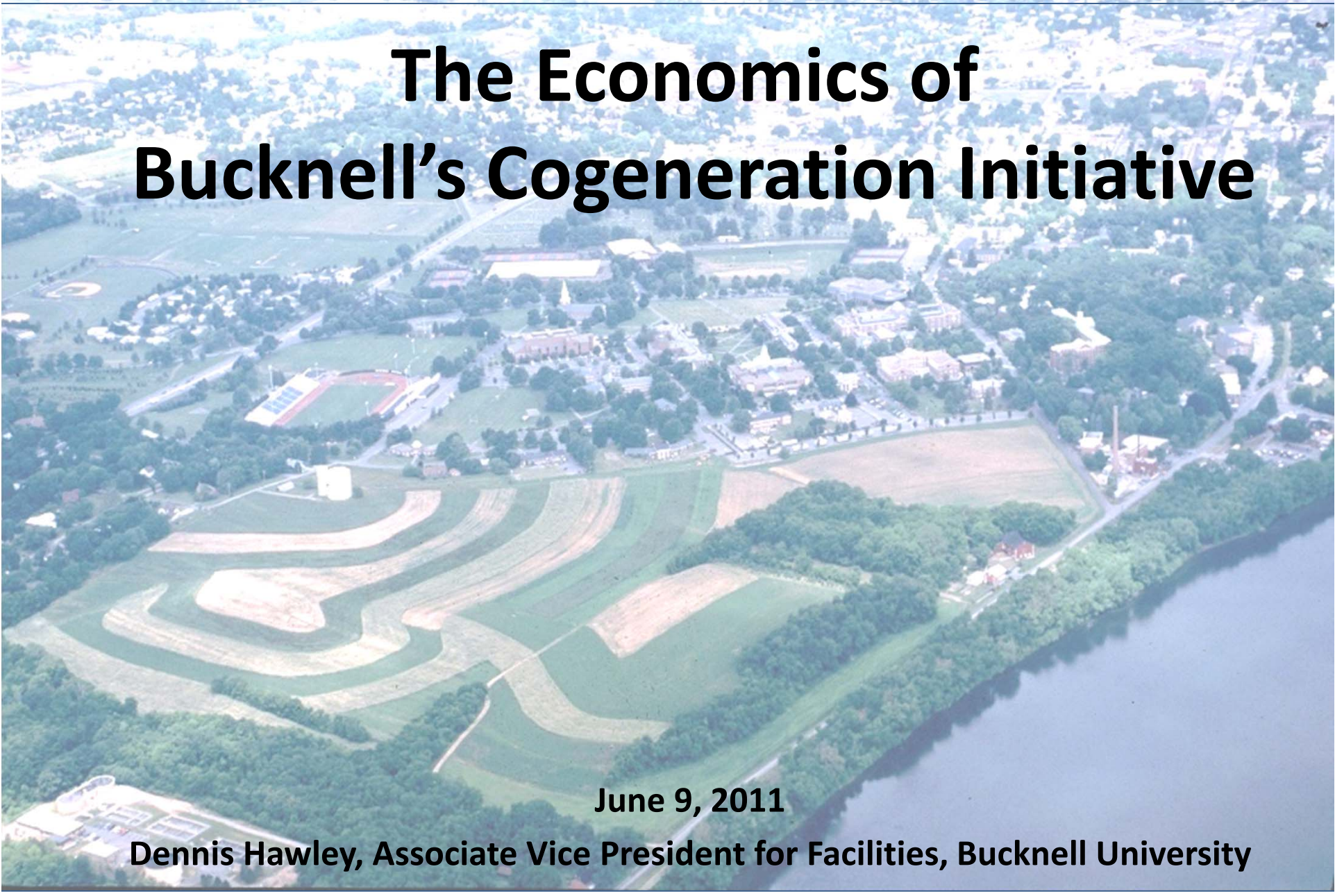


An aerial photograph of the Bucknell University campus. The image shows a mix of green spaces, including a large golf course in the foreground with several sand traps, and various academic and athletic buildings. There are also baseball fields and other sports facilities visible. The campus is surrounded by trees and is situated near a body of water on the right side. The text "The Economics of Bucknell's Cogeneration Initiative" is overlaid in large, bold, black letters across the upper portion of the image.

The Economics of Bucknell's Cogeneration Initiative

June 9, 2011

Dennis Hawley, Associate Vice President for Facilities, Bucknell University

Bucknell University

- Private undergraduate university established 1846
- Located on the Susquehanna River 60 miles north of Harrisburg in rural Central PA
- 3600 students; 3000 reside on campus
- 1200 faculty and staff
- 550 acres
- 165 buildings totaling over 2.6 million gsf

Historical Context

Before 1998

- Coal plant built in 1949 (replaced earlier coal plant)
- Supplied all campus steam for:
 - Heat
 - Cooling (steam absorption process)
 - Domestic hot water
 - Cooking
- Electricity
 - 80% purchased
 - 20% generated with back-pressure turbine generator

Coal Plant

- Three 25,000 pph stoker fired boilers
 - 2 operating, 1 standby
- Operated on mix of anthracite and bituminous coal
- 50,000 pph maximum steam capacity (2 boilers)
- One 850 KW back-pressure steam turbine generator

Since 1998

- Gas turbine based cogeneration plant
- Supplies all campus steam for:
 - Heat
 - Cooling (steam absorption process)
 - Domestic hot water
 - Cooking
- Electricity
 - 5% purchased: wind-based renewable energy credits
 - 95% generated: gas & back-pressure turbine generators

Cogeneration Plant

- One 5 MW gas turbine powered generator
- One 70,000 pph Waste Heat Recovery Boiler
- Two 70,000 pph standard gas/oil boilers
- One 1.2 MW back-pressure turbine generator
- One diesel generator for plant emergency power/dark start capability

Comparing Plant Metrics

Coal Plant-1992

- Campus size: 2.1 million gsf
- Used 22,500 tons of coal at \$40/ton
- 350 million pounds of steam
- Generated 4.3 million kwh
- Purchased 23.3 million kwh
- Exported no electricity
- Net Energy cost \$2.2 million

Cogeneration Plant-2004

- Campus size: 2.6 million gsf
- Used 600,000 DTH natural gas at \$3.60/DTH
- 270 million pounds of steam
- Generated 44 million kwh
- Purchased 2.5 million kwh
- Exported 5.2 million kwh
- Net Energy cost \$2.4 million

BU Power Plant Emissions

Annual Emissions (ton/yr)	1996	2004	Percent Reduction
NO _x	94.7	22.5	76%
CO	112.3	7.6	93%
VOC	0.9	0.44	51%
TSP	100.4	1.2	99%
SO _x	703.7	0.16	99.98%

The Elements of the Initiative

Project Goals

- I. **Provide the long term least cost plant** when considering all costs such as capital investment, yearly operating expenses and fuel costs.
- II. **Maximize the efficiency of the overall energy conversion process** through the application of appropriate concepts and technologies.
- III. **Minimize the impact on the environment** while providing a facility that will meet the tightening regulatory requirements without major modifications or expense.
- IV. **Provide for the long term energy needs**, including equipment for maintenance backup and redundancy for breakdowns.
- V. **Provide fuel flexibility** to be able to respond to changing supply and cost factors.

