\$141	\$0	
14.6	Water Treatment Buildings	\$0	\$373	\$340	\$0	\$713	\$143	\$0	\$128	\$983	\$2	
14.7	Machine Shop	\$0	\$520	\$332	\$0	\$853	\$171	\$0	\$153	\$1,177	\$2	
14.8	Warehouse	\$0	\$402	\$243	\$0	\$644	\$129	\$0	\$116	\$889	\$2	
14.9	Other Buildings & Structures	\$0	\$286	\$208	\$0	\$493	\$99	\$0	\$89	\$681	\$1	
14.10	Waste Treating Building & Structures	\$0	\$1,216	\$2,168	\$0	\$3,384	\$677	\$0	\$609	\$4,670	\$8	
	Subtotal	\$0	\$6,317	\$7,375	\$0	\$13,692	\$2,738	\$0	\$2,465	\$18,895	\$33	
	Total	\$446,002	\$80,726	\$227,360	\$0	\$754,088	\$150,818	\$43,297	\$166,280	\$1,114,483	\$1,949	

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-11. Case B32B.1.97 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,755	\$12
1 Month Maintenance Materials	\$1,246	\$2
1 Month Non-fuel Consumables	\$557	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,176	\$6
2% of TPC	\$22,290	\$39
Total	\$34,025	\$59
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$797	\$1
0.5% of TPC (spare parts)	\$5,572	\$10
Total	\$6,370	\$11
Other Costs		
Initial Cost for Catalyst and Chemicals	\$638	\$1
Land	\$300	\$1
Other Owner's Costs	\$167,173	\$292
Financing Costs	\$30,091	\$53
Total Overnight Costs (TOC)	\$1,353,080	\$2,366
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,478,438	\$2,585

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-12. Case B32B.1.97 initial and annual operating and maintenance costs

Case:	B32B.1.97	– NGCC H-Class (1×1) – Natural Gas with 97% CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	572	Heat Rate-net (Btu/kWh):	6,884		Capacity Factor (%):	85
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0	
Operating Labor Burden:		30.00	% of base	Operator:	2.3	
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0	
				Lab Techs, etc.:	1.0	
				Total:	5.3	
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$4.088
Maintenance Labor:					\$8,470,074	\$14.810
Administrative & Support Labor:					\$2,702,066	\$4.725
Property Taxes and Insurance:					\$22,289,669	\$38.974
Total:					\$35,799,999	\$62.598
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$12,705,111	\$2.984
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,733	\$1.90	\$0	\$1,611,097	\$0.378
Makeup and Waste Water Treatment Chemicals (ton):	0	8.14	\$550	\$0	\$1,389,251	\$0.326
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,423	\$0.173
SCR Catalyst (ft³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,822,394	\$0.428
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,589	\$0.002
Subtotal:				\$637,811	\$5,678,181	\$1.333
Waste Disposal						
SCR Catalyst (ft³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$442	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.63	\$38.0	\$0	\$19,159	\$0.004
Subtotal:				\$0	\$21,408	\$0.005
Variable Operating Costs Total:				\$637,811	\$18,404,700	\$4.322
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$30.427
Total:				\$0	\$129,568,562	\$30.427

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

A.2 X-CLASS COST ESTIMATING

Exhibit A-13. Case B3XA.1 total plant cost details

Case:		B3XA.1	– NGCC X-Class (1×1) – Natural Gas w/o CO ₂ Capture				Estimate Type:			Conceptual	
Plant Size (MW, net):		780					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,806	\$3,096	\$1,548	\$0	\$6,451	\$1,290	\$0	\$1,161	\$8,902	\$11
3.2	Water Makeup & Pretreating	\$3,612	\$361	\$2,047	\$0	\$6,019	\$1,204	\$0	\$1,445	\$8,668	\$11
3.3	Other Feedwater Subsystems	\$1,028	\$337	\$320	\$0	\$1,684	\$337	\$0	\$303	\$2,325	\$3
3.4	Service Water Systems	\$1,099	\$2,097	\$6,792	\$0	\$9,988	\$1,998	\$0	\$2,397	\$14,382	\$18
3.5	Other Boiler Plant Systems	\$273	\$99	\$248	\$0	\$619	\$124	\$0	\$111	\$855	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$17
3.7	Waste Water Treatment Equipment	\$5,154	\$0	\$3,159	\$0	\$8,312	\$1,662	\$0	\$1,995	\$11,970	\$15
3.9	Miscellaneous Plant Equipment	\$15,328	\$2,010	\$7,789	\$0	\$25,127	\$5,025	\$0	\$6,031	\$36,183	\$46
	Subtotal	\$37,354	\$8,391	\$22,194	\$0	\$67,939	\$13,588	\$0	\$15,196	\$96,723	\$124
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$199
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$5
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$4
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$210
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$50,187	\$0	\$12,547	\$0	\$62,734	\$12,547	\$0	\$11,292	\$86,573	\$111
7.2	Heat Recovery Steam Generator Accessories	\$17,379	\$0	\$3,216	\$0	\$20,595	\$4,119	\$0	\$3,707	\$28,421	\$36
7.3	Ductwork	\$0	\$836	\$581	\$0	\$1,416	\$283	\$0	\$255	\$1,954	\$3
7.4	Stack	\$7,991	\$0	\$1,479	\$0	\$9,470	\$1,894	\$0	\$1,705	\$13,068	\$17
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$623	\$585	\$0	\$1,208	\$242	\$0	\$290	\$1,739	\$2
7.6	Selective Catalytic Reduction System	\$1,320	\$555	\$773	\$0	\$2,647	\$529	\$0	\$477	\$3,653	\$5
	Subtotal	\$76,877	\$2,013	\$19,180	\$0	\$98,070	\$19,614	\$0	\$17,725	\$135,409	\$174
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$42,514	\$0	\$6,226	\$0	\$48,740	\$9,748	\$0	\$8,773	\$67,262	\$86
8.2	Steam Turbine Plant Auxiliaries	\$146	\$0	\$334	\$0	\$480	\$96	\$0	\$86	\$663	\$1
8.3	Condenser & Auxiliaries	\$6,665	\$0	\$3,198	\$0	\$9,863	\$1,973	\$0	\$1,775	\$13,611	\$17
8.4	Steam Piping	\$10,399	\$0	\$4,214	\$0	\$14,613	\$2,923	\$0	\$2,630	\$20,165	\$26
8.5	Turbine Generator Foundations	\$0	\$1,257	\$2,077	\$0	\$3,334	\$667	\$0	\$800	\$4,800	\$6
	Subtotal	\$59,725	\$1,257	\$16,048	\$0	\$77,030	\$15,406	\$0	\$14,065	\$106,501	\$136
9 Cooling Water System											
9.1	Cooling Towers	\$7,884	\$0	\$2,405	\$0	\$10,289	\$2,058	\$0	\$1,852	\$14,199	\$18
9.2	Circulating Water Pumps	\$1,030	\$0	\$61	\$0	\$1,090	\$218	\$0	\$196	\$1,504	\$2

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XA.1 – NGCC X-Class (1×1) – Natural Gas w/o CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		780					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
9.3	Circulating Water System Auxiliaries	\$7,946	\$0	\$1,048	\$0	\$8,994	\$1,799	\$0	\$1,619	\$12,412	\$16
9.4	Circulating Water Piping	\$0	\$2,229	\$2,018	\$0	\$4,247	\$849	\$0	\$764	\$5,860	\$8
9.5	Make-Up Water System	\$296	\$0	\$379	\$0	\$675	\$135	\$0	\$121	\$931	\$1
9.6	Component Cooling Water System	\$328	\$0	\$252	\$0	\$581	\$116	\$0	\$105	\$801	\$1
9.7	Circulating Water System Foundations	\$0	\$516	\$856	\$0	\$1,372	\$274	\$0	\$329	\$1,975	\$3
	Subtotal	\$17,483	\$2,744	\$7,020	\$0	\$27,247	\$5,449	\$0	\$4,987	\$37,683	\$48
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,686	\$0	\$2,027	\$0	\$4,713	\$943	\$0	\$848	\$6,504	\$8
11.2	Station Service Equipment	\$2,873	\$0	\$246	\$0	\$3,119	\$624	\$0	\$561	\$4,305	\$6
11.3	Switchgear & Motor Control	\$4,102	\$0	\$712	\$0	\$4,814	\$963	\$0	\$866	\$6,643	\$9
11.4	Conduit & Cable Tray	\$0	\$991	\$2,857	\$0	\$3,848	\$770	\$0	\$693	\$5,310	\$7
11.5	Wire & Cable	\$0	\$1,480	\$2,645	\$0	\$4,125	\$825	\$0	\$742	\$5,692	\$7
11.6	Protective Equipment	\$112	\$0	\$390	\$0	\$502	\$100	\$0	\$90	\$692	\$1
11.7	Standby Equipment	\$674	\$0	\$622	\$0	\$1,296	\$259	\$0	\$233	\$1,788	\$2
11.8	Main Power Transformers	\$9,268	\$0	\$189	\$0	\$9,457	\$1,891	\$0	\$1,702	\$13,050	\$17
11.9	Electrical Foundations	\$0	\$98	\$250	\$0	\$349	\$70	\$0	\$84	\$502	\$1
	Subtotal	\$19,715	\$2,569	\$9,937	\$0	\$32,222	\$6,444	\$0	\$5,821	\$44,487	\$57
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$181	\$0	\$115	\$0	\$297	\$59	\$0	\$53	\$409	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$290	\$0	\$185	\$0	\$475	\$95	\$0	\$86	\$656	\$1
12.4	Other Major Component Control Equipment	\$491	\$0	\$312	\$0	\$803	\$161	\$0	\$145	\$1,108	\$1
12.5	Signal Processing Equipment	\$406	\$0	\$12	\$0	\$419	\$84	\$0	\$75	\$578	\$1
12.6	Control Boards, Panels & Racks	\$108	\$0	\$66	\$0	\$174	\$35	\$0	\$31	\$241	\$0
12.7	Distributed Control System Equipment	\$6,011	\$0	\$183	\$0	\$6,194	\$1,239	\$0	\$1,115	\$8,548	\$11
12.8	Instrument Wiring & Tubing	\$496	\$397	\$1,588	\$0	\$2,481	\$496	\$0	\$447	\$3,424	\$4
12.9	Other Instrumentation & Controls Equipment	\$344	\$0	\$796	\$0	\$1,140	\$228	\$0	\$205	\$1,573	\$2
	Subtotal	\$8,710	\$397	\$3,501	\$0	\$12,608	\$2,522	\$0	\$2,269	\$17,399	\$22
13 Improvements to Site											
13.1	Site Preparation	\$0	\$564	\$11,976	\$0	\$12,540	\$2,508	\$0	\$3,010	\$18,058	\$23
13.2	Site Improvements	\$0	\$1,815	\$2,397	\$0	\$4,211	\$842	\$0	\$1,011	\$6,065	\$8
13.3	Site Facilities	\$1,741	\$0	\$1,827	\$0	\$3,568	\$714	\$0	\$856	\$5,138	\$7
	Subtotal	\$1,741	\$2,379	\$16,199	\$0	\$20,319	\$4,064	\$0	\$4,877	\$29,260	\$37
14 Buildings & Structures											
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$3,498	\$4,653	\$0	\$8,150	\$1,630	\$0	\$1,467	\$11,247	\$14
14.4	Administration Building	\$0	\$378	\$256	\$0	\$634	\$127	\$0	\$114	\$875	\$1
14.5	Circulation Water Pumphouse	\$0	\$53	\$26	\$0	\$79	\$16	\$0	\$14	\$109	\$0

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XA.1 – NGCC X-Class (1×1) – Natural Gas w/o CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		780					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14.6	Water Treatment Buildings	\$0	\$300	\$273	\$0	\$573	\$115	\$0	\$103	\$791	\$1
14.7	Machine Shop	\$0	\$567	\$363	\$0	\$930	\$186	\$0	\$167	\$1,283	\$2
14.8	Warehouse	\$0	\$438	\$265	\$0	\$703	\$141	\$0	\$127	\$970	\$1
14.9	Other Buildings & Structures	\$0	\$312	\$226	\$0	\$538	\$108	\$0	\$97	\$743	\$1
14.10	Waste Treating Building & Structures	\$0	\$708	\$1,262	\$0	\$1,970	\$394	\$0	\$355	\$2,718	\$3
	Subtotal	\$0	\$6,647	\$7,532	\$0	\$14,179	\$2,836	\$0	\$2,552	\$19,567	\$25
	Total	\$330,446	\$28,198	\$109,460	\$0	\$468,103	\$93,621	\$0	\$88,940	\$650,664	\$834

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-14. Case B3XA.1 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$4,187	\$5
1 Month Maintenance Materials	\$727	\$1
1 Month Non-fuel Consumables	\$308	\$0
1 Month Waste Disposal	\$0	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,764	\$5
2% of TPC	\$13,013	\$17
Total	\$21,999	\$28
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$389	\$0
0.5% of TPC (spare parts)	\$3,253	\$4
Total	\$3,643	\$5
Other Costs		
Initial Cost for Catalyst and Chemicals	\$643	\$1
Land	\$300	\$0
Other Owner's Costs	\$97,600	\$125
Financing Costs	\$17,568	\$23
Total Overnight Costs (TOC)	\$792,416	\$1,015
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$865,831	\$1,110

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-15. Case B3XA.1 initial and annual operating and maintenance costs

