Northwest **Power** and **Conservation** Council

April 29, 2014

MEMORANDUM

TO: Council Members

FROM: Charlie Black, Power Planning Division Director

SUBJECT: McCullough Research Study of Columbia Generating Station

In early 2013, the Physicians for Social Responsibility retained Robert McCullough to evaluate the future cost-effectiveness of continuing operation of the Columbia Generating Station. Mr. McCullough is a well-known energy and economic consultant based in Portland.

The results of McCullough's study of the economics of the Columbia Generating Station were published in December 2013. The study concludes that operating and maintaining CGS on an ongoing basis would be more costly than closing the plant and replacing it with firm power supplies procured from the wholesale market.

At the Council meeting in Boise on May 6, 2014, Mr. McCullough will provide a summary of his study, including the approach, assumptions and conclusions. He will also be available to respond to questions from the Council.

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Executive Director

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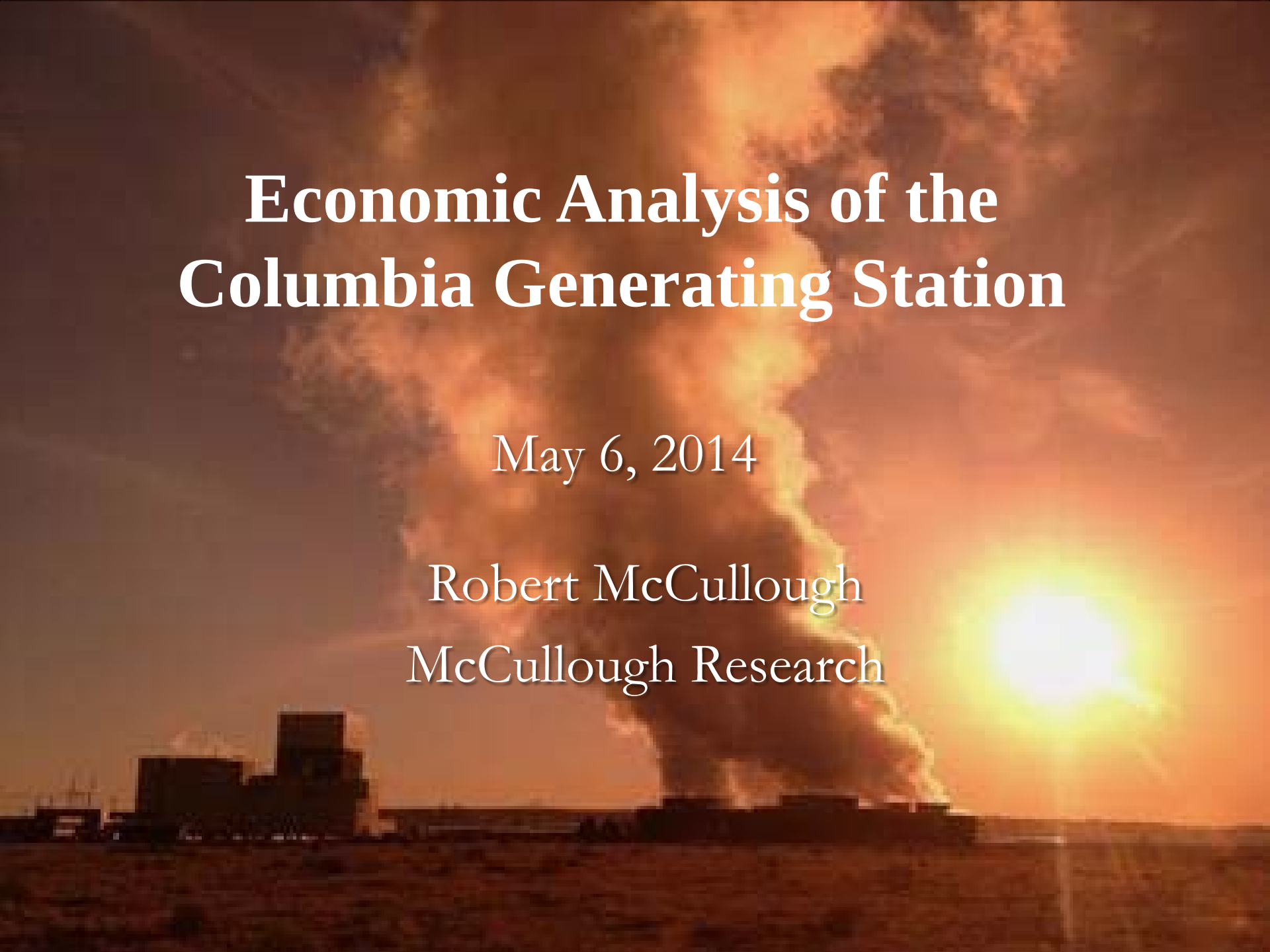
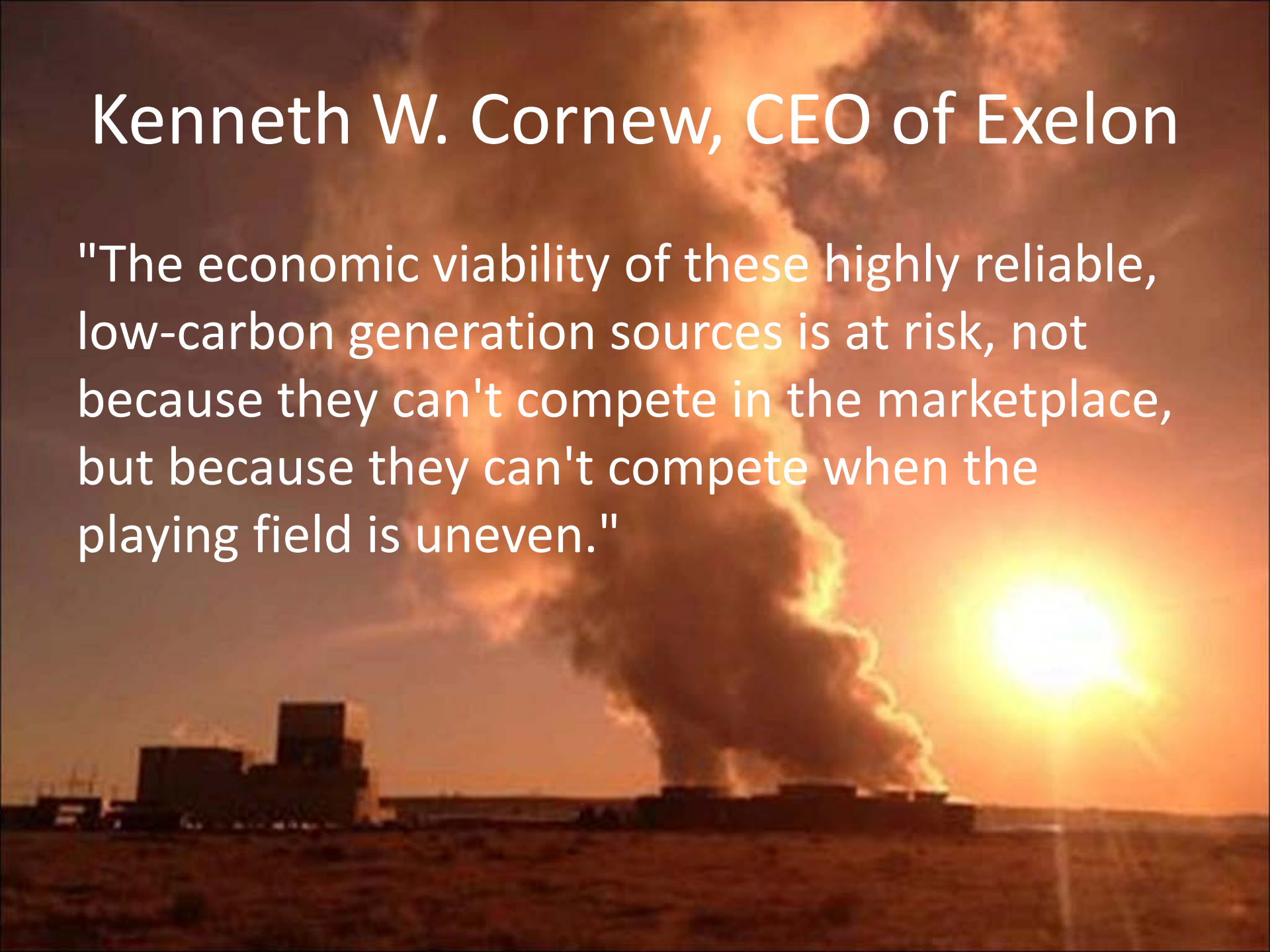


Economic Analysis of the Columbia Generating Station

May 6, 2014

Robert McCullough
McCullough Research



Kenneth W. Cornew, CEO of Exelon

"The economic viability of these highly reliable, low-carbon generation sources is at risk, not because they can't compete in the marketplace, but because they can't compete when the playing field is uneven."

CRAIN'S CHICAGO BUSINESS.