Electric and Thermal Load Balance Considerations

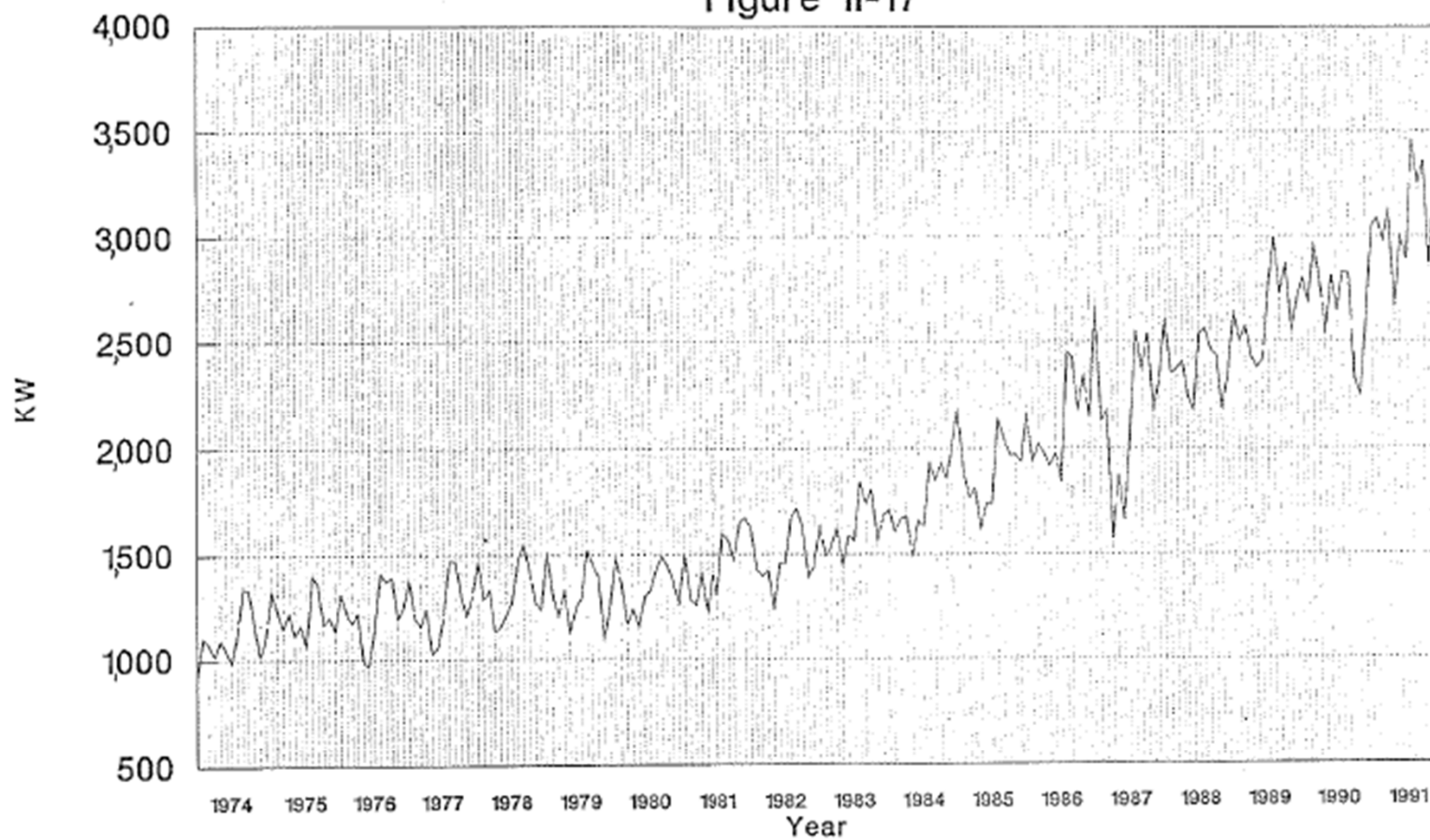
- Onsite thermal load determines size of electric generation capabilities-must be able to use all of waste heat generated
- Daily and Seasonal Load profile variations need to be analyzed-averages do not suffice
- Future load growth/reductions need to be projected
- Electric production should replace purchased power or sold at rates above generation costs

Comparative Fuel Efficiencies

for providing 100 units of energy

Energy	Coal	Natural Gas	Cogeneration NG
Fuel	152	102	116
Electric	48	48	0
Total	200	150	116
Efficiency	50%	66%	86%

Bucknell University
Historical Average KW Usage
1974 - 1991
Figure II-17



LUTZ, DAILY & BRAIN
Consulting Engineers

TABLE II-9

BUCKNELL UNIVERSITY
STEAM LOAD GROWTH PROJECTIONS
FOR ECONOMIC SENSITIVITY ANALYSIS

Year	Demand, lb/hr		Usage, Million lbs	
	1% Growth	3.5% Growth	1% Growth	3.5% Growth
1991	-	-	287*	287*
1992	60,200*	60,200*	290	297
1993	60,800	62,300	293	307
1994	67,300**	70,400**	320***	342***
1995	68,000	72,900	323	354
1996	68,700	75,500	326	366
1997	69,400	78,100	329	379
1998	70,100	80,800	332	392
1999	70,800	83,600	335	406
2000	71,500	86,500	338	420
2001	72,200	89,500	341	435
2002	72,900	92,600	344	450
2003	73,600	95,800	347	466
2004	74,300	99,200	350	482
2005	75,000	102,700	354	499
2006	75,800	106,300	358	516
2007	76,600	110,000	362	534
2008	77,400	113,900	366	553
2009	78,200	117,900	370	572
2010	79,000	122,000	374	592

* Actual steam data.

** An increase of 5,880 lbs/hr in peak demand for additions listed in the University's long range plans has been included.

***Usage addition for the University's long range plans is added. Addition is based on actual and is calculated as follows:

$$\frac{287,000,000 \text{ lbs in 1991}}{1,842,000 \text{ ft}^2 \text{ connected}} = 155.8 \text{ lb/ft}^2$$

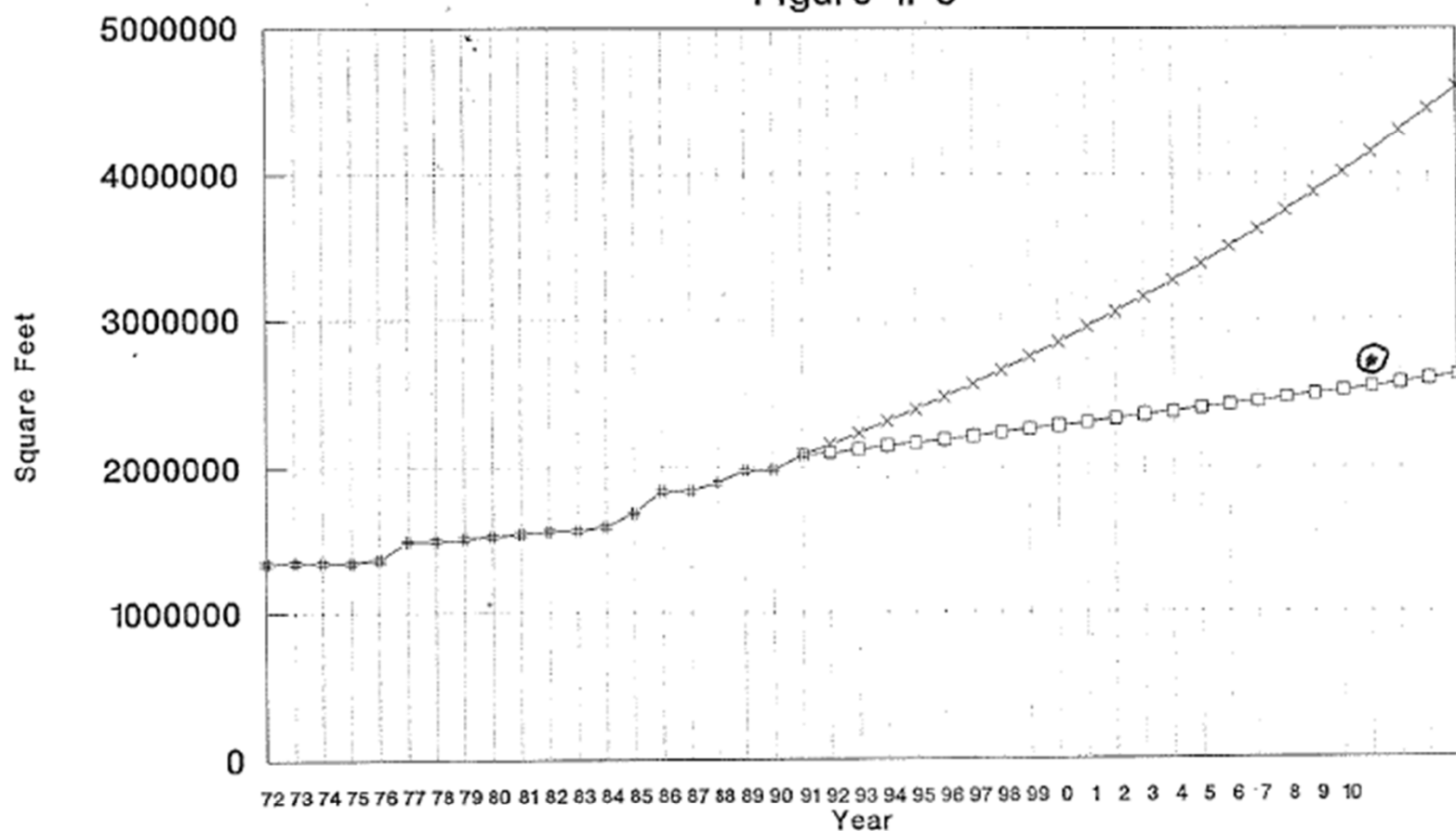
$$155.8 \text{ lb/ft}^2 \cdot 155,500 \text{ ft}^2 = 24,200,000 \text{ lb}$$