Case:	B3XA.1	– NGCC X-Class (1×1) – Natural Gas w/o CO ₂ capture		Cost Base:	Dec 2018	
Plant Size (MW, net):	780	Heat Rate-net (Btu/kWh):	5,979	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor			Operating Labor Requirements per Shift			
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0	
Operating Labor Burden:		30.00	% of base	Operator:	1.0	
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0	
				Lab Techs, etc.:	1.0	
				Total:	4.0	
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$1,753,752	\$2.247
Maintenance Labor:					\$4,945,043	\$6.337
Administrative & Support Labor:					\$1,674,699	\$2.146
Property Taxes and Insurance:					\$13,013,272	\$16.676
Total:					\$21,386,767	\$27.407
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$7,417,565	\$1.277
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	1,965	\$1.90	\$0	\$1,158,446	\$0.199
Makeup and Waste Water Treatment Chemicals (ton):	0	5.85	\$550	\$0	\$998,930	\$0.172
Ammonia (19 wt%, ton):	0	9.42	\$300	\$0	\$877,212	\$0.151
SCR Catalyst (ft³):	4,288	2.35	\$150	\$643,158	\$109,337	\$0.019
Subtotal:				\$643,158	\$3,143,925	\$0.541
Waste Disposal						
SCR Catalyst (ft³):	0	2.35	\$2.50	\$0	\$1,822	\$0.000
Subtotal:				\$0	\$1,822	\$0.000
Variable Operating Costs Total:				\$643,158	\$10,563,313	\$1.818
Fuel Cost						
Natural Gas (MMBtu):	0	111,977	\$4.42	\$0	\$153,561,905	\$26.429
Total:				\$0	\$153,561,905	\$26.429

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-16. Case B3XB.1.90 total plant cost details

Case:		B3XB.1.90	– NGCC X-Cass (1x1) – Natural Gas with 90%				Estimate Type:			Conceptual	
Plant Size (MW, net):		720	Advanced CO ₂ Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,807	\$3,099	\$1,549	\$0	\$6,455	\$1,291	\$0	\$1,162	\$8,908	\$12
3.2	Water Makeup & Pretreating	\$5,220	\$522	\$2,958	\$0	\$8,699	\$1,740	\$0	\$2,088	\$12,527	\$17
3.3	Other Feedwater Subsystems	\$1,028	\$337	\$320	\$0	\$1,686	\$337	\$0	\$303	\$2,326	\$3
3.4	Service Water Systems	\$1,573	\$3,002	\$9,722	\$0	\$14,298	\$2,860	\$0	\$3,431	\$20,588	\$29
3.5	Other Boiler Plant Systems	\$273	\$99	\$248	\$0	\$620	\$124	\$0	\$112	\$855	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$19
3.7	Waste Water Treatment Equipment	\$10,205	\$0	\$6,255	\$0	\$16,460	\$3,292	\$0	\$3,950	\$23,702	\$33
3.9	Miscellaneous Plant Equipment	\$15,328	\$2,010	\$7,789	\$0	\$25,127	\$5,025	\$0	\$6,031	\$36,183	\$50
	Subtotal	\$44,490	\$9,459	\$29,134	\$0	\$83,083	\$16,617	\$0	\$18,830	\$118,529	\$165
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$52,626	\$22,527	\$47,306	\$0	\$122,458	\$24,492	\$22,042	\$33,798	\$202,790	\$282
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$27,075	\$4,062	\$11,233	\$0	\$42,369	\$8,474	\$0	\$10,169	\$61,012	\$85
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$226	\$36	\$97	\$0	\$359	\$72	\$0	\$86	\$516	\$1
5.12	Gas Cleanup Foundations	\$0	\$384	\$415	\$0	\$800	\$160	\$0	\$192	\$1,152	\$2
	Subtotal	\$79,927	\$27,008	\$59,050	\$0	\$165,986	\$33,197	\$22,042	\$44,245	\$265,470	\$369
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$216
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$5
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$4
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$227
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$49,548	\$0	\$12,387	\$0	\$61,935	\$12,387	\$0	\$11,148	\$85,471	\$119
7.2	Heat Recovery Steam Generator Accessories	\$17,158	\$0	\$3,175	\$0	\$20,333	\$4,067	\$0	\$3,660	\$28,060	\$39
7.3	Ductwork	\$0	\$703	\$489	\$0	\$1,192	\$238	\$0	\$214	\$1,644	\$2
7.4	Stack	\$6,724	\$0	\$1,244	\$0	\$7,969	\$1,594	\$0	\$1,434	\$10,997	\$15
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$524	\$492	\$0	\$1,016	\$203	\$0	\$244	\$1,463	\$2
7.6	Selective Catalytic Reduction System	\$1,313	\$551	\$769	\$0	\$2,633	\$527	\$0	\$474	\$3,634	\$5
	Subtotal	\$74,743	\$1,779	\$18,556	\$0	\$95,078	\$19,016	\$0	\$17,175	\$131,268	\$182
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$38,040	\$0	\$5,571	\$0	\$43,611	\$8,722	\$0	\$7,850	\$60,183	\$84
8.2	Steam Turbine Plant Auxiliaries	\$132	\$0	\$302	\$0	\$434	\$87	\$0	\$78	\$599	\$1
8.3	Condenser & Auxiliaries	\$5,060	\$0	\$2,428	\$0	\$7,488	\$1,498	\$0	\$1,348	\$10,333	\$14
8.4	Steam Piping	\$10,398	\$0	\$4,214	\$0	\$14,612	\$2,922	\$0	\$2,630	\$20,165	\$28

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.90	– NGCC X-Cass (1×1) – Natural Gas with 90%				Estimate Type:		Conceptual		
Plant Size (MW, net):		720	Advanced CO ₂ Capture				Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$1,136	\$1,876	\$0	\$3,012	\$602	\$0	\$723	\$4,337	\$6
	Subtotal	\$53,630	\$1,136	\$14,390	\$0	\$69,156	\$13,831	\$0	\$12,629	\$95,616	\$133
9 Cooling Water System											
9.1	Cooling Towers	\$11,286	\$0	\$3,443	\$0	\$14,729	\$2,946	\$0	\$2,651	\$20,325	\$28
9.2	Circulating Water Pumps	\$1,481	\$0	\$87	\$0	\$1,569	\$314	\$0	\$282	\$2,165	\$3
9.3	Circulating Water System Auxiliaries	\$10,178	\$0	\$1,343	\$0	\$11,520	\$2,304	\$0	\$2,074	\$15,898	\$22
9.4	Circulating Water Piping	\$0	\$3,018	\$2,733	\$0	\$5,751	\$1,150	\$0	\$1,035	\$7,936	\$11
9.5	Make-Up Water System	\$364	\$0	\$467	\$0	\$831	\$166	\$0	\$150	\$1,146	\$2
9.6	Component Cooling Water System	\$445	\$0	\$341	\$0	\$786	\$157	\$0	\$142	\$1,085	\$2
9.7	Circulating Water System Foundations	\$0	\$698	\$1,159	\$0	\$1,857	\$371	\$0	\$446	\$2,675	\$4
	Subtotal	\$23,753	\$3,716	\$9,573	\$0	\$37,042	\$7,408	\$0	\$6,779	\$51,230	\$71
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,617	\$0	\$1,974	\$0	\$4,592	\$918	\$0	\$827	\$6,337	\$9
11.2	Station Service Equipment	\$5,766	\$0	\$495	\$0	\$6,261	\$1,252	\$0	\$1,127	\$8,640	\$12
11.3	Switchgear & Motor Control	\$8,233	\$0	\$1,428	\$0	\$9,661	\$1,932	\$0	\$1,739	\$13,332	\$19
11.4	Conduit & Cable Tray	\$0	\$1,989	\$5,733	\$0	\$7,723	\$1,545	\$0	\$1,390	\$10,657	\$15
11.5	Wire & Cable	\$0	\$2,970	\$5,309	\$0	\$8,279	\$1,656	\$0	\$1,490	\$11,425	\$16
11.6	Protective Equipment	\$225	\$0	\$782	\$0	\$1,007	\$201	\$0	\$181	\$1,390	\$2
11.7	Standby Equipment	\$660	\$0	\$609	\$0	\$1,269	\$254	\$0	\$228	\$1,751	\$2
11.8	Main Power Transformers	\$8,976	\$0	\$183	\$0	\$9,159	\$1,832	\$0	\$1,649	\$12,640	\$18
11.9	Electrical Foundations	\$0	\$95	\$243	\$0	\$338	\$68	\$0	\$81	\$487	\$1
	Subtotal	\$26,477	\$5,055	\$16,756	\$0	\$48,288	\$9,658	\$0	\$8,712	\$66,658	\$93
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$348	\$0	\$222	\$0	\$570	\$114	\$0	\$103	\$787	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$558	\$0	\$355	\$0	\$913	\$183	\$0	\$164	\$1,261	\$2
12.4	Other Major Component Control Equipment	\$943	\$0	\$600	\$0	\$1,543	\$309	\$77	\$289	\$2,218	\$3
12.5	Signal Processing Equipment	\$781	\$0	\$24	\$0	\$805	\$161	\$0	\$145	\$1,110	\$2
12.6	Control Boards, Panels & Racks	\$208	\$0	\$127	\$0	\$335	\$67	\$17	\$63	\$482	\$1
12.7	Distributed Control System Equipment	\$11,551	\$0	\$352	\$0	\$11,903	\$2,381	\$595	\$2,232	\$17,110	\$24
12.8	Instrument Wiring & Tubing	\$954	\$763	\$3,051	\$0	\$4,768	\$954	\$238	\$894	\$6,854	\$10
12.9	Other Instrumentation & Controls Equipment	\$660	\$0	\$1,530	\$0	\$2,190	\$438	\$109	\$411	\$3,148	\$4
	Subtotal	\$16,385	\$763	\$6,504	\$0	\$23,651	\$4,730	\$1,037	\$4,413	\$33,831	\$47
13 Improvements to Site											
13.1	Site Preparation	\$0	\$675	\$14,333	\$0	\$15,008	\$3,002	\$0	\$3,602	\$21,611	\$30
13.2	Site Improvements	\$0	\$2,172	\$2,868	\$0	\$5,040	\$1,008	\$0	\$1,210	\$7,258	\$10
13.3	Site Facilities	\$2,084	\$0	\$2,186	\$0	\$4,270	\$854	\$0	\$1,025	\$6,149	\$9
	Subtotal	\$2,084	\$2,847	\$19,387	\$0	\$24,318	\$4,864	\$0	\$5,836	\$35,018	\$49

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.90	– NGCC X-Cass (1×1) – Natural Gas with 90%				Estimate Type:			Conceptual	
Plant Size (MW, net):		720	Advanced CO ₂ Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$3,218	\$4,280	\$0	\$7,498	\$1,500	\$0	\$1,350	\$10,347	\$14
14.4	Administration Building	\$0	\$372	\$252	\$0	\$625	\$125	\$0	\$112	\$862	\$1
14.5	Circulation Water Pumphouse	\$0	\$80	\$40	\$0	\$120	\$24	\$0	\$22	\$165	\$0
14.6	Water Treatment Buildings	\$0	\$422	\$385	\$0	\$807	\$161	\$0	\$145	\$1,114	\$2
14.7	Machine Shop	\$0	\$559	\$357	\$0	\$916	\$183	\$0	\$165	\$1,264	\$2
14.8	Warehouse	\$0	\$432	\$261	\$0	\$692	\$138	\$0	\$125	\$956	\$1
14.9	Other Buildings & Structures	\$0	\$307	\$223	\$0	\$530	\$106	\$0	\$95	\$732	\$1
14.10	Waste Treating Building & Structures	\$0	\$1,402	\$2,499	\$0	\$3,901	\$780	\$0	\$702	\$5,383	\$7
	Subtotal	\$0	\$7,185	\$8,505	\$0	\$15,690	\$3,138	\$0	\$2,824	\$21,653	\$30
	Total	\$430,330	\$60,748	\$189,704	\$0	\$680,782	\$136,156	\$23,079	\$142,891	\$982,909	\$1,365

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-17. Case B3XB.1.90 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,130	\$9
1 Month Maintenance Materials	\$1,099	\$2
1 Month Non-fuel Consumables	\$552	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,764	\$5
2% of TPC	\$19,658	\$27
Total	\$31,205	\$43
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$723	\$1
0.5% of TPC (spare parts)	\$4,915	\$7
Total	\$5,637	\$8
Other Costs		
Initial Cost for Catalyst and Chemicals	\$643	\$1
Land	\$300	\$0
Other Owner's Costs	\$147,436	\$205
Financing Costs	\$26,539	\$37
Total Overnight Costs (TOC)	\$1,194,669	\$1,659
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,305,352	\$1,812

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-18. Case B3XB.1.90 initial and annual operating and maintenance costs

Case:	B3XB.1.90	– NGCC X-Class (1×1) – Natural Gas with 90% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	720	Heat Rate-net (Btu/kWh):	6,477	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.246
Maintenance Labor:					\$7,470,106	\$10.370
Administrative & Support Labor:					\$2,452,074	\$3.404
Property Taxes and Insurance:					\$19,658,173	\$27.291
Total:					\$31,918,542	\$44.311
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$11,205,158	\$2.089
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	3,301	\$1.90	\$0	\$1,945,986	\$0.363
Makeup and Waste Water Treatment Chemicals (ton):	0	9.83	\$550	\$0	\$1,678,026	\$0.313
Ammonia (19 wt%, ton):	0	9.48	\$300	\$0	\$881,923	\$0.164
SCR Catalyst (ft ³):	4,288	2.35	\$150	\$643,158	\$109,337	\$0.020
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,007,906	\$0.188
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$9,434	\$0.002
Subtotal:				\$643,158	\$5,632,612	\$1.050
Waste Disposal						
SCR Catalyst (ft ³):	0	2.35	\$2.50	\$0	\$1,822	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$486	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.76	\$38.0	\$0	\$20,792	\$0.004
Subtotal:				\$0	\$23,100	\$0.004
Variable Operating Costs Total:				\$643,158	\$16,860,871	\$3.144
Fuel Cost						
Natural Gas (MMBtu):	0	111,977	\$4.42	\$0	\$153,561,905	\$28.631
Total:				\$0	\$153,561,905	\$28.631

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-19. Case B3XB.1.95 total plant cost details

Case:		B3XB.1.95	– NGCC X-Class (1×1) – Natural Gas with 95%				Estimate Type:			Conceptual	
Plant Size (MW, net):		717	Advanced CO ₂ Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,807	\$3,099	\$1,549	\$0	\$6,455	\$1,291	\$0	\$1,162	\$8,908	\$12
3.2	Water Makeup & Pretreating	\$5,259	\$526	\$2,980	\$0	\$8,765	\$1,753	\$0	\$2,104	\$12,622	\$18
3.3	Other Feedwater Subsystems	\$1,028	\$337	\$320	\$0	\$1,686	\$337	\$0	\$303	\$2,326	\$3
3.4	Service Water Systems	\$1,584	\$3,024	\$9,792	\$0	\$14,399	\$2,880	\$0	\$3,456	\$20,735	\$29
3.5	Other Boiler Plant Systems	\$273	\$99	\$248	\$0	\$620	\$124	\$0	\$112	\$855	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$19
3.7	Waste Water Treatment Equipment	\$10,285	\$0	\$6,303	\$0	\$16,588	\$3,318	\$0	\$3,981	\$23,887	\$33
3.9	Miscellaneous Plant Equipment	\$15,328	\$2,010	\$7,789	\$0	\$25,127	\$5,025	\$0	\$6,031	\$36,183	\$50
	Subtotal	\$44,620	\$9,484	\$29,274	\$0	\$83,379	\$16,676	\$0	\$18,901	\$118,955	\$166
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$55,265	\$23,354	\$49,042	\$0	\$127,661	\$25,532	\$22,979	\$35,234	\$211,406	\$295
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$27,681	\$4,152	\$11,484	\$0	\$43,317	\$8,663	\$0	\$10,396	\$62,376	\$87
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$236	\$38	\$101	\$0	\$375	\$75	\$0	\$90	\$540	\$1
5.12	Gas Cleanup Foundations	\$0	\$401	\$433	\$0	\$835	\$167	\$0	\$200	\$1,202	\$2
	Subtotal	\$83,182	\$27,945	\$61,061	\$0	\$172,187	\$34,437	\$22,979	\$45,921	\$275,525	\$384
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$217
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$5
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$4
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$228
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$49,514	\$0	\$12,379	\$0	\$61,893	\$12,379	\$0	\$11,141	\$85,412	\$119
7.2	Heat Recovery Steam Generator Accessories	\$17,146	\$0	\$3,173	\$0	\$20,319	\$4,064	\$0	\$3,657	\$28,040	\$39
7.3	Ductwork	\$0	\$701	\$487	\$0	\$1,189	\$238	\$0	\$214	\$1,641	\$2
7.4	Stack	\$6,709	\$0	\$1,242	\$0	\$7,951	\$1,590	\$0	\$1,431	\$10,972	\$15
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$523	\$491	\$0	\$1,014	\$203	\$0	\$243	\$1,460	\$2
7.6	Selective Catalytic Reduction System	\$1,312	\$551	\$769	\$0	\$2,632	\$526	\$0	\$474	\$3,632	\$5
	Subtotal	\$74,681	\$1,776	\$18,540	\$0	\$94,997	\$18,999	\$0	\$17,160	\$131,157	\$183
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$37,802	\$0	\$5,536	\$0	\$43,337	\$8,667	\$0	\$7,801	\$59,806	\$83
8.2	Steam Turbine Plant Auxiliaries	\$131	\$0	\$300	\$0	\$432	\$86	\$0	\$78	\$596	\$1
8.3	Condenser & Auxiliaries	\$4,968	\$0	\$2,384	\$0	\$7,352	\$1,470	\$0	\$1,323	\$10,146	\$14
8.4	Steam Piping	\$10,398	\$0	\$4,214	\$0	\$14,612	\$2,922	\$0	\$2,630	\$20,164	\$28

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.95 – NGCC X-Class (1×1) – Natural Gas with 95% Advanced CO ₂ Capture					Estimate Type:		Conceptual		
Plant Size (MW, net):		717					Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$1,129	\$1,865	\$0	\$2,995	\$599	\$0	\$719	\$4,312	\$6
	Subtotal	\$53,300	\$1,129	\$14,299	\$0	\$68,728	\$13,746	\$0	\$12,551	\$95,024	\$132
9 Cooling Water System											
9.1	Cooling Towers	\$11,366	\$0	\$3,468	\$0	\$14,833	\$2,967	\$0	\$2,670	\$20,470	\$29
9.2	Circulating Water Pumps	\$1,492	\$0	\$88	\$0	\$1,580	\$316	\$0	\$284	\$2,180	\$3
9.3	Circulating Water System Auxiliaries	\$10,228	\$0	\$1,349	\$0	\$11,577	\$2,315	\$0	\$2,084	\$15,976	\$22
9.4	Circulating Water Piping	\$0	\$3,036	\$2,749	\$0	\$5,785	\$1,157	\$0	\$1,041	\$7,983	\$11
9.5	Make-Up Water System	\$365	\$0	\$469	\$0	\$834	\$167	\$0	\$150	\$1,151	\$2
9.6	Component Cooling Water System	\$447	\$0	\$343	\$0	\$791	\$158	\$0	\$142	\$1,092	\$2
9.7	Circulating Water System Foundations	\$0	\$702	\$1,166	\$0	\$1,869	\$374	\$0	\$448	\$2,691	\$4
	Subtotal	\$23,898	\$3,738	\$9,633	\$0	\$37,269	\$7,454	\$0	\$6,821	\$51,543	\$72
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,614	\$0	\$1,972	\$0	\$4,585	\$917	\$0	\$825	\$6,328	\$9
11.2	Station Service Equipment	\$5,895	\$0	\$506	\$0	\$6,400	\$1,280	\$0	\$1,152	\$8,832	\$12
11.3	Switchgear & Motor Control	\$8,416	\$0	\$1,460	\$0	\$9,877	\$1,975	\$0	\$1,778	\$13,630	\$19
11.4	Conduit & Cable Tray	\$0	\$2,034	\$5,861	\$0	\$7,895	\$1,579	\$0	\$1,421	\$10,895	\$15
11.5	Wire & Cable	\$0	\$3,036	\$5,427	\$0	\$8,464	\$1,693	\$0	\$1,523	\$11,680	\$16
11.6	Protective Equipment	\$230	\$0	\$799	\$0	\$1,029	\$206	\$0	\$185	\$1,421	\$2
11.7	Standby Equipment	\$659	\$0	\$608	\$0	\$1,267	\$253	\$0	\$228	\$1,749	\$2
11.8	Main Power Transformers	\$8,960	\$0	\$183	\$0	\$9,143	\$1,829	\$0	\$1,646	\$12,617	\$18
11.9	Electrical Foundations	\$0	\$95	\$242	\$0	\$338	\$68	\$0	\$81	\$486	\$1
	Subtotal	\$26,774	\$5,165	\$17,059	\$0	\$48,998	\$9,800	\$0	\$8,840	\$67,638	\$94
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$356	\$0	\$226	\$0	\$582	\$116	\$0	\$105	\$803	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$570	\$0	\$363	\$0	\$933	\$187	\$0	\$168	\$1,287	\$2
12.4	Other Major Component Control Equipment	\$962	\$0	\$613	\$0	\$1,575	\$315	\$79	\$295	\$2,264	\$3
12.5	Signal Processing Equipment	\$797	\$0	\$24	\$0	\$821	\$164	\$0	\$148	\$1,133	\$2
12.6	Control Boards, Panels & Racks	\$213	\$0	\$130	\$0	\$342	\$68	\$17	\$64	\$492	\$1
12.7	Distributed Control System Equipment	\$11,792	\$0	\$359	\$0	\$12,151	\$2,430	\$608	\$2,278	\$17,468	\$24
12.8	Instrument Wiring & Tubing	\$973	\$779	\$3,115	\$0	\$4,867	\$973	\$243	\$913	\$6,997	\$10
12.9	Other Instrumentation & Controls Equipment	\$674	\$0	\$1,562	\$0	\$2,236	\$447	\$112	\$419	\$3,214	\$4
	Subtotal	\$16,719	\$779	\$6,634	\$0	\$24,132	\$4,826	\$1,059	\$4,503	\$34,520	\$48
13 Improvements to Site											
13.1	Site Preparation	\$0	\$679	\$14,409	\$0	\$15,088	\$3,018	\$0	\$3,621	\$21,726	\$30
13.2	Site Improvements	\$0	\$2,184	\$2,883	\$0	\$5,067	\$1,013	\$0	\$1,216	\$7,296	\$10
13.3	Site Facilities	\$2,095	\$0	\$2,198	\$0	\$4,293	\$859	\$0	\$1,030	\$6,181	\$9
	Subtotal	\$2,095	\$2,862	\$19,490	\$0	\$24,447	\$4,889	\$0	\$5,867	\$35,204	\$49

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.95	– NGCC X-Class (1×1) – Natural Gas with 95%				Estimate Type:			Conceptual	
Plant Size (MW, net):		717	Advanced CO ₂ Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$3,203	\$4,260	\$0	\$7,463	\$1,493	\$0	\$1,343	\$10,299	\$14
14.4	Administration Building	\$0	\$372	\$252	\$0	\$624	\$125	\$0	\$112	\$861	\$1
14.5	Circulation Water Pumphouse	\$0	\$81	\$40	\$0	\$121	\$24	\$0	\$22	\$167	\$0
14.6	Water Treatment Buildings	\$0	\$425	\$388	\$0	\$813	\$163	\$0	\$146	\$1,122	\$2
14.7	Machine Shop	\$0	\$559	\$357	\$0	\$915	\$183	\$0	\$165	\$1,263	\$2
14.8	Warehouse	\$0	\$431	\$260	\$0	\$692	\$138	\$0	\$125	\$955	\$1
14.9	Other Buildings & Structures	\$0	\$307	\$223	\$0	\$530	\$106	\$0	\$95	\$731	\$1
14.10	Waste Treating Building & Structures	\$0	\$1,413	\$2,518	\$0	\$3,931	\$786	\$0	\$708	\$5,425	\$8
	Subtotal	\$0	\$7,183	\$8,506	\$0	\$15,690	\$3,138	\$0	\$2,824	\$21,652	\$30
	Total	\$434,111	\$61,862	\$192,344	\$0	\$688,317	\$137,663	\$24,038	\$144,835	\$994,852	\$1,387

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-20. Case B3XB.1.95 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,187	\$9
1 Month Maintenance Materials	\$1,112	\$2
1 Month Non-fuel Consumables	\$560	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,764	\$5
2% of TPC	\$19,897	\$28
Total	\$31,522	\$44
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$735	\$1
0.5% of TPC (spare parts)	\$4,974	\$7
Total	\$5,709	\$8
Other Costs		
Initial Cost for Catalyst and Chemicals	\$643	\$1
Land	\$300	\$0
Other Owner's Costs	\$149,228	\$208
Financing Costs	\$26,861	\$37
Total Overnight Costs (TOC)	\$1,209,116	\$1,686
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,321,137	\$1,842

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-21. Case B3XB.1.95 initial and annual operating and maintenance costs

Case:	B3XB.1.95	– NGCC X-Class (1×1) – Natural Gas with 95% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	717	Heat Rate-net (Btu/kWh):	6,506	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.260
Maintenance Labor:					\$7,560,877	\$10.543
Administrative & Support Labor:					\$2,474,767	\$3.451
Property Taxes and Insurance:					\$19,897,044	\$27.744
Total:					\$32,270,878	\$44.998
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$11,341,315	\$2.124
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	3,336	\$1.90	\$0	\$1,966,752	\$0.368
Makeup and Waste Water Treatment Chemicals (ton):	0	9.94	\$550	\$0	\$1,695,933	\$0.318
Ammonia (19 wt%, ton):	0	9.48	\$300	\$0	\$882,042	\$0.165
SCR Catalyst (ft ³):	4,288	2.35	\$150	\$643,158	\$109,337	\$0.020
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,051,505	\$0.197
Triethylene Glycol (gal):	w/equip.	5	\$6.80	\$0	\$9,959	\$0.002
Subtotal:				\$643,158	\$5,715,527	\$1.070
Waste Disposal						
SCR Catalyst (ft ³):	0	2.35	\$2.50	\$0	\$1,822	\$0.000
Triethylene Glycol (gal):	0	5	\$0.35	\$0	\$513	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.84	\$38.0	\$0	\$21,738	\$0.004
Subtotal:				\$0	\$24,073	\$0.005
Variable Operating Costs Total:				\$643,158	\$17,080,915	\$3.199
Fuel Cost						
Natural Gas (MMBtu):	0	111,977	\$4.42	\$0	\$153,561,905	\$28.757
Total:				\$0	\$153,561,905	\$28.757

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-22. Case B3XB.1.97 total plant cost details