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II-19

BUCKNELL UNIVERSITY Building Square Footage Figure II-3



—+— Hist. Sq.Feet

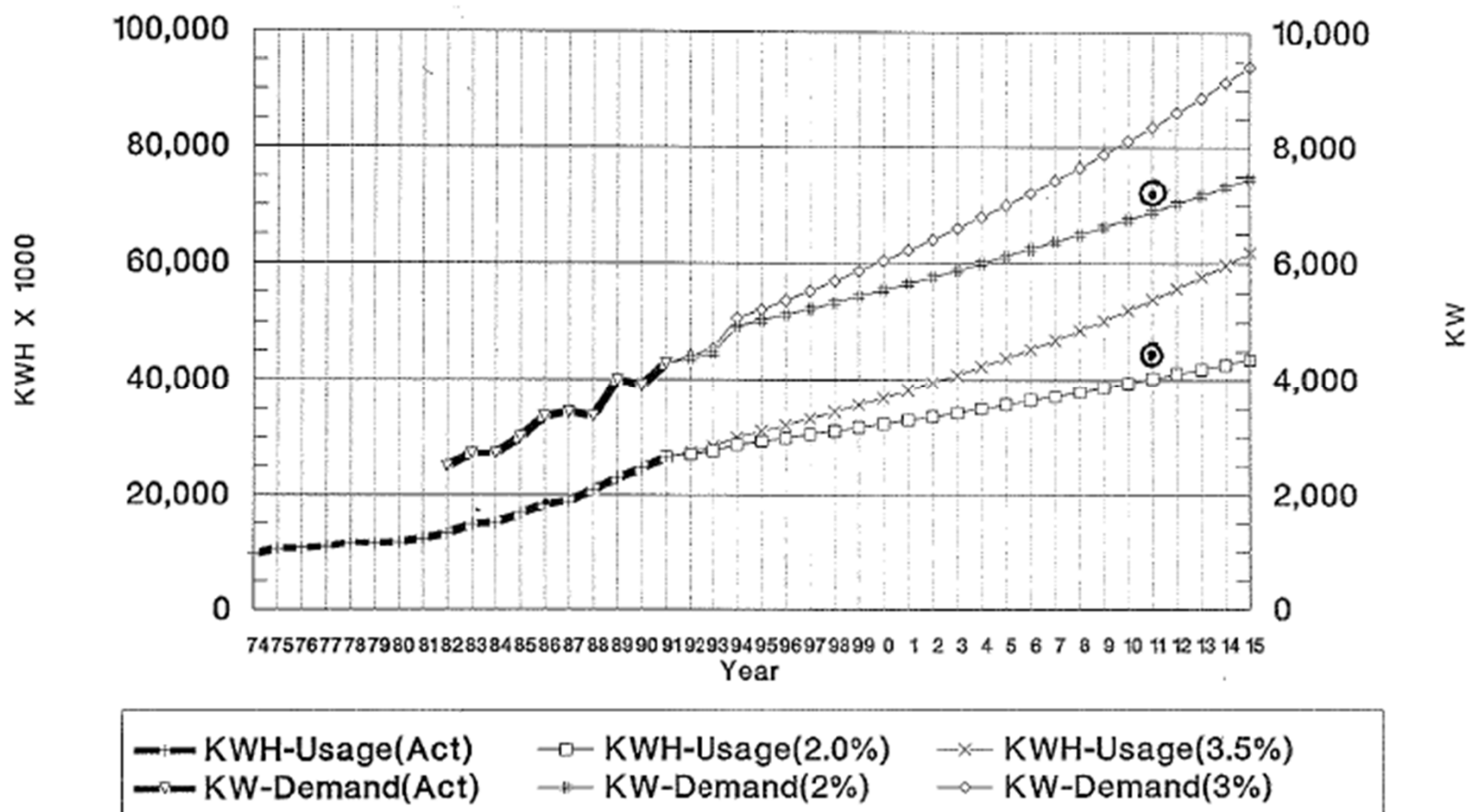
—□— Future 1% Growth

—x— Future 3.5% Growth

LUTZ, DAILY & BRAIN
Consulting Engineers

Bucknell University Historical & Predicted Electric Usages

Figure II-18



LUTZ, DAILY & BRAIN
Consulting Engineers

TABLE IV-1

BUCKNELL UNIVERSITY
STEAM SYSTEM SUPPLY OPTIONS - INITIAL CONSIDERATIONS

Option No.	Alternative	Steam Output Size Range, Pounds Per Hour (pph)	Steam Generating Unit Steam Outlet Conditions	Comments
1	Natural gas & No. 2 fuel oil fired packaged water tube boilers	25,000 to 70,000	175 psig/sat'd	Steam conditions of these boilers are the same as the existing boilers. Unit sizes less than 50,000 pph require too many units at the plant site. Installation of new back pressure turbine (BPT) in range of 1,000 to 2,000 kw will be considered.
2	Natural gas & No. 2 fuel oil fired high pressure packaged water tube boilers	25,000 to 70,000	600 psig/sat'd & 600 psig/600 F	Steam conditions are higher than existing boilers' steam conditions. Options are being studied to determine feasibility of new, more efficient BPTs in the range of 1,400 to 3,000 kw.
3	Fluidized bed coal fired boiler	70,000 to 100,000	600 psig/600 F or higher	This 8,000 to 10,000 kw cogeneration option is estimated to cost over \$29,000,000.
4	Stoker fired boilers firing coal.	25,000 to 70,000	175 psig/sat'd	This option like Option No. 3 is very capital intensive due to current environmental allowable emission limits. No further study will be given to this option.
5	Diesel Engine Generators (DEG) with heat recovery steam generators (HRSG)	1500 to 3000 kw	---	Indiana University has DEGs with HRSGs. 6,000 kw DEG generates only 11,000 pph of steam. Electric output to steam output ratio is unsuitable for meeting Bucknell University's needs. No further study will be given to this option.
6	Upgrading existing boilers steam output	--	175 psig/sat'd	The boiler manufacturer, Tampella Power, as well as our firm, do not believe that this option is feasible especially in light of the lower cost of lower grade coals.
7	Conversion of existing boilers to fire natural gas & No. 2 fuel oil	--	175 psig/sat'd	Construction cost estimate is in the range of \$200,000 to \$250,000 on each boiler plus ancillary equipment costs. Conversion costs are too high in relation to cost of new boilers to merit further consideration.
8	3,300 kw natural gas & No. 2 fuel oil fired cogeneration (Cogen) plant addition, combustion turbine (CT) with HRSG.	70,000*	175 psig/sat'd	A Cogen plant configuration that is very similar to this one has been installed at Baylor University, Waco, TX. Merits further study. Will be analyzed with additional BPTs.