Case:		B3XB.1.97	– NGCC X-Class (1×1) – Natural Gas with 97% Advanced CO ₂ Capture				Estimate Type:			Conceptual	
Plant Size (MW, net):		715					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1,808	\$3,099	\$1,549	\$0	\$6,455	\$1,291	\$0	\$1,162	\$8,908	\$12
3.2	Water Makeup & Pretreating	\$5,291	\$529	\$2,998	\$0	\$8,819	\$1,764	\$0	\$2,117	\$12,699	\$18
3.3	Other Feedwater Subsystems	\$1,028	\$337	\$320	\$0	\$1,686	\$337	\$0	\$303	\$2,326	\$3
3.4	Service Water Systems	\$1,593	\$3,041	\$9,847	\$0	\$14,481	\$2,896	\$0	\$3,476	\$20,853	\$29
3.5	Other Boiler Plant Systems	\$273	\$99	\$248	\$0	\$620	\$124	\$0	\$112	\$855	\$1
3.6	Natural Gas Pipeline and Start-Up System	\$9,056	\$390	\$292	\$0	\$9,738	\$1,948	\$0	\$1,753	\$13,439	\$19
3.7	Waste Water Treatment Equipment	\$10,250	\$0	\$6,282	\$0	\$16,533	\$3,307	\$0	\$3,968	\$23,807	\$33
3.9	Miscellaneous Plant Equipment	\$15,328	\$2,010	\$7,789	\$0	\$25,127	\$5,025	\$0	\$6,031	\$36,183	\$51
	Subtotal	\$44,627	\$9,505	\$29,327	\$0	\$83,459	\$16,692	\$0	\$18,920	\$119,071	\$167
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$56,576	\$23,927	\$50,246	\$0	\$130,750	\$26,150	\$23,535	\$36,087	\$216,521	\$303
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$27,918	\$4,188	\$11,582	\$0	\$43,688	\$8,738	\$0	\$10,485	\$62,910	\$88
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$240	\$38	\$103	\$0	\$382	\$76	\$0	\$92	\$550	\$1
5.12	Gas Cleanup Foundations	\$0	\$408	\$441	\$0	\$848	\$170	\$0	\$204	\$1,222	\$2
	Subtotal	\$84,735	\$28,561	\$62,372	\$0	\$175,668	\$35,134	\$23,535	\$46,867	\$281,203	\$393
6 Combustion Turbine & Accessories											
6.1	Combustion Turbine Generator	\$106,286	\$0	\$6,468	\$0	\$112,754	\$22,551	\$0	\$20,296	\$155,601	\$218
6.3	Combustion Turbine Accessories	\$2,555	\$0	\$156	\$0	\$2,711	\$542	\$0	\$488	\$3,741	\$5
6.4	Compressed Air Piping	\$0	\$844	\$191	\$0	\$1,035	\$207	\$0	\$186	\$1,428	\$2
6.5	Combustion Turbine Foundations	\$0	\$956	\$1,033	\$0	\$1,990	\$398	\$0	\$478	\$2,865	\$4
	Subtotal	\$108,842	\$1,800	\$7,848	\$0	\$118,489	\$23,698	\$0	\$21,447	\$163,635	\$229
7 HRSG, Ductwork, & Stack											
7.1	Heat Recovery Steam Generator	\$49,483	\$0	\$12,371	\$0	\$61,854	\$12,371	\$0	\$11,134	\$85,358	\$119
7.2	Heat Recovery Steam Generator Accessories	\$17,135	\$0	\$3,171	\$0	\$20,306	\$4,061	\$0	\$3,655	\$28,023	\$39
7.3	Ductwork	\$0	\$704	\$489	\$0	\$1,193	\$239	\$0	\$215	\$1,647	\$2
7.4	Stack	\$6,734	\$0	\$1,246	\$0	\$7,980	\$1,596	\$0	\$1,436	\$11,012	\$15
7.5	Heat Recovery Steam Generator, Ductwork & Stack Foundations	\$0	\$525	\$493	\$0	\$1,018	\$204	\$0	\$244	\$1,465	\$2
7.6	Selective Catalytic Reduction System	\$1,312	\$551	\$769	\$0	\$2,632	\$526	\$0	\$474	\$3,631	\$5
	Subtotal	\$74,664	\$1,780	\$18,538	\$0	\$94,983	\$18,997	\$0	\$17,158	\$131,137	\$183
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$37,576	\$0	\$5,503	\$0	\$43,079	\$8,616	\$0	\$7,754	\$59,449	\$83
8.2	Steam Turbine Plant Auxiliaries	\$131	\$0	\$298	\$0	\$429	\$86	\$0	\$77	\$592	\$1
8.3	Condenser & Auxiliaries	\$4,885	\$0	\$2,344	\$0	\$7,229	\$1,446	\$0	\$1,301	\$9,976	\$14
8.4	Steam Piping	\$10,398	\$0	\$4,214	\$0	\$14,612	\$2,922	\$0	\$2,630	\$20,165	\$28

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.97 – NGCC X-Class (1×1) – Natural Gas with 97% Advanced CO ₂ Capture					Estimate Type:		Conceptual		
Plant Size (MW, net):		715					Cost Base:		Dec 2018		
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
8.5	Turbine Generator Foundations	\$0	\$1,123	\$1,855	\$0	\$2,978	\$596	\$0	\$715	\$4,289	\$6
	Subtotal	\$52,990	\$1,123	\$14,214	\$0	\$68,328	\$13,666	\$0	\$12,478	\$94,471	\$132
9 Cooling Water System											
9.1	Cooling Towers	\$11,431	\$0	\$3,487	\$0	\$14,918	\$2,984	\$0	\$2,685	\$20,587	\$29
9.2	Circulating Water Pumps	\$1,501	\$0	\$88	\$0	\$1,589	\$318	\$0	\$286	\$2,193	\$3
9.3	Circulating Water System Auxiliaries	\$10,268	\$0	\$1,355	\$0	\$11,622	\$2,324	\$0	\$2,092	\$16,039	\$22
9.4	Circulating Water Piping	\$0	\$3,050	\$2,762	\$0	\$5,813	\$1,163	\$0	\$1,046	\$8,022	\$11
9.5	Make-Up Water System	\$366	\$0	\$471	\$0	\$837	\$167	\$0	\$151	\$1,155	\$2
9.6	Component Cooling Water System	\$450	\$0	\$345	\$0	\$795	\$159	\$0	\$143	\$1,097	\$2
9.7	Circulating Water System Foundations	\$0	\$706	\$1,172	\$0	\$1,878	\$376	\$0	\$451	\$2,704	\$4
	Subtotal	\$24,015	\$3,756	\$9,680	\$0	\$37,452	\$7,490	\$0	\$6,854	\$51,796	\$72
11 Accessory Electric Plant											
11.1	Generator Equipment	\$2,610	\$0	\$1,969	\$0	\$4,579	\$916	\$0	\$824	\$6,320	\$9
11.2	Station Service Equipment	\$5,965	\$0	\$512	\$0	\$6,477	\$1,295	\$0	\$1,166	\$8,938	\$13
11.3	Switchgear & Motor Control	\$8,517	\$0	\$1,478	\$0	\$9,994	\$1,999	\$0	\$1,799	\$13,792	\$19
11.4	Conduit & Cable Tray	\$0	\$2,058	\$5,931	\$0	\$7,989	\$1,598	\$0	\$1,438	\$11,025	\$15
11.5	Wire & Cable	\$0	\$3,072	\$5,492	\$0	\$8,564	\$1,713	\$0	\$1,542	\$11,819	\$17
11.6	Protective Equipment	\$233	\$0	\$809	\$0	\$1,042	\$208	\$0	\$187	\$1,437	\$2
11.7	Standby Equipment	\$658	\$0	\$608	\$0	\$1,266	\$253	\$0	\$228	\$1,747	\$2
11.8	Main Power Transformers	\$8,946	\$0	\$183	\$0	\$9,128	\$1,826	\$0	\$1,643	\$12,597	\$18
11.9	Electrical Foundations	\$0	\$95	\$242	\$0	\$337	\$67	\$0	\$81	\$485	\$1
	Subtotal	\$26,928	\$5,226	\$17,222	\$0	\$49,377	\$9,875	\$0	\$8,908	\$68,160	\$95
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$360	\$0	\$229	\$0	\$589	\$118	\$0	\$106	\$812	\$1
12.2	Combustion Turbine Control Equipment	\$382	\$0	\$243	\$0	\$625	\$125	\$0	\$112	\$862	\$1
12.3	Steam Turbine Control Equipment	\$576	\$0	\$367	\$0	\$943	\$189	\$0	\$170	\$1,301	\$2
12.4	Other Major Component Control Equipment	\$973	\$0	\$620	\$0	\$1,593	\$319	\$80	\$299	\$2,289	\$3
12.5	Signal Processing Equipment	\$806	\$0	\$25	\$0	\$831	\$166	\$0	\$149	\$1,146	\$2
12.6	Control Boards, Panels & Racks	\$215	\$0	\$131	\$0	\$346	\$69	\$17	\$65	\$497	\$1
12.7	Distributed Control System Equipment	\$11,924	\$0	\$363	\$0	\$12,287	\$2,457	\$614	\$2,304	\$17,663	\$25
12.8	Instrument Wiring & Tubing	\$984	\$787	\$3,150	\$0	\$4,922	\$984	\$246	\$923	\$7,075	\$10
12.9	Other Instrumentation & Controls Equipment	\$682	\$0	\$1,579	\$0	\$2,261	\$452	\$113	\$424	\$3,250	\$5
	Subtotal	\$16,902	\$787	\$6,706	\$0	\$24,395	\$4,879	\$1,070	\$4,552	\$34,896	\$49
13 Improvements to Site											
13.1	Site Preparation	\$0	\$681	\$14,449	\$0	\$15,130	\$3,026	\$0	\$3,631	\$21,787	\$30
13.2	Site Improvements	\$0	\$2,190	\$2,891	\$0	\$5,081	\$1,016	\$0	\$1,219	\$7,317	\$10
13.3	Site Facilities	\$2,101	\$0	\$2,204	\$0	\$4,305	\$861	\$0	\$1,033	\$6,199	\$9
	Subtotal	\$2,101	\$2,870	\$19,545	\$0	\$24,516	\$4,903	\$0	\$5,884	\$35,303	\$49

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B3XB.1.97	– NGCC X-Class (1×1) – Natural Gas with 97%				Estimate Type:			Conceptual	
Plant Size (MW, net):		715	Advanced CO ₂ Capture				Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$394	\$208	\$0	\$601	\$120	\$0	\$108	\$830	\$1
14.3	Steam Turbine Building	\$0	\$3,188	\$4,241	\$0	\$7,429	\$1,486	\$0	\$1,337	\$10,252	\$14
14.4	Administration Building	\$0	\$372	\$252	\$0	\$624	\$125	\$0	\$112	\$861	\$1
14.5	Circulation Water Pumphouse	\$0	\$81	\$40	\$0	\$122	\$24	\$0	\$22	\$168	\$0
14.6	Water Treatment Buildings	\$0	\$428	\$390	\$0	\$817	\$163	\$0	\$147	\$1,128	\$2
14.7	Machine Shop	\$0	\$558	\$357	\$0	\$915	\$183	\$0	\$165	\$1,262	\$2
14.8	Warehouse	\$0	\$431	\$260	\$0	\$691	\$138	\$0	\$124	\$954	\$1
14.9	Other Buildings & Structures	\$0	\$307	\$223	\$0	\$529	\$106	\$0	\$95	\$730	\$1
14.10	Waste Treating Building & Structures	\$0	\$1,408	\$2,510	\$0	\$3,918	\$784	\$0	\$705	\$5,406	\$8
	Subtotal	\$0	\$7,166	\$8,480	\$0	\$15,646	\$3,129	\$0	\$2,816	\$21,592	\$30
	Total	\$435,804	\$62,575	\$193,933	\$0	\$692,312	\$138,462	\$24,605	\$145,884	\$1,001,264	\$1,401

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-23. Case B3XB.1.97 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$6,217	\$9
1 Month Maintenance Materials	\$1,119	\$2
1 Month Non-fuel Consumables	\$568	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$3,764	\$5
2% of TPC	\$20,025	\$28
Total	\$31,696	\$44
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$747	\$1
0.5% of TPC (spare parts)	\$5,006	\$7
Total	\$5,753	\$8
Other Costs		
Initial Cost for Catalyst and Chemicals	\$643	\$1
Land	\$300	\$0
Other Owner's Costs	\$150,190	\$210
Financing Costs	\$27,034	\$38
Total Overnight Costs (TOC)	\$1,216,879	\$1,703
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$1,329,620	\$1,860

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-24. Case B3XB.1.97 initial and annual operating and maintenance costs

Case:	B3XB.1.97	– NGCC X-Class (1×1) – Natural Gas with 97% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	715	Heat Rate-net (Btu/kWh):	6,528	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.272
Maintenance Labor:					\$7,609,606	\$10.647
Administrative & Support Labor:					\$2,486,949	\$3.480
Property Taxes and Insurance:					\$20,025,279	\$28.019
Total:					\$32,460,024	\$45.417
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$11,414,409	\$2.145
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	3,365	\$1.90	\$0	\$1,983,695	\$0.373
Makeup and Waste Water Treatment Chemicals (ton):	0	10.02	\$550	\$0	\$1,710,543	\$0.321
Ammonia (19 wt%, ton):	0	9.48	\$300	\$0	\$881,966	\$0.166
SCR Catalyst (ft ³):	4,288	2.35	\$150	\$643,158	\$109,337	\$0.021
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,095,601	\$0.206
Triethylene Glycol (gal):	w/equip.	5	\$6.80	\$0	\$10,168	\$0.002
Subtotal:				\$643,158	\$5,791,308	\$1.088
Waste Disposal						
SCR Catalyst (ft ³):	0	2.35	\$2.50	\$0	\$1,822	\$0.000
Triethylene Glycol (gal):	0	5	\$0.35	\$0	\$523	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.92	\$38.0	\$0	\$22,683	\$0.004
Subtotal:				\$0	\$25,028	\$0.005
Variable Operating Costs Total:				\$643,158	\$17,230,746	\$3.238
Fuel Cost						
Natural Gas (MMBtu):	0	111,977	\$4.42	\$0	\$153,561,905	\$28.855
Total:				\$0	\$153,561,905	\$28.855