* Approximately 25,000 pph of steam can be generated without supplemental firing of HRSG at full CT output. The 70,000 pph steam capability requires supplemental firing of natural gas and No. 2 fuel oil.

LUTZ, DAILY & BRAIN
CONSULTING ENGINEERS

TABLE IV-5

BUCKNELL UNIVERSITY CAPABILITY ANALYSIS

2/10/1993

PLAN 70C: ADD GAS/OIL COMBUSTION TURBINE GENERATORS AND PACKAGE BOILER; RETIRE & DEMOLISH EXISTING COAL FIRED BOILERS
(3.34/YR STEAM LOAD GROWTH; 3.0%/YR ELECTRIC LOAD GROWTH)

FISCAL YEAR	IMPROVEMENTS	STEAM SYSTEM								ELECTRIC SYSTEM								
		COLD STEAM		SYSTEM CAPABILITY, 1000 LB/HR						SYSTEM CAPABILITY, 1000 KW					PROJECTED PURCHASE POWER 1000 KW			
		PEAK STEAM DEMAND 1000 LB/HR	PEAK STEAM DEMAND 1000 LB/HR	EXISTING		PLANNED		LARGEST UNIT	FIRM CAPACITY	EXCESS	FISCAL YEAR	PEAK ELECTRIC DEMAND 1000 KW	EXISTING			PLANNED	LARGEST UNIT	FIRM CAPACITY
1992		60.2	69.8	75.0	.0	25.0	50.0	(19.8)	1992	4.41	.85	.0	.85	.00	4.41			
1993		62.3	72.3	75.0	.0	25.0	50.0	(22.3)	1993	4.54	.85	.0	.85	.00	4.54			
1994		70.4	81.7	75.0	.0	25.0	50.0	(31.7)	1994	5.05	.85	.0	.85	.00	5.05			
1995	ADD TWO 3.3MW CT W/70,000 LB/HR HRSG's WITH A 70,000 LB/HR GAS/OIL PKG BOILER AND TWO 2MW BP STEAM TURBINES. RETIRE AND REMOVE EXISTING COAL FIRED BOILERS.	72.9	84.6	.0	210.0	70.0	140.0	55.4	1995	5.20	.85	10.6	3.30	5.23	(.03)			
1996		75.5	87.6	.0	210.0	70.0	140.0	52.4	1996	5.36	.85	10.6	3.30	5.30	.06			
1997		78.1	90.6	.0	210.0	70.0	140.0	49.4	1997	5.52	.85	10.6	3.30	5.36	.10			
1998		80.8	93.7	.0	210.0	70.0	140.0	46.3	1998	5.69	.85	10.6	3.30	5.44	.25			
1999		83.6	97.0	.0	210.0	70.0	140.0	43.0	1999	5.86	.85	10.6	3.30	5.51	.35			
2000		86.5	100.3	.0	210.0	70.0	140.0	39.7	2000	6.04	.85	10.6	3.30	5.59	.45			
2001		89.5	103.8	.0	210.0	70.0	140.0	36.2	2001	6.22	.85	10.6	3.30	5.67	.55			
2002		92.6	107.4	.0	210.0	70.0	140.0	32.6	2002	6.41	.85	10.6	3.30	5.75	.66			
2003		95.8	111.1	.0	210.0	70.0	140.0	28.9	2003	6.60	.85	10.6	3.30	5.83	.77			
2004		99.2	115.1	.0	210.0	70.0	140.0	24.9	2004	6.80	.85	10.6	3.30	5.92	.88			
2005		102.7	119.1	.0	210.0	70.0	140.0	20.9	2005	7.01	.85	10.6	3.30	6.01	1.00			
2006		106.3	123.3	.0	210.0	70.0	140.0	16.7	2006	7.22	.85	10.6	3.30	6.11	1.11			
2007		110.0	127.6	.0	210.0	70.0	140.0	12.4	2007	7.44	.85	10.6	3.30	6.21	1.23			
2008		113.9	132.1	.0	210.0	70.0	140.0	7.9	2008	7.66	.85	10.6	3.30	6.31	1.35			
2009		117.9	136.8	.0	210.0	70.0	140.0	3.2	2009	7.89	.85	10.6	3.30	6.42	1.47			
2010		122.0	141.5	.0	210.0	70.0	140.0	(1.5)	2010	8.13	.85	10.6	3.30	6.52	1.61			

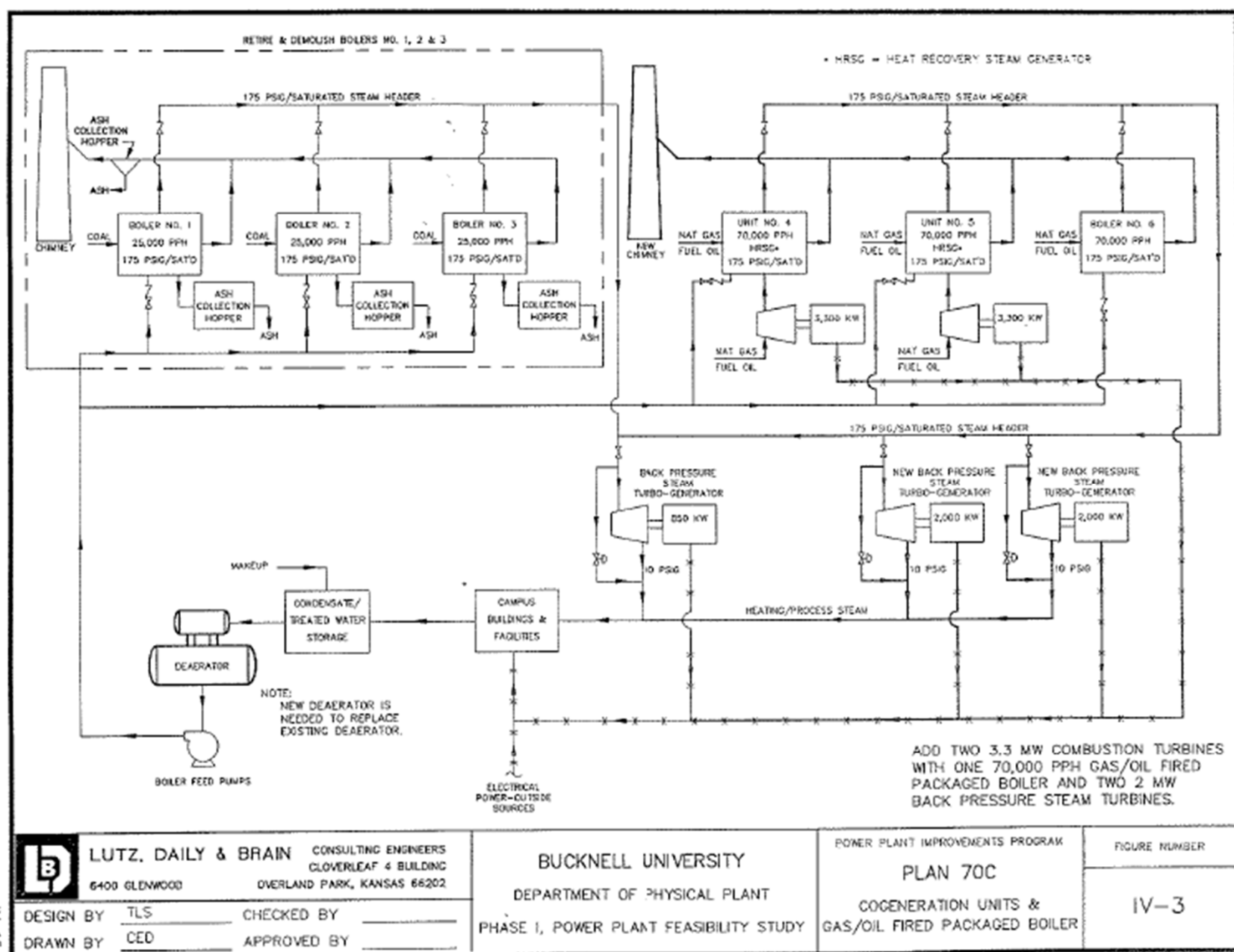


TABLE VI-2
BUCKNELL UNIVERSITY
CONSTRUCTION COST ESTIMATE FOR PLAN 70B
(TWO 70,000 PPH FLUIDIZED BED BOILERS)
(ONE 70,000 PPH GAS/OIL BOILER, TWO 2MW BPT'S)
(RETIRE AND REMOVE EXISTING COAL FIRED BOILERS)
(IN OPERATION - 1997)

ITEM	ESTIMATED COST, \$
A. EQUIPMENT	
1. TWO 70,000 PPH ACFB COAL FIRED BOILERS & BAGHOUSES (DELIVERED & ERECTED [D&E])	\$9,600,000
2. ONE 70,000 PPH GAS/OIL PKG BOILER	500,000
3. TWO 2 MW BPT'S	1,042,000
4. DISTRIBUTED CONTROL SYSTEM	700,000
5. 140,000 PPH DEAERATOR	100,000
6. ASH HANDLING EQUIPMENT (D&E)	860,000
7. COAL HANDLING EQUIPMENT (D&E)	780,000
8. CONTINUOUS EMISSIONS MONITORING EQUIPMENT	250,000
9. MECHANICAL AUXILIARIES	340,000
10. ELECTRICAL EQUIPMENT	500,000
B. DEMOLITION & REMOVAL	
1. ASBESTOS REMOVAL	100,000
2. POWER PLANT STRUCTURE	100,000
3. WAREHOUSE (RELOCATED)	500,000
C. INSTALLATION	
1. MISCELLANEOUS FOUNDATIONS & SITE WORK	400,000
2. NEW POWER PLANT BUILDING w/ SUBSTRUCTURE, STRUCTURAL STEEL, SUPERSTRUCTURE & PAINTING	3,450,000
4. POWER PIPING	1,420,000
5. POWER WIRING & CONTROLS	1,130,000
6. RENTAL BOILERS, DEAERATOR & PUMPS	360,000
7. OIL STORAGE TANK AND BERM	50,000
D. PERMITTING	160,000
E. SALES TAX (6% OF MATERIAL COSTS)	630,000
	=====
SUBTOTAL	\$22,972,000
ESCALATION ALLOWANCE (10%)	2,297,000
	=====
SUBTOTAL	\$25,269,000
ENGINEERING & CONTINGENCY (15%)	3,790,000
	=====
TOTAL INSTALLED COST	\$29,059,000

TABLE VI-3
BUCKNELL UNIVERSITY
CONSTRUCTION COST ESTIMATE FOR PLAN 70C
(TWO COMBUSTION TURBINES (CT) WITH HEAT RECOVERY STEAM GENERATORS (HRSG))
(ONE GAS/OIL FIRED BOILER, TWO BPT'S, IN EXISTING BUILDING)
(RETIRE AND REMOVE EXISTING COAL FIRED BOILERS)
(IN OPERATION - 1995)

ITEM	ESTIMATED COST, \$
A. EQUIPMENT	
1. TWO 3.3MW COMBUSTION TURBINES(CT) W/ 70,000 PPH HRSG'S	\$5,600,000
2. ONE 70,000 PPH GAS/OIL PACKAGED BOILER & COMBUSTION CONTROLS	500,000
3. INSTRUMENTS & CONTROLS	150,000
4. 140,000 PPH DEAERATOR	100,000
5. BOILER FEED PUMPS	20,000
6. TWO 2MW BACKPRESSURE TURBOGENERATORS (BPT)	1,042,000
B. DEMOLITION & REMOVAL	
1. ASBESTOS REMOVAL	100,000
2. DEMOLITION & REMOVAL OF EXISTING BOILERS	100,000
C. INSTALLATION	
1. REPAIRS TO EXISTING BUILDING STRUCTURE FROM REMOVAL OF EXISTING BOILERS & INSTALLATION OF NEW EQUIPMENT	50,000
2. MISCELLANEOUS FOUNDATIONS & SITE WORK	75,000
3. INSTALLATION OF CT'S, NEW BOILER, BPT'S, MECHANICAL EQUIPMENT, POWER PIPING, WIRING & CONTROLS	1,300,000
4. RENTAL BOILERS, DEAERATOR & PUMPS	360,000
5. OIL STORAGE TANK AND BERM	100,000
D. PERMITTING	25,000
E. SALES TAX (6% OF MATERIAL COSTS)	457,000
	=====
SUBTOTAL	\$9,979,000
ESCALATION ALLOWANCE (5%)	499,000
	=====
SUBTOTAL	\$10,478,000
ENGINEERING & CONTINGENCY (15%)	1,572,000
	=====
TOTAL INSTALLED COST	\$12,050,000