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

A.4 RETROFIT H-CLASS COST ESTIMATING

Exhibit A-25. Case B32A.1-BR.90 total plant cost details

Case: B32A.1-BR.90		– NGCC H-Class (1×1) – Natural Gas Retrofit with 90% CO ₂ Capture					Estimate Type: Cost Base:			Conceptual Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$6	\$0
3.2	Water Makeup & Pretreating	\$1,290	\$129	\$731	\$0	\$2,150	\$430	\$0	\$516	\$3,095	\$5
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$373	\$711	\$2,303	\$0	\$3,387	\$677	\$0	\$813	\$4,878	\$8
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,228	\$0	\$2,592	\$0	\$6,820	\$1,364	\$0	\$1,637	\$9,821	\$17
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$5,893	\$843	\$5,627	\$0	\$12,363	\$2,473	\$0	\$2,967	\$17,802	\$31
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$89,060	\$42,276	\$88,780	\$0	\$220,116	\$44,023	\$39,621	\$60,752	\$364,513	\$634
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,266	\$3,790	\$10,482	\$0	\$39,538	\$7,908	\$0	\$9,489	\$56,935	\$99
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$196	\$31	\$84	\$0	\$312	\$62	\$0	\$75	\$449	\$1
5.12	Gas Cleanup Foundations	\$0	\$336	\$363	\$0	\$700	\$140	\$0	\$168	\$1,008	\$2
	Subtotal	\$114,522	\$46,434	\$99,710	\$0	\$260,666	\$52,133	\$39,621	\$70,484	\$422,905	\$735
6 Combustion Turbine & Accessories											
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7 HRSG, Ductwork, & Stack											
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$4,993	\$0	\$2,023	\$0	\$7,016	\$1,403	\$0	\$1,263	\$9,683	\$17
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$4,993	\$0	\$2,023	\$0	\$7,016	\$1,403	\$0	\$1,263	\$9,683	\$17
9 Cooling Water System											
9.1	Cooling Towers	\$2,674	\$0	\$816	\$0	\$3,490	\$698	\$0	\$628	\$4,816	\$8
9.2	Circulating Water Pumps	\$354	\$0	\$21	\$0	\$375	\$75	\$0	\$68	\$518	\$1
9.3	Circulating Water System Auxiliaries	\$1,828	\$0	\$241	\$0	\$2,069	\$414	\$0	\$372	\$2,855	\$5
9.4	Circulating Water Piping	\$0	\$633	\$573	\$0	\$1,207	\$241	\$0	\$217	\$1,665	\$3
9.5	Make-Up Water System	\$58	\$0	\$74	\$0	\$132	\$26	\$0	\$24	\$182	\$0
9.6	Component Cooling Water System	\$93	\$0	\$72	\$0	\$165	\$33	\$0	\$30	\$228	\$0
9.7	Circulating Water System Foundations	\$0	\$146	\$243	\$0	\$390	\$78	\$0	\$94	\$561	\$1
	Subtotal	\$5,007	\$780	\$2,040	\$0	\$7,827	\$1,565	\$0	\$1,432	\$10,825	\$19
11 Accessory Electric Plant											

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case: B32A.1-BR.90 – NGCC H-Class (1×1) – Natural Gas Retrofit with 90% CO ₂ Capture		Plant Size (MW, net): 575		Estimate Type: Conceptual		Cost Base: Dec 2018					
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$3,291	\$0	\$282	\$0	\$3,574	\$715	\$0	\$643	\$4,932	\$9
11.3	Switchgear & Motor Control	\$4,699	\$0	\$815	\$0	\$5,515	\$1,103	\$0	\$993	\$7,610	\$13
11.4	Conduit & Cable Tray	\$0	\$1,136	\$3,273	\$0	\$4,408	\$882	\$0	\$794	\$6,084	\$11
11.5	Wire & Cable	\$0	\$1,695	\$3,030	\$0	\$4,726	\$945	\$0	\$851	\$6,522	\$11
11.6	Protective Equipment	\$128	\$0	\$446	\$0	\$575	\$115	\$0	\$103	\$793	\$1
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$8,119	\$2,831	\$7,847	\$0	\$18,797	\$3,759	\$0	\$3,384	\$25,940	\$45
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$190	\$0	\$121	\$0	\$312	\$62	\$0	\$56	\$430	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$305	\$0	\$194	\$0	\$499	\$100	\$0	\$90	\$689	\$1
12.4	Other Major Component Control Equipment	\$515	\$0	\$328	\$0	\$843	\$169	\$42	\$158	\$1,212	\$2
12.5	Signal Processing Equipment	\$427	\$0	\$13	\$0	\$440	\$88	\$0	\$79	\$607	\$1
12.6	Control Boards, Panels & Racks	\$114	\$0	\$69	\$0	\$183	\$37	\$9	\$34	\$263	\$0
12.7	Distributed Control System Equipment	\$6,313	\$0	\$192	\$0	\$6,505	\$1,301	\$325	\$1,220	\$9,351	\$16
12.8	Instrument Wiring & Tubing	\$521	\$417	\$1,668	\$0	\$2,606	\$521	\$130	\$489	\$3,746	\$7
12.9	Other Instrumentation & Controls Equipment	\$361	\$0	\$836	\$0	\$1,197	\$239	\$60	\$224	\$1,721	\$3
	Subtotal	\$8,746	\$417	\$3,422	\$0	\$12,585	\$2,517	\$567	\$2,350	\$18,019	\$31
13 Improvements to Site											
13.1	Site Preparation	\$0	\$159	\$3,380	\$0	\$3,539	\$708	\$0	\$849	\$5,096	\$9
13.2	Site Improvements	\$0	\$512	\$676	\$0	\$1,188	\$238	\$0	\$285	\$1,711	\$3
13.3	Site Facilities	\$491	\$0	\$515	\$0	\$1,007	\$201	\$0	\$242	\$1,450	\$3
	Subtotal	\$491	\$671	\$4,571	\$0	\$5,734	\$1,147	\$0	\$1,376	\$8,257	\$14
14 Buildings & Structures											
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$21	\$10	\$0	\$31	\$6	\$0	\$6	\$43	\$0
14.6	Water Treatment Buildings	\$0	\$99	\$90	\$0	\$189	\$38	\$0	\$34	\$261	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$120	\$101	\$0	\$221	\$44	\$0	\$40	\$305	\$1
	Pre-Retrofit Difficulty Factor Total	\$147,772	\$52,096	\$125,342	\$0	\$325,210	\$65,042	\$40,188	\$83,296	\$513,735	\$893
Retrofit Difficulty Factor:											1.09
Adjusted Total										\$559,971	\$973

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-26. Case B32A.1-BR.90 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$2,806	\$5
1 Month Maintenance Materials	\$574	\$1
1 Month Non-fuel Consumables	\$275	\$0
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$11,199	\$19
Total	\$14,856	\$26
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$432	\$1
0.5% of TPC (spare parts)	\$2,800	\$5
Total	\$3,232	\$6
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$83,996	\$146
Financing Costs	\$15,119	\$26
Total Overnight Costs (TOC)	\$677,174	\$1,097
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$739,912	\$1,286

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-27. Case B32A.1-BR.90 initial and annual operating and maintenance costs

Case:	B32A.1-BR.90	– NGCC H-Class (1×1) – Natural Gas Retrofit with 90% CO ₂ Capture		Cost Base:	Dec 2018
Plant Size (MW, net):	575	Heat Rate-net (Btu/kWh):	6,844	Capacity Factor (%):	85
Operating & Maintenance Labor					
Operating Labor			Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0
Operating Labor Burden:		30.00	% of base	Operator:	2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0
				Lab Techs, etc.:	1.0
				Total:	5.3
Fixed Operating Costs					
				Annual Cost	
				(\$)	(\$/kW-net)
Annual Operating Labor:				\$2,338,190	\$4.065
Maintenance Labor:				\$8,460,551	\$14.708
Administrative & Support Labor:				\$2,699,685	\$4.693
Property Taxes and Insurance:				\$22,264,608	\$38.705
Total:				\$35,763,035	\$62.170
Variable Operating Costs					
				(\$)	(\$/MWh-net)
Maintenance Material:				\$12,690,827	\$2.963
Consumables					
	Initial Fill	Per Day	Per Unit	Initial Fill	
Water (/1000 gallons):	0	2,694	\$1.90	\$0	\$1,588,299
Makeup and Waste Water Treatment Chemicals (ton):	0	8.03	\$550	\$0	\$1,369,592
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,408
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,675,586
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$7,969
Subtotal:				\$637,811	\$5,488,282
Waste Disposal					
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$410
Thermal Reclaimer Unit Waste (ton):	0	1.49	\$38.0	\$0	\$17,562
Subtotal:				\$0	\$19,779
Variable Operating Costs Total:				\$637,811	\$18,198,888
Fuel Cost					
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562
Total:				\$0	\$129,568,562

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-28. Case B32A.1-BR.95 total plant cost details

Case:		B32A.1-BR.95	– NGCC H-Class (1x1) – Natural Gas Retrofit with 95% CO ₂ Capture				Estimate Type:			Conceptual	
Plant Size (MW, net):		571					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3		Feedwater & Miscellaneous BOP Systems									
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$6	\$0
3.2	Water Makeup & Pretreating	\$1,315	\$132	\$745	\$0	\$2,192	\$438	\$0	\$526	\$3,156	\$6
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$379	\$724	\$2,345	\$0	\$3,448	\$690	\$0	\$828	\$4,965	\$9
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,297	\$0	\$2,634	\$0	\$6,930	\$1,386	\$0	\$1,663	\$9,980	\$17
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$5,993	\$858	\$5,725	\$0	\$12,576	\$2,515	\$0	\$3,018	\$18,109	\$32
5		Flue Gas Cleanup									
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$92,966	\$43,833	\$92,049	\$0	\$228,848	\$45,770	\$41,193	\$63,162	\$378,972	\$663
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,828	\$3,874	\$10,715	\$0	\$40,418	\$8,084	\$0	\$9,700	\$58,202	\$102
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$205	\$33	\$88	\$0	\$326	\$65	\$0	\$78	\$469	\$1
5.12	Gas Cleanup Foundations	\$0	\$351	\$379	\$0	\$730	\$146	\$0	\$175	\$1,052	\$2
	Subtotal	\$119,000	\$48,091	\$103,231	\$0	\$270,322	\$54,064	\$41,193	\$73,116	\$438,695	\$768
6		Combustion Turbine & Accessories									
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7		HRSG, Ductwork, & Stack									
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8		Steam Turbine & Accessories									
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$5,185	\$0	\$2,101	\$0	\$7,287	\$1,457	\$0	\$1,312	\$10,056	\$18
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$5,185	\$0	\$2,101	\$0	\$7,287	\$1,457	\$0	\$1,312	\$10,056	\$18
9		Cooling Water System									
9.1	Cooling Towers	\$2,722	\$0	\$830	\$0	\$3,552	\$710	\$0	\$639	\$4,902	\$9
9.2	Circulating Water Pumps	\$361	\$0	\$21	\$0	\$382	\$76	\$0	\$69	\$527	\$1
9.3	Circulating Water System Auxiliaries	\$1,859	\$0	\$245	\$0	\$2,104	\$421	\$0	\$379	\$2,904	\$5
9.4	Circulating Water Piping	\$0	\$644	\$583	\$0	\$1,228	\$246	\$0	\$221	\$1,694	\$3
9.5	Make-Up Water System	\$59	\$0	\$76	\$0	\$135	\$27	\$0	\$24	\$186	\$0
9.6	Component Cooling Water System	\$95	\$0	\$73	\$0	\$168	\$34	\$0	\$30	\$232	\$0
9.7	Circulating Water System Foundations	\$0	\$149	\$247	\$0	\$397	\$79	\$0	\$95	\$571	\$1
	Subtotal	\$5,095	\$793	\$2,076	\$0	\$7,965	\$1,593	\$0	\$1,457	\$11,015	\$19
11		Accessory Electric Plant									
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$3,446	\$0	\$296	\$0	\$3,742	\$748	\$0	\$674	\$5,164	\$9

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32A.1-BR.95 – NGCC H-Class (1×1) – Natural Gas Retrofit with 95% CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		571					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.3	Switchgear & Motor Control	\$4,921	\$0	\$854	\$0	\$5,775	\$1,155	\$0	\$1,039	\$7,969	\$14
11.4	Conduit & Cable Tray	\$0	\$1,189	\$3,427	\$0	\$4,616	\$923	\$0	\$831	\$6,370	\$11
11.5	Wire & Cable	\$0	\$1,775	\$3,173	\$0	\$4,949	\$990	\$0	\$891	\$6,829	\$12
11.6	Protective Equipment	\$135	\$0	\$467	\$0	\$602	\$120	\$0	\$108	\$831	\$1
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$8,502	\$2,964	\$8,217	\$0	\$19,683	\$3,937	\$0	\$3,543	\$27,163	\$48
12		Instrumentation & Control									
12.1	Natural Gas Combined Cycle Control Equipment	\$199	\$0	\$127	\$0	\$326	\$65	\$0	\$59	\$450	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$319	\$0	\$203	\$0	\$522	\$104	\$0	\$94	\$721	\$1
12.4	Other Major Component Control Equipment	\$539	\$0	\$343	\$0	\$882	\$176	\$44	\$165	\$1,268	\$2
12.5	Signal Processing Equipment	\$446	\$0	\$14	\$0	\$460	\$92	\$0	\$83	\$635	\$1
12.6	Control Boards, Panels & Racks	\$119	\$0	\$73	\$0	\$192	\$38	\$10	\$36	\$275	\$0
12.7	Distributed Control System Equipment	\$6,604	\$0	\$201	\$0	\$6,805	\$1,361	\$340	\$1,276	\$9,782	\$17
12.8	Instrument Wiring & Tubing	\$545	\$436	\$1,745	\$0	\$2,726	\$545	\$136	\$511	\$3,918	\$7
12.9	Other Instrumentation & Controls Equipment	\$378	\$0	\$874	\$0	\$1,252	\$250	\$63	\$235	\$1,800	\$3
	Subtotal	\$9,149	\$436	\$3,579	\$0	\$13,165	\$2,633	\$593	\$2,459	\$18,849	\$33
13		Improvements to Site									
13.1	Site Preparation	\$0	\$164	\$3,485	\$0	\$3,649	\$730	\$0	\$876	\$5,255	\$9
13.2	Site Improvements	\$0	\$528	\$697	\$0	\$1,226	\$245	\$0	\$294	\$1,765	\$3
13.3	Site Facilities	\$507	\$0	\$532	\$0	\$1,038	\$208	\$0	\$249	\$1,495	\$3
	Subtotal	\$507	\$692	\$4,714	\$0	\$5,913	\$1,183	\$0	\$1,419	\$8,515	\$15
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$21	\$11	\$0	\$32	\$6	\$0	\$6	\$44	\$0
14.6	Water Treatment Buildings	\$0	\$101	\$92	\$0	\$193	\$39	\$0	\$35	\$266	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$122	\$103	\$0	\$225	\$45	\$0	\$40	\$310	\$1
	Pre-Retrofit Difficulty Factor Total	\$153,432	\$53,957	\$129,746	\$0	\$337,135	\$67,427	\$41,785	\$86,364	\$532,711	\$933
Retrofit Difficulty Factor:										1.09	
Adjusted Total										\$580,655	\$1,017