ASSUMED AVERAGE ANNUAL INFLATION RATE: 3.00%

10:39

YEAR	AVERAGE FUEL PRICE INDICES			FUEL COST, CENTS per MILLION BTU								YEARLY PERCENT INCREASE		
				WITHOUT INFLATION				WITH INFLATION						
				EXISTING		ACFB		EXISTING		ACFB				
	NATURAL GAS	DISTILLATE FUEL OIL	STEAM COAL	NATURAL GAS	DISTILLATE FUEL OIL	STEAM COAL	STEAM COAL	NATURAL GAS	DISTILLATE FUEL OIL	STEAM COAL	STEAM COAL	NATURAL GAS	DISTILLATE FUEL OIL	STEAM COAL
1992	1.00	1.00	1.00	264.00		180.00		264.00		180.00				
1993	1.02	1.01	1.01	300.00	453.80	181.80	171.00	300.00	467.41	187.25	171.00	13.64		4.03
1994	1.04	1.03	1.04	312.00	467.41	187.20	177.84	331.00	495.88	198.60	188.67	10.33	6.09	6.06
1995	1.06	1.06	1.05	318.00	481.03	189.00	179.55	347.49	525.63	206.53	196.20	4.98	6.00	3.99
1996	1.08	1.10	1.07	324.00	499.18	192.60	182.97	364.66	561.83	216.77	203.93	4.94	6.89	4.96
1997	1.11	1.15	1.08	333.00	521.87	194.40	184.68	386.04	604.99	225.36	214.09	5.86	7.68	3.96
1998	1.15	1.19	1.10	345.00	540.02	198.00	188.10	411.95	644.81	236.42	224.60	6.71	6.58	4.91
1999	1.20	1.24	1.12	360.00	562.71	201.60	191.52	442.75	692.06	247.94	235.55	7.48	7.33	4.87
2000	1.25	1.28	1.14	375.00	580.86	205.20	194.94	475.04	735.82	259.94	246.94	7.29	6.32	4.84
2001	1.30	1.31	1.16	390.00	594.48	208.80	198.36	508.86	775.66	272.44	258.81	7.12	5.41	4.81
2002	1.35	1.34	1.17	405.00	608.09	210.60	200.07	544.29	817.22	283.03	268.88	6.96	5.36	3.89
2003	1.40	1.37	1.20	420.00	621.71	216.00	205.20	581.38	860.59	298.99	284.04	6.81	5.31	5.64
2004	1.44	1.40	1.22	432.00	635.32	219.60	208.62	615.93	905.81	313.10	297.44	5.94	5.26	4.72
2005	1.48	1.42	1.25	444.00	644.40	225.00	213.75	652.03	946.32	330.42	313.90	5.86	4.47	5.53
2006	1.52	1.44	1.28	456.00	653.47	230.40	218.88	689.74	988.44	348.50	331.08	5.78	4.45	5.47
2007	1.56	1.47	1.31	468.00	667.09	235.80	224.01	729.13	1,039.30	367.37	349.00	5.71	5.15	5.41
2008	1.61	1.49	1.33	483.00	676.16	239.40	227.43	775.07	1,085.04	384.17	364.96	6.30	4.40	4.57
2009	1.67	1.51	1.36	501.00	685.24	244.80	232.56	828.08	1,132.39	404.62	384.39	6.84	4.38	5.32
2010	1.72	1.53	1.39	516.00	694.31	250.20	237.69	878.46	1,182.02	425.95	404.63	6.08	4.36	5.27
2011	1.75	1.56	1.41	525.00	707.93	253.80	241.11	920.59	1,241.36	445.04	422.79	4.80	5.02	4.48
2012	1.78	1.58	1.43	534.00	717.00	257.40	244.53	964.46	1,294.99	464.89	441.65	4.77	4.32	4.46
2013	1.81	1.61	1.45	543.00	730.62	261.00	247.95	1,010.14	1,359.16	483.54	461.26	4.74	4.96	4.44
2014	1.84	1.64	1.47	552.00	744.23	264.60	251.37	1,057.69	1,426.03	507.00	481.65	4.71	4.92	4.42
2015	1.87	1.67	1.49	561.00	757.85	268.20	254.79	1,107.18	1,495.67	529.32	502.85	4.68	4.88	4.40
2016	1.90	1.69	1.52	570.00	766.92	273.60	259.92	1,158.69	1,558.99	556.17	528.36	4.65	4.23	5.07
2017	1.93	1.72	1.54	579.00	780.54	277.20	263.34	1,212.30	1,634.27	580.40	551.38	4.63	4.83	4.36
2018	1.95	1.74	1.56	585.00	789.61	280.80	266.76	1,261.61	1,702.87	605.57	575.29	4.07	4.20	4.34
2019	1.98	1.76	1.59	594.00	798.69	286.20	271.89	1,319.45	1,774.12	635.73	603.95	4.58	4.18	4.98
2020	2.01	1.79	1.61	603.00	812.30	289.80	275.31	1,379.62	1,858.49	663.04	629.89	4.56	4.76	4.30
2021	2.03	1.81	1.63	609.00	821.38	293.40	278.73	1,435.15	1,935.63	691.42	656.85	4.02	4.15	4.28
2022	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,500.05	2,015.73	725.27	689.00	4.52	4.14	4.90
2023	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,545.05	2,076.20	747.02	709.67	3.00	3.00	3.00
2024	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,591.40	2,138.49	769.43	730.96	3.00	3.00	3.00
2025	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,639.14	2,202.64	792.52	752.89	3.00	3.00	3.00
2026	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,688.32	2,268.72	816.29	775.48	3.00	3.00	3.00
2027	2.06	1.83	1.66	618.00	830.45	298.80	283.86	1,738.97	2,336.78	840.78	798.74	3.00	3.00	3.00

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VII-3

TABLE VII-3
BUCKNELL UNIVERSITY
ECONOMIC EVALUATION SUMMARY
\$ x 1000
BASE CASE

3/ 5/1993

RETIRE EXISTING BOILERS						RENOVATE EXISTING BOILERS				
PLAN 70A GAS/OIL BOILERS			PLAN 70B ACFB BOILERS		PLAN 70C TWO CT's w/HRSG		PLAN 70D GAS/OIL BOILERS		PLAN 70E TWO CT's w/HRSG	
DIFFERENCE			DIFFERENCE		DIFFERENCE		DIFFERENCE		DIFFERENCE	
YEAR	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW
1993	2,680	(48)	2,659	(69)	2,728	0	2,659	(69)	2,659	(69)
1994	3,202	(295)	3,063	(434)	3,497	0	2,970	(527)	2,970	(527)
1995	3,602	(553)	3,633	(522)	4,155	0	3,300	(855)	3,439	(716)
1996	4,292	719	5,025	1,452	3,573	0	3,833	260	4,305	732
1997	4,591	804	6,144	2,357	3,787	0	4,169	382	4,765	978
1998	4,942	894	6,420	2,372	4,048	0	4,932	884	4,175	127
1999	5,342	986	6,698	2,342	4,356	0	5,311	955	4,469	113
2000	5,788	971	7,007	2,190	4,817	0	5,735	918	4,915	98
2001	6,246	1,020	7,319	2,093	5,226	0	6,170	944	5,309	83
2002	6,756	1,079	7,651	1,974	5,677	0	6,652	975	5,740	63
2003	7,309	1,142	8,036	1,869	6,167	0	7,182	1,015	6,216	49
2004	7,898	1,216	8,447	1,765	6,682	0	7,748	1,066	6,716	34
2005	8,497	1,287	8,879	1,669	7,210	0	8,330	1,120	7,234	24
2006	9,164	1,367	9,358	1,561	7,797	0	8,978	1,181	7,810	13
2007	9,885	1,456	9,873	1,444	8,429	0	9,678	1,249	8,431	2
2008	10,725	1,559	10,425	1,259	9,166	0	10,484	1,318	9,146	(20)
2009	11,620	1,656	11,004	1,040	9,964	0	11,345	1,381	9,920	(44)
2010	12,577	1,769	11,645	837	10,808	0	12,271	1,463	10,744	(64)
2011	13,527	1,899	12,311	683	11,628	0	13,197	1,569	11,551	(77)
2012	14,584	2,042	13,050	508	12,542	0	14,228	1,686	12,450	(92)
2013	15,651	2,183	13,794	326	13,468	0	15,271	1,803	13,362	(106)
2014	16,837	2,339	14,619	121	14,498	0	16,431	1,933	14,375	(123)
2015	18,115	2,507	15,506	(102)	15,608	0	17,681	2,073	15,469	(139)
2016	19,539	2,695	16,525	(319)	16,844	0	19,080	2,236	16,692	(152)
TOTAL	223,369	30,694	219,091	26,416	192,675	0	217,635	24,960	192,862	187
1993 PRESENT VALUE										
TOTAL	\$94,092		\$96,656		\$81,926		\$91,378		\$82,248	
RANK	4		5		1		3		2	
DIFF	12,166		14,730		0		9,452		322	