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-29. Case B32A.1-BR.95 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$2,896	\$5
1 Month Maintenance Materials	\$595	\$1
1 Month Non-fuel Consumables	\$284	\$0
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$11,613	\$20
Total	\$15,390	\$27
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$449	\$1
0.5% of TPC (spare parts)	\$2,903	\$5
Total	\$3,352	\$6
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$87,098	\$152
Financing Costs	\$15,678	\$27
Total Overnight Costs (TOC)	\$702,174	\$1,145
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$767,228	\$1,343

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-30. Case B32A.1-BR.95 initial and annual operating and maintenance costs

Case:	B32A.1-BR.95	– NGCC H-Class (1×1) – Natural Gas Retrofit with 95% CO ₂ Capture		Cost Base:	Dec 2018
Plant Size (MW, net):	571	Heat Rate-net (Btu/kWh):	6,892	Capacity Factor (%):	85
Operating & Maintenance Labor					
Operating Labor			Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0
Operating Labor Burden:		30.00	% of base	Operator:	2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0
				Lab Techs, etc.:	1.0
				Total:	5.3
Fixed Operating Costs					
				Annual Cost	
				(\$)	(\$/kW-net)
Annual Operating Labor:				\$2,338,190	\$4.094
Maintenance Labor:				\$8,604,771	\$15.065
Administrative & Support Labor:				\$2,735,740	\$4.790
Property Taxes and Insurance:				\$22,644,135	\$39.644
Total:				\$36,322,837	\$63.592
Variable Operating Costs					
				(\$)	(\$/MWh-net)
Maintenance Material:				\$12,907,157	\$3.035
Consumables					
	Initial Fill	Per Day	Per Unit	Initial Fill	
Water (/1000 gallons):	0	2,716	\$1.90	\$0	\$1,600,897
Makeup and Waste Water Treatment Chemicals (ton):	0	8.09	\$550	\$0	\$1,380,455
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,509
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,748,781
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,411
Subtotal:				\$637,811	\$5,585,481
Waste Disposal					
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$433
Thermal Reclaimer Unit Waste (ton):	0	1.56	\$38.0	\$0	\$18,361
Subtotal:				\$0	\$20,601
Variable Operating Costs Total:				\$637,811	\$18,513,240
Fuel Cost					
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562
Total:				\$0	\$129,568,562

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-31. Case B32A.1-BR.97 total plant cost details

Case:		B32A.1-BR.97 – NGCC H-Class (1×1) – Natural Gas Retrofit with 97% CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		568					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$5	\$0
3.2	Water Makeup & Pretreating	\$1,336	\$134	\$757	\$0	\$2,226	\$445	\$0	\$534	\$3,206	\$6
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$385	\$734	\$2,377	\$0	\$3,496	\$699	\$0	\$839	\$5,034	\$9
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,246	\$0	\$2,602	\$0	\$6,849	\$1,370	\$0	\$1,644	\$9,862	\$17
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$5,968	\$870	\$5,738	\$0	\$12,576	\$2,515	\$0	\$3,018	\$18,109	\$32
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$95,217	\$44,913	\$94,317	\$0	\$234,446	\$46,889	\$42,200	\$64,707	\$388,243	\$684
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$26,051	\$3,908	\$10,807	\$0	\$40,766	\$8,153	\$0	\$9,784	\$58,703	\$103
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$209	\$33	\$90	\$0	\$332	\$66	\$0	\$80	\$478	\$1
5.12	Gas Cleanup Foundations	\$0	\$357	\$386	\$0	\$742	\$148	\$0	\$178	\$1,069	\$2
	Subtotal	\$121,476	\$49,211	\$105,599	\$0	\$276,286	\$55,257	\$42,200	\$74,749	\$448,493	\$790
6 Combustion Turbine & Accessories											
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7 HRSG, Ductwork, & Stack											
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$5,357	\$0	\$2,171	\$0	\$7,528	\$1,506	\$0	\$1,355	\$10,388	\$18
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$5,357	\$0	\$2,171	\$0	\$7,528	\$1,506	\$0	\$1,355	\$10,388	\$18
9 Cooling Water System											
9.1	Cooling Towers	\$2,759	\$0	\$842	\$0	\$3,601	\$720	\$0	\$648	\$4,970	\$9
9.2	Circulating Water Pumps	\$366	\$0	\$22	\$0	\$387	\$77	\$0	\$70	\$534	\$1
9.3	Circulating Water System Auxiliaries	\$1,884	\$0	\$249	\$0	\$2,132	\$426	\$0	\$384	\$2,942	\$5
9.4	Circulating Water Piping	\$0	\$653	\$591	\$0	\$1,244	\$249	\$0	\$224	\$1,717	\$3
9.5	Make-Up Water System	\$60	\$0	\$77	\$0	\$136	\$27	\$0	\$25	\$188	\$0
9.6	Component Cooling Water System	\$96	\$0	\$74	\$0	\$170	\$34	\$0	\$31	\$235	\$0
9.7	Circulating Water System Foundations	\$0	\$151	\$251	\$0	\$402	\$80	\$0	\$96	\$579	\$1
	Subtotal	\$5,165	\$804	\$2,105	\$0	\$8,073	\$1,615	\$0	\$1,477	\$11,165	\$20
11 Accessory Electric Plant											
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$3,536	\$0	\$303	\$0	\$3,839	\$768	\$0	\$691	\$5,298	\$9

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		B32A.1-BR.97 568 – NGCC H-Class (1×1) – Natural Gas Retrofit with 97% CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):							Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.3	Switchgear & Motor Control	\$5,049	\$0	\$876	\$0	\$5,925	\$1,185	\$0	\$1,066	\$8,176	\$14
11.4	Conduit & Cable Tray	\$0	\$1,220	\$3,516	\$0	\$4,736	\$947	\$0	\$853	\$6,536	\$12
11.5	Wire & Cable	\$0	\$1,821	\$3,256	\$0	\$5,077	\$1,015	\$0	\$914	\$7,007	\$12
11.6	Protective Equipment	\$138	\$0	\$479	\$0	\$618	\$124	\$0	\$111	\$852	\$2
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$8,723	\$3,042	\$8,431	\$0	\$20,195	\$4,039	\$0	\$3,635	\$27,869	\$49
12		Instrumentation & Control									
12.1	Natural Gas Combined Cycle Control Equipment	\$204	\$0	\$130	\$0	\$334	\$67	\$0	\$60	\$461	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$327	\$0	\$208	\$0	\$535	\$107	\$0	\$96	\$739	\$1
12.4	Other Major Component Control Equipment	\$553	\$0	\$352	\$0	\$904	\$181	\$45	\$170	\$1,300	\$2
12.5	Signal Processing Equipment	\$458	\$0	\$14	\$0	\$472	\$94	\$0	\$85	\$651	\$1
12.6	Control Boards, Panels & Racks	\$122	\$0	\$74	\$0	\$196	\$39	\$10	\$37	\$282	\$0
12.7	Distributed Control System Equipment	\$6,772	\$0	\$206	\$0	\$6,978	\$1,396	\$349	\$1,308	\$10,031	\$18
12.8	Instrument Wiring & Tubing	\$559	\$447	\$1,789	\$0	\$2,795	\$559	\$140	\$524	\$4,018	\$7
12.9	Other Instrumentation & Controls Equipment	\$387	\$0	\$897	\$0	\$1,284	\$257	\$64	\$241	\$1,846	\$3
	Subtotal	\$9,382	\$447	\$3,670	\$0	\$13,499	\$2,700	\$608	\$2,521	\$19,328	\$34
13		Improvements to Site									
13.1	Site Preparation	\$0	\$167	\$3,547	\$0	\$3,714	\$743	\$0	\$891	\$5,348	\$9
13.2	Site Improvements	\$0	\$538	\$710	\$0	\$1,247	\$249	\$0	\$299	\$1,796	\$3
13.3	Site Facilities	\$516	\$0	\$541	\$0	\$1,057	\$211	\$0	\$254	\$1,522	\$3
	Subtotal	\$516	\$705	\$4,798	\$0	\$6,018	\$1,204	\$0	\$1,444	\$8,666	\$15
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$22	\$11	\$0	\$32	\$6	\$0	\$6	\$45	\$0
14.6	Water Treatment Buildings	\$0	\$103	\$94	\$0	\$196	\$39	\$0	\$35	\$271	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$124	\$104	\$0	\$228	\$46	\$0	\$41	\$315	\$1
	Pre-Retrofit Difficulty Factor Total	\$156,586	\$55,202	\$132,615	\$0	\$344,404	\$68,881	\$42,808	\$88,241	\$544,333	\$958
Retrofit Difficulty Factor:										1.09	
Adjusted Total										\$593,323	\$1,045

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-32. Case B32A.1-BR.97 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$2,951	\$5
1 Month Maintenance Materials	\$608	\$1
1 Month Non-fuel Consumables	\$293	\$1
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$11,866	\$21
Total	\$15,721	\$28
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$465	\$1
0.5% of TPC (spare parts)	\$2,967	\$5
Total	\$3,431	\$6
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$88,999	\$157
Financing Costs	\$16,020	\$28
Total Overnight Costs (TOC)	\$717,494	\$1,177
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$783,968	\$1,380

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-33. Case B32A.1-BR.97 initial and annual operating and maintenance costs

Case:	B32A.1-BR.97	– NGCC H-Class (1×1) – Natural Gas Retrofit with 97% CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	568	Heat Rate-net (Btu/kWh):	6,931	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:	1.0	
Operating Labor Burden:		30.00	% of base	Operator:	2.3	
Labor O-H Charge Rate:		25.00	% of labor	Foreman:	1.0	
				Lab Techs, etc.:	1.0	
				Total:	5.3	
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$4.116
Maintenance Labor:					\$8,693,098	\$15.304
Administrative & Support Labor:					\$2,757,822	\$4.855
Property Taxes and Insurance:					\$22,876,574	\$40.275
Total:					\$36,665,684	\$64.551
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$13,039,647	\$3.083
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,733	\$1.90	\$0	\$1,611,097	\$0.381
Makeup and Waste Water Treatment Chemicals (ton):	0	8.14	\$550	\$0	\$1,389,251	\$0.328
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,423	\$0.175
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.026
CO ₂ Capture System Chemicals ^A :	Proprietary				\$1,822,394	\$0.431
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,589	\$0.002
Subtotal:				\$637,811	\$5,678,181	\$1.343
Waste Disposal						
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$442	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.63	\$38.0	\$0	\$19,159	\$0.005
Subtotal:				\$0	\$21,408	\$0.005
Variable Operating Costs Total:				\$637,811	\$18,739,236	\$4.431
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$30.635
Total:				\$0	\$129,568,562	\$30.635

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

A.5 ADVANCED RETROFIT H-CLASS COST ESTIMATING

Exhibit A-34. Case Adv B32A.1-BR.90 total plant cost details

Case:		Adv B32A.1-BR.90	– NGCC H-Class (1×1) – Natural Gas Retrofit with 90% Advanced CO ₂ Capture				Estimate Type:			Conceptual	
Plant Size (MW, net):		594					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$6	\$0
3.2	Water Makeup & Pretreating	\$1,390	\$139	\$787	\$0	\$2,316	\$463	\$0	\$556	\$3,335	\$6
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$408	\$778	\$2,520	\$0	\$3,705	\$741	\$0	\$889	\$5,336	\$9
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,222	\$0	\$2,588	\$0	\$6,809	\$1,362	\$0	\$1,634	\$9,806	\$16
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$6,021	\$919	\$5,896	\$0	\$12,836	\$2,567	\$0	\$3,080	\$18,484	\$31
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$44,407	\$21,073	\$44,254	\$0	\$109,735	\$21,947	\$19,752	\$30,287	\$181,721	\$306
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,266	\$3,790	\$10,482	\$0	\$39,538	\$7,908	\$0	\$9,489	\$56,935	\$96
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$196	\$31	\$84	\$0	\$312	\$62	\$0	\$75	\$449	\$1
5.12	Gas Cleanup Foundations	\$0	\$336	\$363	\$0	\$700	\$140	\$0	\$168	\$1,008	\$2
	Subtotal	\$69,870	\$25,231	\$55,184	\$0	\$150,285	\$30,057	\$19,752	\$40,019	\$240,112	\$404
6 Combustion Turbine & Accessories											
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7 HRSG, Ductwork, & Stack											
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$3,890	\$0	\$1,576	\$0	\$5,466	\$1,093	\$0	\$984	\$7,543	\$13
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$3,890	\$0	\$1,576	\$0	\$5,466	\$1,093	\$0	\$984	\$7,543	\$13
9 Cooling Water System											
9.1	Cooling Towers	\$2,925	\$0	\$892	\$0	\$3,817	\$763	\$0	\$687	\$5,268	\$9
9.2	Circulating Water Pumps	\$388	\$0	\$23	\$0	\$411	\$82	\$0	\$74	\$567	\$1
9.3	Circulating Water System Auxiliaries	\$1,945	\$0	\$257	\$0	\$2,201	\$440	\$0	\$396	\$3,037	\$5
9.4	Circulating Water Piping	\$0	\$683	\$619	\$0	\$1,302	\$260	\$0	\$234	\$1,796	\$3
9.5	Make-Up Water System	\$60	\$0	\$77	\$0	\$138	\$28	\$0	\$25	\$190	\$0
9.6	Component Cooling Water System	\$101	\$0	\$77	\$0	\$178	\$36	\$0	\$32	\$246	\$0
9.7	Circulating Water System Foundations	\$0	\$158	\$262	\$0	\$420	\$84	\$0	\$101	\$605	\$1
	Subtotal	\$5,418	\$841	\$2,207	\$0	\$8,467	\$1,693	\$0	\$1,549	\$11,709	\$20
11 Accessory Electric Plant											

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case: Adv B32A.1-BR.90		– NGCC H-Class (1×1) – Natural Gas Retrofit with 90% Advanced CO ₂ Capture					Estimate Type: Conceptual			Dec 2018	
Plant Size (MW, net): 594							Cost Base:				
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$2,738	\$0	\$235	\$0	\$2,973	\$595	\$0	\$535	\$4,103	\$7
11.3	Switchgear & Motor Control	\$3,910	\$0	\$678	\$0	\$4,588	\$918	\$0	\$826	\$6,332	\$11
11.4	Conduit & Cable Tray	\$0	\$945	\$2,723	\$0	\$3,668	\$734	\$0	\$660	\$5,062	\$9
11.5	Wire & Cable	\$0	\$1,411	\$2,521	\$0	\$3,932	\$786	\$0	\$708	\$5,426	\$9
11.6	Protective Equipment	\$107	\$0	\$371	\$0	\$478	\$96	\$0	\$86	\$660	\$1
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$6,755	\$2,355	\$6,529	\$0	\$15,640	\$3,128	\$0	\$2,815	\$21,583	\$36
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$160	\$0	\$102	\$0	\$262	\$52	\$0	\$47	\$362	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$257	\$0	\$163	\$0	\$420	\$84	\$0	\$76	\$580	\$1
12.4	Other Major Component Control Equipment	\$434	\$0	\$276	\$0	\$710	\$142	\$35	\$133	\$1,020	\$2
12.5	Signal Processing Equipment	\$359	\$0	\$11	\$0	\$370	\$74	\$0	\$67	\$511	\$1
12.6	Control Boards, Panels & Racks	\$96	\$0	\$58	\$0	\$154	\$31	\$8	\$29	\$222	\$0
12.7	Distributed Control System Equipment	\$5,313	\$0	\$162	\$0	\$5,475	\$1,095	\$274	\$1,027	\$7,871	\$13
12.8	Instrument Wiring & Tubing	\$439	\$351	\$1,404	\$0	\$2,193	\$439	\$110	\$411	\$3,153	\$5
12.9	Other Instrumentation & Controls Equipment	\$304	\$0	\$704	\$0	\$1,007	\$201	\$50	\$189	\$1,448	\$2
	Subtotal	\$7,361	\$351	\$2,880	\$0	\$10,592	\$2,118	\$477	\$1,978	\$15,166	\$26
13 Improvements to Site											
13.1	Site Preparation	\$0	\$241	\$5,109	\$0	\$5,350	\$1,070	\$0	\$1,284	\$7,704	\$13
13.2	Site Improvements	\$0	\$774	\$1,022	\$0	\$1,797	\$359	\$0	\$431	\$2,587	\$4
13.3	Site Facilities	\$743	\$0	\$779	\$0	\$1,522	\$304	\$0	\$365	\$2,192	\$4
	Subtotal	\$743	\$1,015	\$6,911	\$0	\$8,668	\$1,734	\$0	\$2,080	\$12,483	\$21
14 Buildings & Structures											
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$23	\$11	\$0	\$35	\$7	\$0	\$6	\$48	\$0
14.6	Water Treatment Buildings	\$0	\$106	\$97	\$0	\$203	\$41	\$0	\$37	\$280	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$129	\$108	\$0	\$238	\$48	\$0	\$43	\$328	\$1
	Pre-Retrofit Difficulty Factor Total	\$100,059	\$30,842	\$81,291	\$0	\$212,192	\$42,438	\$20,229	\$52,549	\$327,408	\$551
Retrofit Difficulty Factor:										1.09	
Adjusted Total										\$356,875	\$600

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-35. Case Adv B32A.1-BR.90 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$1,920	\$3
1 Month Maintenance Materials	\$366	\$1
1 Month Non-fuel Consumables	\$206	\$0
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$7,137	\$12
Total	\$9,632	\$16
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$282	\$0
0.5% of TPC (spare parts)	\$1,784	\$3
Total	\$2,066	\$3
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$53,531	\$90
Financing Costs	\$9,636	\$16
Total Overnight Costs (TOC)	\$431,739	\$677
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$471,739	\$794

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-36. Case Adv B32A.1-BR.90 initial and annual operating and maintenance costs

Case:	Adv B32A.1-BR.90	– NGCC H-Class (1×1) – Natural Gas Retrofit with 90% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	594	Heat Rate-net (Btu/kWh):	6,624	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.934
Maintenance Labor:					\$7,044,466	\$11.852
Administrative & Support Labor:					\$2,345,664	\$3.947
Property Taxes and Insurance:					\$18,538,068	\$31.190
Total:					\$30,266,388	\$50.923
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$10,566,699	\$2.388
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,807	\$1.90	\$0	\$1,654,564	\$0.374
Makeup and Waste Water Treatment Chemicals (ton):	0	8.36	\$550	\$0	\$1,426,733	\$0.322
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,409	\$0.167
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO ₂ Capture System Chemicals ^A :	Proprietary				\$851,324	\$0.192
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$7,969	\$0.002
Subtotal:				\$637,811	\$4,787,426	\$1.082
Waste Disposal						
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$410	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.49	\$38.0	\$0	\$17,562	\$0.004
Subtotal:				\$0	\$19,779	\$0.004
Variable Operating Costs Total:				\$637,811	\$15,373,904	\$3.474
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$29.277
Total:				\$0	\$129,568,562	\$29.277

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-37. Case Adv B32A.1-BR.95 total plant cost details

Case:		Adv B32A.1-BR.95 – NGCC H-Class (1×1) – Natural Gas Retrofit with 95% Advanced CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		591					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$6	\$0
3.2	Water Makeup & Pretreating	\$1,422	\$142	\$806	\$0	\$2,370	\$474	\$0	\$569	\$3,413	\$6
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$417	\$796	\$2,576	\$0	\$3,788	\$758	\$0	\$909	\$5,455	\$9
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,293	\$0	\$2,631	\$0	\$6,923	\$1,385	\$0	\$1,662	\$9,970	\$17
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$6,133	\$940	\$6,014	\$0	\$13,087	\$2,617	\$0	\$3,141	\$18,845	\$32
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$46,349	\$21,846	\$45,876	\$0	\$114,071	\$22,814	\$20,533	\$31,483	\$188,901	\$319
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$25,828	\$3,874	\$10,715	\$0	\$40,418	\$8,084	\$0	\$9,700	\$58,202	\$98
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$205	\$33	\$88	\$0	\$326	\$65	\$0	\$78	\$469	\$1
5.12	Gas Cleanup Foundations	\$0	\$351	\$379	\$0	\$730	\$146	\$0	\$175	\$1,052	\$2
	Subtotal	\$72,383	\$26,104	\$57,058	\$0	\$155,545	\$31,109	\$20,533	\$41,437	\$248,624	\$420
6 Combustion Turbine & Accessories											
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7 HRSG, Ductwork, & Stack											
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$4,040	\$0	\$1,637	\$0	\$5,677	\$1,135	\$0	\$1,022	\$7,834	\$13
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$4,040	\$0	\$1,637	\$0	\$5,677	\$1,135	\$0	\$1,022	\$7,834	\$13
9 Cooling Water System											
9.1	Cooling Towers	\$2,990	\$0	\$912	\$0	\$3,902	\$780	\$0	\$702	\$5,385	\$9
9.2	Circulating Water Pumps	\$397	\$0	\$23	\$0	\$420	\$84	\$0	\$76	\$580	\$1
9.3	Circulating Water System Auxiliaries	\$1,984	\$0	\$262	\$0	\$2,245	\$449	\$0	\$404	\$3,099	\$5
9.4	Circulating Water Piping	\$0	\$698	\$632	\$0	\$1,329	\$266	\$0	\$239	\$1,834	\$3
9.5	Make-Up Water System	\$62	\$0	\$79	\$0	\$141	\$28	\$0	\$25	\$194	\$0
9.6	Component Cooling Water System	\$103	\$0	\$79	\$0	\$182	\$36	\$0	\$33	\$251	\$0
9.7	Circulating Water System Foundations	\$0	\$161	\$268	\$0	\$429	\$86	\$0	\$103	\$618	\$1
	Subtotal	\$5,535	\$859	\$2,255	\$0	\$8,649	\$1,730	\$0	\$1,583	\$11,961	\$20
11 Accessory Electric Plant											
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$2,865	\$0	\$246	\$0	\$3,110	\$622	\$0	\$560	\$4,292	\$7

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		Adv B32A.1-BR.95 591 – NGCC H-Class (1×1) – Natural Gas Retrofit with 95% Advanced CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):							Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.3	Switchgear & Motor Control	\$4,090	\$0	\$710	\$0	\$4,800	\$960	\$0	\$864	\$6,624	\$11
11.4	Conduit & Cable Tray	\$0	\$988	\$2,848	\$0	\$3,837	\$767	\$0	\$691	\$5,295	\$9
11.5	Wire & Cable	\$0	\$1,476	\$2,638	\$0	\$4,113	\$823	\$0	\$740	\$5,676	\$10
11.6	Protective Equipment	\$112	\$0	\$388	\$0	\$500	\$100	\$0	\$90	\$690	\$1
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$7,067	\$2,464	\$6,830	\$0	\$16,361	\$3,272	\$0	\$2,945	\$22,578	\$38
12		Instrumentation & Control									
12.1	Natural Gas Combined Cycle Control Equipment	\$167	\$0	\$107	\$0	\$274	\$55	\$0	\$49	\$378	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$268	\$0	\$171	\$0	\$439	\$88	\$0	\$79	\$606	\$1
12.4	Other Major Component Control Equipment	\$453	\$0	\$289	\$0	\$742	\$148	\$37	\$139	\$1,066	\$2
12.5	Signal Processing Equipment	\$375	\$0	\$11	\$0	\$387	\$77	\$0	\$70	\$534	\$1
12.6	Control Boards, Panels & Racks	\$100	\$0	\$61	\$0	\$161	\$32	\$8	\$30	\$232	\$0
12.7	Distributed Control System Equipment	\$5,553	\$0	\$169	\$0	\$5,722	\$1,144	\$286	\$1,073	\$8,225	\$14
12.8	Instrument Wiring & Tubing	\$458	\$367	\$1,467	\$0	\$2,292	\$458	\$115	\$430	\$3,295	\$6
12.9	Other Instrumentation & Controls Equipment	\$317	\$0	\$735	\$0	\$1,053	\$211	\$53	\$197	\$1,513	\$3
	Subtotal	\$7,693	\$367	\$3,010	\$0	\$11,070	\$2,214	\$498	\$2,067	\$15,849	\$27
13		Improvements to Site									
13.1	Site Preparation	\$0	\$263	\$5,574	\$0	\$5,836	\$1,167	\$0	\$1,401	\$8,404	\$14
13.2	Site Improvements	\$0	\$845	\$1,115	\$0	\$1,960	\$392	\$0	\$470	\$2,823	\$5
13.3	Site Facilities	\$810	\$0	\$850	\$0	\$1,661	\$332	\$0	\$399	\$2,391	\$4
	Subtotal	\$810	\$1,107	\$7,539	\$0	\$9,457	\$1,891	\$0	\$2,270	\$13,618	\$23
14		Buildings & Structures									
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$24	\$12	\$0	\$36	\$7	\$0	\$6	\$49	\$0
14.6	Water Treatment Buildings	\$0	\$109	\$99	\$0	\$208	\$42	\$0	\$37	\$287	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$132	\$111	\$0	\$243	\$49	\$0	\$44	\$336	\$1
	Pre-Retrofit Difficulty Factor Total	\$103,661	\$31,973	\$84,454	\$0	\$220,088	\$44,018	\$21,031	\$54,508	\$339,645	\$574
Retrofit Difficulty Factor:										1.09	
Adjusted Total										\$370,213	\$626

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-38. Case Adv B32A.1-BR.95 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$1,979	\$3
1 Month Maintenance Materials	\$380	\$1
1 Month Non-fuel Consumables	\$213	\$0
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$7,404	\$13
Total	\$9,977	\$17
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$292	\$0
0.5% of TPC (spare parts)	\$1,851	\$3
Total	\$2,143	\$4
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$55,532	\$94
Financing Costs	\$9,996	\$17
Total Overnight Costs (TOC)	\$447,861	\$706
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$489,354	\$828

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-39. Case Adv B32A.1-BR.95 initial and annual operating and maintenance costs