TABLE VII-4
BUCKNELL UNIVERSITY
ECONOMIC EVALUATION SUMMARY
\$ x 1000

3/ 5/1993

SENSITIVITY CASE: STEAM LOAD GROWTH, 1.0% DEMAND & 1.0% ENERGY

RETIRE EXISTING BOILERS						RENOVATE EXISTING BOILERS						
PLAN 70A			PLAN 70B			PLAN 70C		PLAN 70D		PLAN 70E		
GAS/OIL BOILERS			ACFB BOILERS			TWO CT'S W/HRSG		GAS/OIL BOILERS		TWO CT'S W/HRSG		
DIFFERENCE			DIFFERENCE			DIFFERENCE		DIFFERENCE		DIFFERENCE		
YEAR	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW	ANNUAL \$	OVER LOW
1993	2,680	(48)	2,659	(69)	2,728	0	2,659	(69)	2,659	(69)	2,659	(69)
1994	3,185	(295)	3,045	(435)	3,480	0	2,953	(527)	2,953	(527)	2,953	(527)
1995	3,563	(553)	3,594	(522)	4,116	0	3,262	(854)	3,400	(716)	3,400	(716)
1996	4,192	712	4,961	1,481	3,480	0	3,769	289	4,242	762	4,242	762
1997	4,446	793	6,053	2,400	3,653	0	4,078	425	4,674	1,021	4,674	1,021
1998	4,742	878	6,307	2,443	3,864	0	4,733	869	3,991	127	3,991	127
1999	5,076	858	6,553	2,335	4,218	0	5,045	827	4,331	113	4,331	113
2000	5,444	894	6,824	2,274	4,550	0	5,390	840	4,649	99	4,649	99
2001	5,812	926	7,095	2,209	4,886	0	5,736	850	4,969	83	4,969	83
2002	6,219	963	7,382	2,126	5,256	0	6,114	858	5,318	62	5,318	62
2003	6,652	1,001	7,712	2,061	5,651	0	6,525	874	5,700	49	5,700	49
2004	7,109	1,047	8,064	2,002	6,062	0	6,960	898	6,096	34	6,096	34
2005	7,564	1,094	8,428	1,958	6,470	0	7,397	927	6,494	24	6,494	24
2006	8,067	1,152	8,829	1,914	6,915	0	7,880	965	6,929	14	6,929	14
2007	8,602	1,210	9,257	1,865	7,392	0	8,395	1,003	7,394	2	7,394	2
2008	9,219	1,271	9,716	1,768	7,948	0	8,978	1,030	7,927	(21)	7,927	(21)
2009	9,860	1,321	10,188	1,649	8,539	0	9,585	1,046	8,496	(43)	8,496	(43)
2010	10,540	1,383	10,709	1,552	9,157	0	10,233	1,076	9,094	(63)	9,094	(63)
2011	11,209	1,458	11,250	1,499	9,751	0	10,879	1,128	9,674	(77)	9,674	(77)
2012	11,949	1,541	11,848	1,440	10,408	0	11,594	1,186	10,316	(92)	10,316	(92)
2013	12,682	1,619	12,445	1,382	11,063	0	12,303	1,240	10,956	(107)	10,956	(107)
2014	13,492	1,705	13,104	1,317	11,787	0	13,086	1,299	11,665	(122)	11,665	(122)
2015	14,356	1,795	13,808	1,247	12,561	0	13,922	1,361	12,422	(139)	12,422	(139)
2016	15,312	1,895	14,607	1,190	13,417	0	14,852	1,435	13,265	(152)	13,265	(152)
TOTAL	191,972	24,620	204,438	37,086	167,352	0	186,328	18,976	167,614	262	167,614	262
1993 PRESENT VALUE												
TOTAL	83,394		91,569		73,317		80,752		73,696		73,696	
RANK	4		5		1		3		2		2	
DIFF	10,077		18,252		0		7,435		379		379	

Capital Cost

\$5 million

\$29 million

\$12 million

\$6 million

\$13 million

TABLE IV-2

BUCKNELL UNIVERSITY POWER PLANT EXPANSION PLANS

Expansion Plan	Description
70A (all gas/oil; no coal firing capability)	Demolish and remove existing coal fired boilers; reuse existing buildings; install three 70,000 pph gas/oil fired packaged boilers operating at 175 psig/sat'd and two 2 MW back pressure steam turbines (BPT).
70B (coal, gas, oil and other "opportunity" fuel firing capability)	Demolish and remove existing coal fired boilers and building structure; install two 70,000 pph coal (primary), gas/oil (secondary) atmospheric circulating fluidized bed (ACFB) boilers and one 70,000 pph gas/oil fired packaged boiler plus two 2 MW BPTs.
70C (all gas/oil; no coal firing; additional electric/steam cogen capability)	Demolish and remove existing coal fired boilers; reuse existing building; install two 3.3 MW combustion turbines (CT) with 70,000 pph heat recovery steam generators (HRSG) and one 70,000 pph gas/oil fired packaged boiler plus two 2 MW BPTs.
70D (maintain existing coal firing capability; and all new gas/oil packaged boilers)	Maintain the three existing 25,000 pph boilers by refurbishing/replacing deaerator and other feedwater system components, modernizing combustion controls; install three 70,000 pph gas/oil fired packaged boilers located in an adjacent new building plus two 2 MW BPTs.
70E (maintain existing coal fired capability; add new cogen capability - gas/oil fired)	Same as 70D except instead of installing three 70,000 pph gas/oil fired packaged boilers install two 3.3 MW CTs with 70,000 pph HRSGs and one 70,000 pph gas/oil fired packaged boiler.

NOTE: For the five "base case" scenarios given above, the boiler steam outlet pressure will be 175 psig/saturated; high load growth. Sensitivity testing would be done for 600 psig/sat'd steam outlet conditions; lower load growth and varying fuel costs.

LUTZ, DAILY & BRAIN
Consulting Engineers

TABLE II
BUCKNELL UNIVERSITY
ECONOMIC EVALUATION SUMMARY - TOTAL COST OVER 24-YEAR STUDY PERIOD
(1993 Present Valued \$ x 1000)

Plan	Base Case			Low Load Growth-Steam			Low Load Growth-Electric			Low Inflation			High Inflation		
	1993 \$x1000	Rank	Difference Over Low \$x1000/%	1993 \$x1000	Rank	Difference Over Low \$x1000/%	1993 \$x1000	Rank	Difference Over Low \$x1000/%	1993 \$x1000	Rank	Difference Over Low \$x1000/%	1993 \$x1000	Rank	Difference Over Low \$x1000/%
70A	94,092	4	12,166 14.8%	83,394	4	10,077 13.7%	85,550	4	12,285 16.8%	73,834	4	8,456 12.9%	121,587	5	17,161 16.4%
70B	96,656	5	14,730 18.0%	91,569	5	18,625 24.9%	88,625	5	15,360 21.0%	79,276	5	13,898 21.3%	119,614	4	15,188 14.5%
70C	81,926	1	-0-	73,317	1	-0-	73,265	1	-0-	65,378	1	-0-	104,426	1	-0-
70D	91,378	3	9,452 1.5%	80,752	3	7,435 10.1%	82,859	3	9,594 13.1%	71,627	3	6,249 9.6%	118,149	3	13,783 13.1%
70E	82,248	2	322 0.4%	73,696	2	379 0.5%	73,473	2	208 0.3%	65,566	2	188 0.3%	104,806	2	380 0.4%

Cogeneration Feasibility Analysis

- 1) Electric and Thermal Load Balance
- 2) Fuel cost compared to purchased electric cost
- 3) Life cycle cost
- 4) Reliability/redundancy/risk factors
- 5) Environmental Impact
- 6) Initial Investment

Campus Energy Cost History

		1992	2004	2010	
Steam					
	\$/MMBtu	2.60	3.73	11.26	
	Annual	\$900,000	\$1,400,000	\$4,200,000	
Electric					
	\$/MMBtu	16.70	7.44	19.94	
	Annual	\$1,300,000	\$1,040,000	\$2,720,000	
Total		\$2,200,000	\$2,440,000	\$6,820,000	

Utility Cost Comparisons

<u>Utility</u>	<u>Actual 1994</u> coal-based plant	<u>Actual 1999</u> cogeneration plant	<u>Increase</u>
Electric Demand			
Average	3150 kw	3600 kw	14%
Peak	4550 kw	5100 kw	12%
Electric Consumption	27,500,000 kwh	31,500,000 kwh	15%
Steam Demand-Average	30,000 #/hr	35,000 #/hr	17%
Total Energy Cost	\$ 2,165,000	\$ 2,430,000	12%