Case:	Adv B32A.1-BR.95	– NGCC H-Class (1×1) – Natural Gas Retrofit with 95% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	591	Heat Rate-net (Btu/kWh):	6,657		Capacity Factor (%):	85
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.954
Maintenance Labor:					\$7,137,464	\$12.070
Administrative & Support Labor:					\$2,368,914	\$4.006
Property Taxes and Insurance:					\$18,782,801	\$31.763
Total:					\$30,627,368	\$51.793
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$10,706,196	\$2.431
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,837	\$1.90	\$0	\$1,672,106	\$0.380
Makeup and Waste Water Treatment Chemicals (ton):	0	8.45	\$550	\$0	\$1,441,859	\$0.327
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,509	\$0.168
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO ₂ Capture System Chemicals ^A :	Proprietary				\$888,150	\$0.202
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,411	\$0.002
Subtotal:				\$637,811	\$4,857,464	\$1.103
Waste Disposal						
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$433	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.56	\$38.0	\$0	\$18,361	\$0.004
Subtotal:				\$0	\$20,601	\$0.005
Variable Operating Costs Total:				\$637,811	\$15,584,261	\$3.539
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$29.426
Total:				\$0	\$129,568,562	\$29.426

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-40. Case Adv B32A.1-BR.97 total plant cost details

Case:		Adv B32A.1-BR.97 – NGCC H-Class (1×1) – Natural Gas Retrofit with 97% Advanced CO ₂ Capture					Estimate Type:			Conceptual	
Plant Size (MW, net):		589					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
3 Feedwater & Miscellaneous BOP Systems											
3.1	Feedwater System	\$1	\$2	\$1	\$0	\$4	\$1	\$0	\$1	\$5	\$0
3.2	Water Makeup & Pretreating	\$1,449	\$145	\$821	\$0	\$2,414	\$483	\$0	\$579	\$3,477	\$6
3.3	Other Feedwater Subsystems	\$1	\$0	\$0	\$0	\$1	\$0	\$0	\$0	\$1	\$0
3.4	Service Water Systems	\$424	\$809	\$2,621	\$0	\$3,855	\$771	\$0	\$925	\$5,551	\$9
3.5	Other Boiler Plant Systems	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$1	\$0
3.6	Natural Gas Pipeline and Start-Up System	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
3.7	Waste Water Treatment Equipment	\$4,243	\$0	\$2,600	\$0	\$6,843	\$1,369	\$0	\$1,642	\$9,854	\$17
3.9	Miscellaneous Plant Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$6,117	\$957	\$6,044	\$0	\$13,118	\$2,624	\$0	\$3,148	\$18,889	\$32
5 Flue Gas Cleanup											
5.1	CANSOLV Carbon Dioxide (CO ₂) Removal System	\$47,465	\$22,381	\$46,999	\$0	\$116,845	\$23,369	\$21,032	\$32,249	\$193,495	\$328
5.4	Carbon Dioxide (CO ₂) Compression & Drying	\$26,051	\$3,908	\$10,807	\$0	\$40,766	\$8,153	\$0	\$9,784	\$58,703	\$100
5.5	Carbon Dioxide (CO ₂) Compressor Aftercooler	\$209	\$33	\$90	\$0	\$332	\$66	\$0	\$80	\$478	\$1
5.12	Gas Cleanup Foundations	\$0	\$357	\$386	\$0	\$742	\$148	\$0	\$178	\$1,069	\$2
	Subtotal	\$73,724	\$26,678	\$58,282	\$0	\$158,685	\$31,737	\$21,032	\$42,291	\$253,745	\$431
6 Combustion Turbine & Accessories											
6.1-6.5	Combustion Turbine & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
7 HRSG, Ductwork, & Stack											
7.1-7.6	HRSG, Ductwork, & Stack	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8 Steam Turbine & Accessories											
8.1	Steam Turbine Generator & Accessories	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.2	Steam Turbine Plant Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.3	Condenser & Auxiliaries	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
8.4	Steam Piping	\$4,173	\$0	\$1,691	\$0	\$5,864	\$1,173	\$0	\$1,056	\$8,093	\$14
8.5	Turbine Generator Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$4,173	\$0	\$1,691	\$0	\$5,864	\$1,173	\$0	\$1,056	\$8,093	\$14
9 Cooling Water System											
9.1	Cooling Towers	\$3,043	\$0	\$928	\$0	\$3,971	\$794	\$0	\$715	\$5,480	\$9
9.2	Circulating Water Pumps	\$404	\$0	\$24	\$0	\$428	\$86	\$0	\$77	\$590	\$1
9.3	Circulating Water System Auxiliaries	\$2,015	\$0	\$266	\$0	\$2,281	\$456	\$0	\$411	\$3,147	\$5
9.4	Circulating Water Piping	\$0	\$709	\$642	\$0	\$1,351	\$270	\$0	\$243	\$1,865	\$3
9.5	Make-Up Water System	\$63	\$0	\$80	\$0	\$143	\$29	\$0	\$26	\$197	\$0
9.6	Component Cooling Water System	\$105	\$0	\$80	\$0	\$185	\$37	\$0	\$33	\$255	\$0
9.7	Circulating Water System Foundations	\$0	\$164	\$272	\$0	\$436	\$87	\$0	\$105	\$628	\$1
	Subtotal	\$5,628	\$873	\$2,293	\$0	\$8,794	\$1,759	\$0	\$1,609	\$12,163	\$21
11 Accessory Electric Plant											
11.1	Generator Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.2	Station Service Equipment	\$2,928	\$0	\$251	\$0	\$3,179	\$636	\$0	\$572	\$4,388	\$7

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Case:		Adv B32A.1-BR.97 589					Estimate Type:			Conceptual	
Plant Size (MW, net):		– NGCC H-Class (1×1) – Natural Gas Retrofit with 97% Advanced CO ₂ Capture					Cost Base:			Dec 2018	
Item No.	Description	Equipment Cost	Material Cost	Labor		Bare Erected Cost	Eng'g CM H.O. & Fee	Contingencies		Total Plant Cost	
				Direct	Indirect			Process	Project	\$/1,000	\$/kW
11.3	Switchgear & Motor Control	\$4,181	\$0	\$725	\$0	\$4,906	\$981	\$0	\$883	\$6,771	\$11
11.4	Conduit & Cable Tray	\$0	\$1,010	\$2,912	\$0	\$3,922	\$784	\$0	\$706	\$5,412	\$9
11.5	Wire & Cable	\$0	\$1,508	\$2,696	\$0	\$4,205	\$841	\$0	\$757	\$5,802	\$10
11.6	Protective Equipment	\$114	\$0	\$397	\$0	\$511	\$102	\$0	\$92	\$706	\$1
11.7	Standby Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.8	Main Power Transformers	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
11.9	Electrical Foundations	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$7,224	\$2,519	\$6,982	\$0	\$16,724	\$3,345	\$0	\$3,010	\$23,079	\$39
12 Instrumentation & Control											
12.1	Natural Gas Combined Cycle Control Equipment	\$171	\$0	\$109	\$0	\$280	\$56	\$0	\$50	\$386	\$1
12.2	Combustion Turbine Control Equipment	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
12.3	Steam Turbine Control Equipment	\$274	\$0	\$175	\$0	\$449	\$90	\$0	\$81	\$619	\$1
12.4	Other Major Component Control Equipment	\$463	\$0	\$295	\$0	\$758	\$152	\$38	\$142	\$1,089	\$2
12.5	Signal Processing Equipment	\$384	\$0	\$12	\$0	\$395	\$79	\$0	\$71	\$545	\$1
12.6	Control Boards, Panels & Racks	\$102	\$0	\$62	\$0	\$165	\$33	\$8	\$31	\$237	\$0
12.7	Distributed Control System Equipment	\$5,674	\$0	\$173	\$0	\$5,847	\$1,169	\$292	\$1,096	\$8,405	\$14
12.8	Instrument Wiring & Tubing	\$468	\$375	\$1,499	\$0	\$2,342	\$468	\$117	\$439	\$3,367	\$6
12.9	Other Instrumentation & Controls Equipment	\$324	\$0	\$751	\$0	\$1,076	\$215	\$54	\$202	\$1,546	\$3
	Subtotal	\$7,861	\$375	\$3,075	\$0	\$11,311	\$2,262	\$509	\$2,112	\$16,195	\$27
13 Improvements to Site											
13.1	Site Preparation	\$0	\$278	\$5,911	\$0	\$6,189	\$1,238	\$0	\$1,485	\$8,912	\$15
13.2	Site Improvements	\$0	\$896	\$1,183	\$0	\$2,079	\$416	\$0	\$499	\$2,993	\$5
13.3	Site Facilities	\$859	\$0	\$902	\$0	\$1,761	\$352	\$0	\$423	\$2,536	\$4
	Subtotal	\$859	\$1,174	\$7,995	\$0	\$10,029	\$2,006	\$0	\$2,407	\$14,441	\$25
14 Buildings & Structures											
14.1	Combustion Turbine Area	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.3	Steam Turbine Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.4	Administration Building	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.5	Circulation Water Pumphouse	\$0	\$24	\$12	\$0	\$36	\$7	\$0	\$7	\$50	\$0
14.6	Water Treatment Buildings	\$0	\$111	\$101	\$0	\$211	\$42	\$0	\$38	\$292	\$0
14.7	Machine Shop	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.8	Warehouse	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.9	Other Buildings & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
14.10	Waste Treating Building & Structures	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Subtotal	\$0	\$135	\$113	\$0	\$248	\$50	\$0	\$45	\$342	\$1
	Pre-Retrofit Difficulty Factor Total	\$105,588	\$32,711	\$86,475	\$0	\$224,773	\$44,955	\$21,541	\$55,678	\$346,947	\$589
										Retrofit Difficulty Factor:	
										1.09	
										Adjusted Total	\$642

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-41. Case Adv B32A.1-BR.97 owner's costs

Description	\$/1,000	\$/kW
Pre-Production Costs		
6 Months All Labor	\$2,013	\$3
1 Month Maintenance Materials	\$388	\$1
1 Month Non-fuel Consumables	\$219	\$0
1 Month Waste Disposal	\$2	\$0
25% of 1 Months Fuel Cost at 100% CF	\$0	\$0
2% of TPC	\$7,563	\$13
Total	\$10,186	\$17
Inventory Capital		
60-Day Supply of Fuel and Consumables at 100% CF	\$302	\$1
0.5% of TPC (spare parts)	\$1,891	\$3
Total	\$2,193	\$4
Other Costs		
Initial Cost for Catalyst and Chemicals	\$0	\$0
Land	\$0	\$0
Other Owner's Costs	\$56,726	\$96
Financing Costs	\$10,211	\$17
Total Overnight Costs (TOC)	\$457,487	\$723
TASC Multiplier (IOU, 33 year)	1.093	
Total As-Spent Cost (TASC)	\$499,871	\$848

COST AND PERFORMANCE ESTIMATES FOR STATE-OF-THE-ART AND ADVANCED 1×1 H-CLASS NATURAL GAS-FIRED POWER PLANTS, TECHNOTE

Exhibit A-42. Case Adv B32A.1-BR.97 initial and annual operating and maintenance costs

Case:	Adv B32A.1-BR.97	– NGCC H-Class (1×1) – Natural Gas Retrofit with 97% Advanced CO ₂ Capture			Cost Base:	Dec 2018
Plant Size (MW, net):	589	Heat Rate-net (Btu/kWh):	6,681	Capacity Factor (%):	85	
Operating & Maintenance Labor						
Operating Labor				Operating Labor Requirements per Shift		
Operating Labor Rate (base):		38.50	\$/hour	Skilled Operator:		1.0
Operating Labor Burden:		30.00	% of base	Operator:		2.3
Labor O-H Charge Rate:		25.00	% of labor	Foreman:		1.0
				Lab Techs, etc.:		1.0
				Total:		5.3
Fixed Operating Costs						
					Annual Cost	
					(\$)	(\$/kW-net)
Annual Operating Labor:					\$2,338,190	\$3.968
Maintenance Labor:					\$7,192,960	\$12.207
Administrative & Support Labor:					\$2,382,787	\$4.044
Property Taxes and Insurance:					\$18,928,842	\$32.123
Total:					\$30,842,780	\$52.342
Variable Operating Costs						
					(\$)	(\$/MWh-net)
Maintenance Material:					\$10,789,440	\$2.459
Consumables						
	Initial Fill	Per Day	Per Unit	Initial Fill		
Water (/1000 gallons):	0	2,861	\$1.90	\$0	\$1,686,402	\$0.384
Makeup and Waste Water Treatment Chemicals (ton):	0	8.52	\$550	\$0	\$1,454,187	\$0.331
Ammonia (19 wt%, ton):	0	7.93	\$300	\$0	\$738,423	\$0.168
SCR Catalyst (ft ³):	4,252	2.33	\$150	\$637,811	\$108,428	\$0.025
CO ₂ Capture System Chemicals ^A :	Proprietary				\$925,395	\$0.211
Triethylene Glycol (gal):	w/equip.	4	\$6.80	\$0	\$8,589	\$0.002
Subtotal:				\$637,811	\$4,921,424	\$1.122
Waste Disposal						
SCR Catalyst (ft ³):	0	2.33	\$2.50	\$0	\$1,807	\$0.000
Triethylene Glycol (gal):	0	4	\$0.35	\$0	\$442	\$0.000
Thermal Reclaimer Unit Waste (ton):	0	1.63	\$38.0	\$0	\$19,159	\$0.004
Subtotal:				\$0	\$21,408	\$0.005
Variable Operating Costs Total:				\$637,811	\$15,732,272	\$3.586
Fuel Cost						
Natural Gas (MMBtu):	0	94,481	\$4.42	\$0	\$129,568,562	\$29.531
Total:				\$0	\$129,568,562	\$29.531

^ACO₂ Capture System Chemicals includes NaOH and CANSOLV Solvent

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