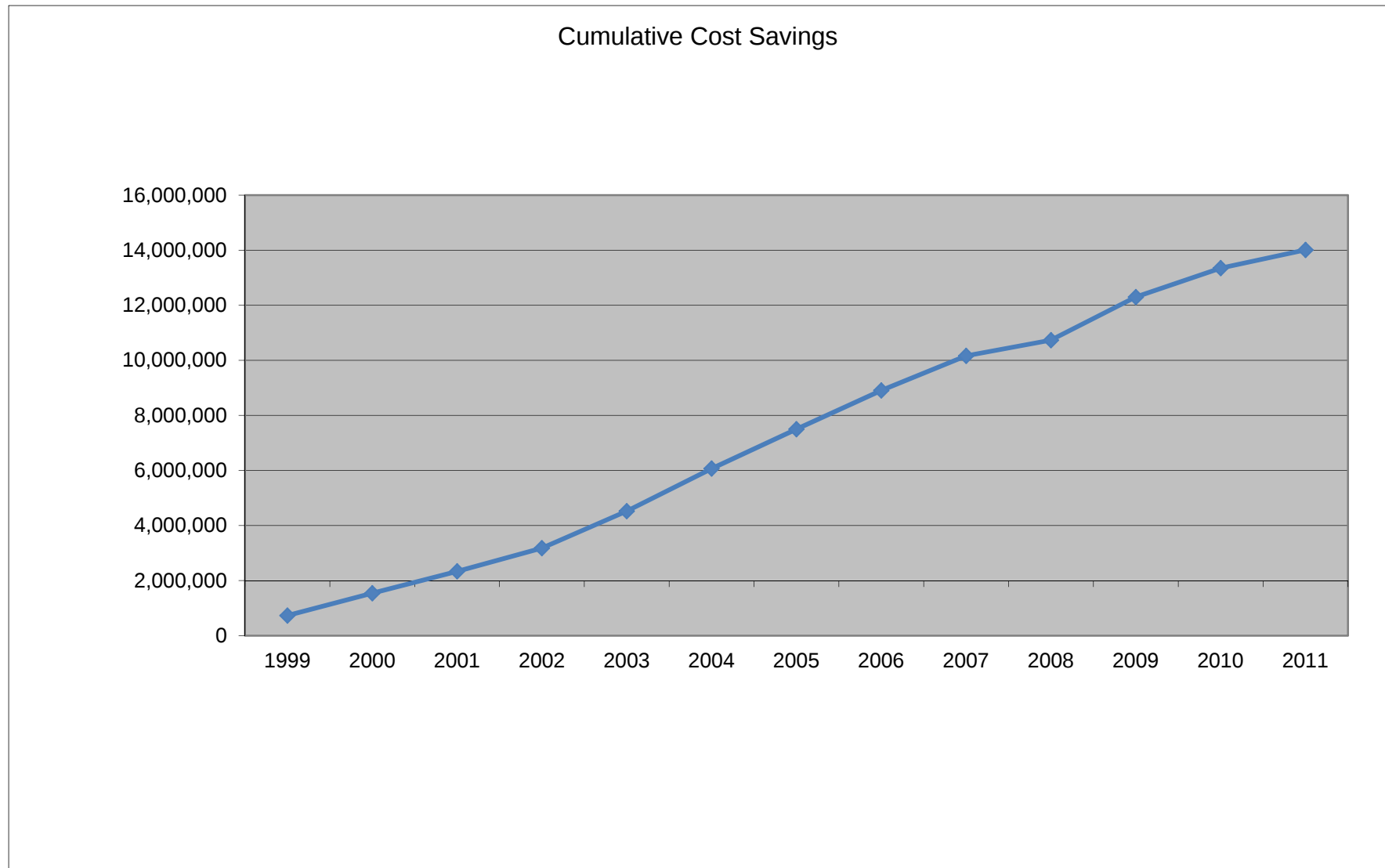
Adjustments to project projections

Stranded Cost Fee	\$ 96,294	
	\$ 2,333,706	8%
Gas Curtailment/Contamination cost	\$ 125,000	
	\$ 2,208,706	2%
Fixed Price Contract Premium	\$ 545,000	
	\$ 1,663,706	-23%

Comparison of Cogeneration Plant to next best option

Calculated 1999 cost without cogeneration (gas boilers)	\$ 2,896,300	
Actual 1999 Cogeneration Plant Utility costs	\$ 2,430,000	
Savings	\$ 466,300	19%

Savings Compared to Conventional Plant

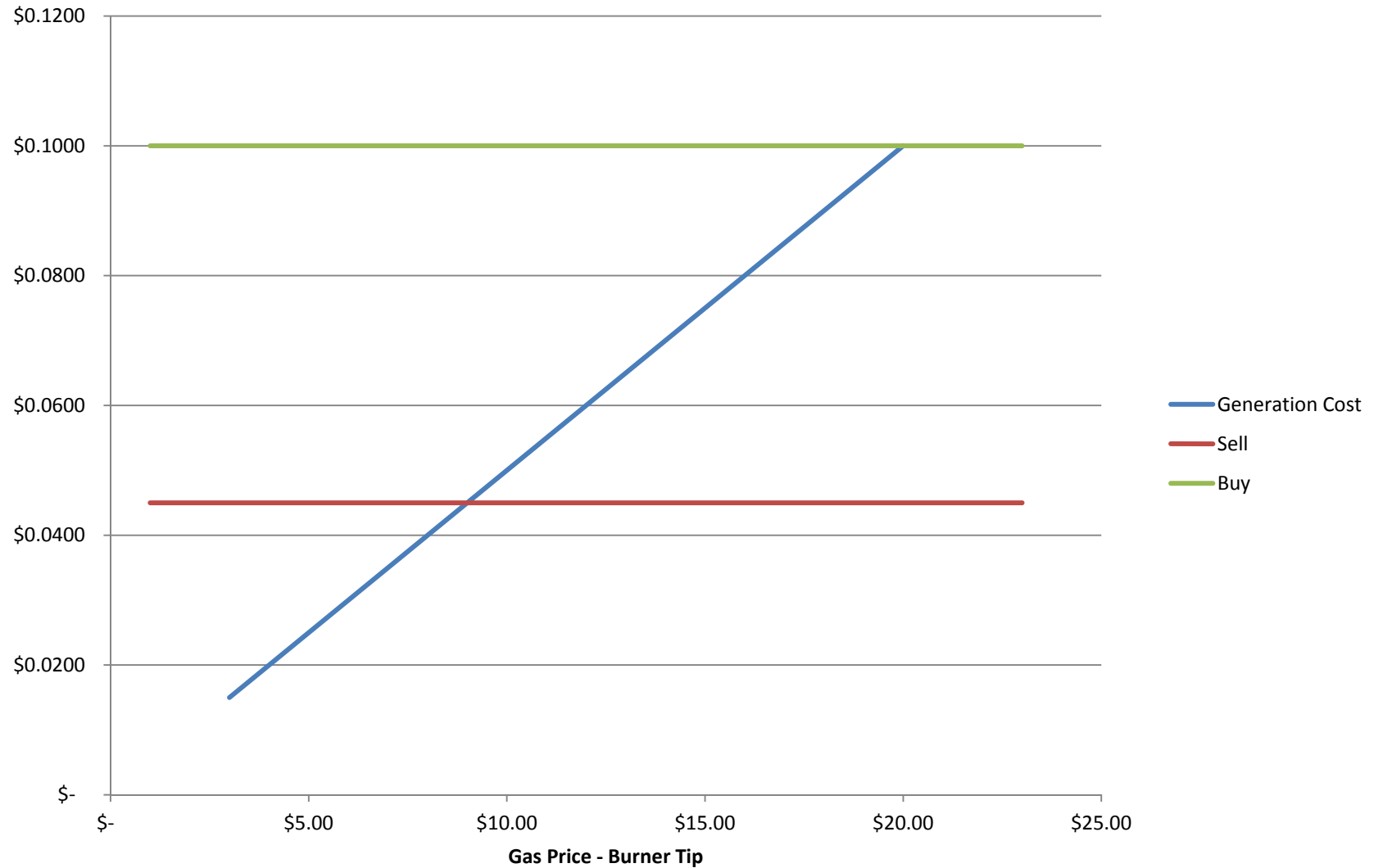


Current Energy Costs

- Purchased Electric 10 cents/kwh
- Generated Electric 5.4 cents/kwh
- Exported Electric 4.5 cents/kwh

- Natural Gas
 - Wellhead \$ 7.90 per DTH
 - Delivery \$ 2.39 per DTH
 - Burner tip \$10.29 per DTH

Gas vs Electric Costs



Challenges to Successful Cogeneration

- Availability of historic data
- Predicting future loads
- Predicting future fuel costs
- Regulatory changes
- Utility industry resistance
- Technical expertise for project development and ongoing operations, including fuel supply