Print Story

Printed from ChicagoBusiness.com

Why Exelon will unload its nuclear plants

By Joe Cahill May 02, 2014

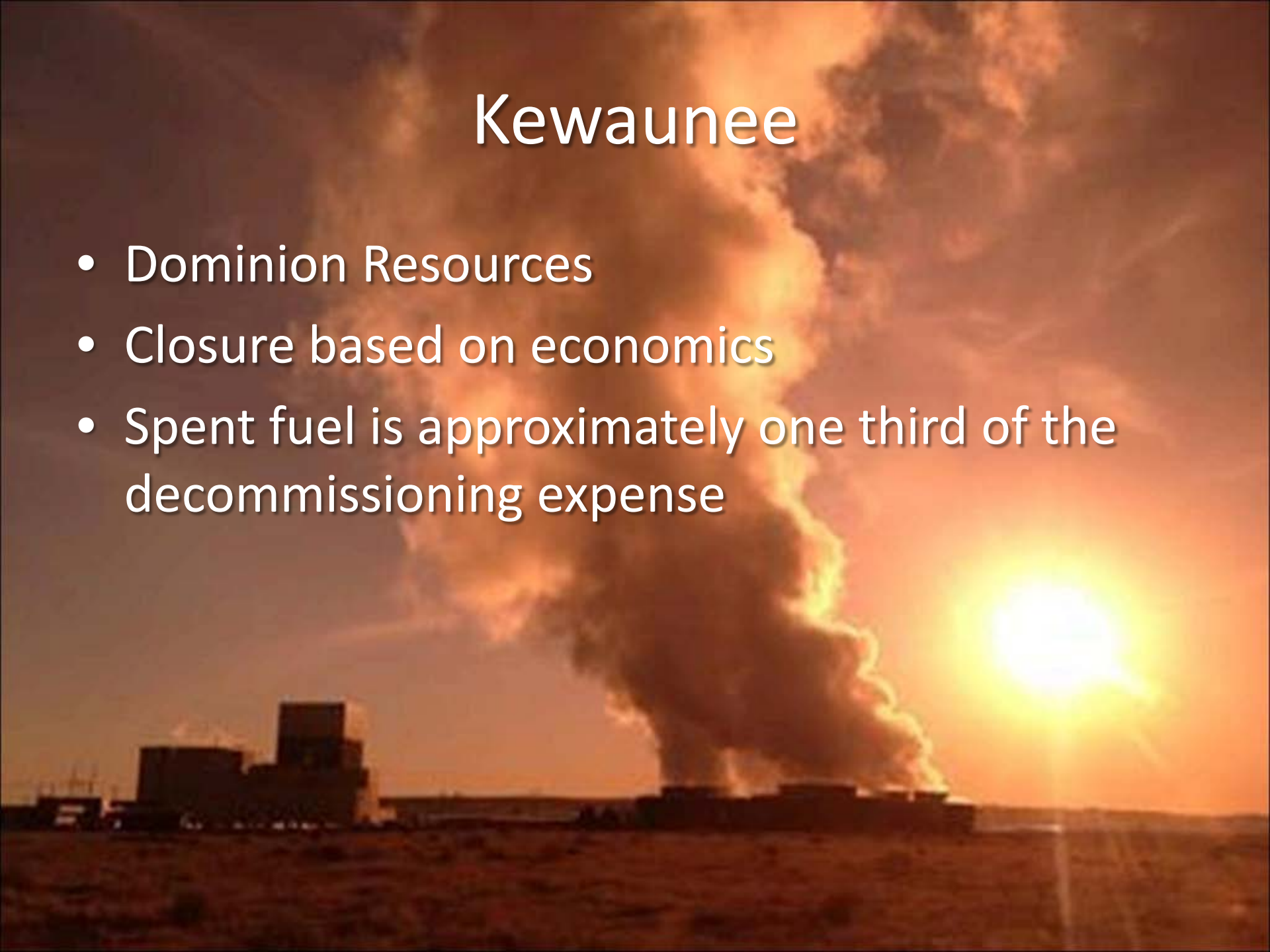
A hardened cold warrior thawed U.S. relations with China. A pain-feeling Democrat ended welfare as we knew it.

And a nuclear engineer just set the stage for Exelon Corp. to exit the nuclear power business.

CEO Christopher Crane's agreement this week to **acquire Washington's Pepco Holdings Inc.** for $6.8 billion would shift Exelon's center of gravity decisively toward regulated utility operations and away from the fleet of nuclear power plants that has been the centerpiece of company strategy for the better part of two decades under Mr. Crane and predecessor John Rowe. If the Pepco acquisition proceeds as planned, Exelon would get well over half its profit from utility ratepayers in Illinois, Pennsylvania, Maryland and the District of Columbia. A far smaller share will come from nuclear operations that once generated as much as two-thirds of corporate earnings.

The deal speaks volumes about Mr. Crane's view of the **nuclear business he oversaw** before succeeding Mr. Rowe in 2012. Since taking over, he has largely stuck to the nuclear-focused script penned by his predecessor, assuring Wall Street that depressed electricity prices squeezing profits in the nuclear unit will rise in the not-too-distant future. But prices remain stubbornly low, as expanding natural gas supplies reduce costs at gas-fueled electric power plants.

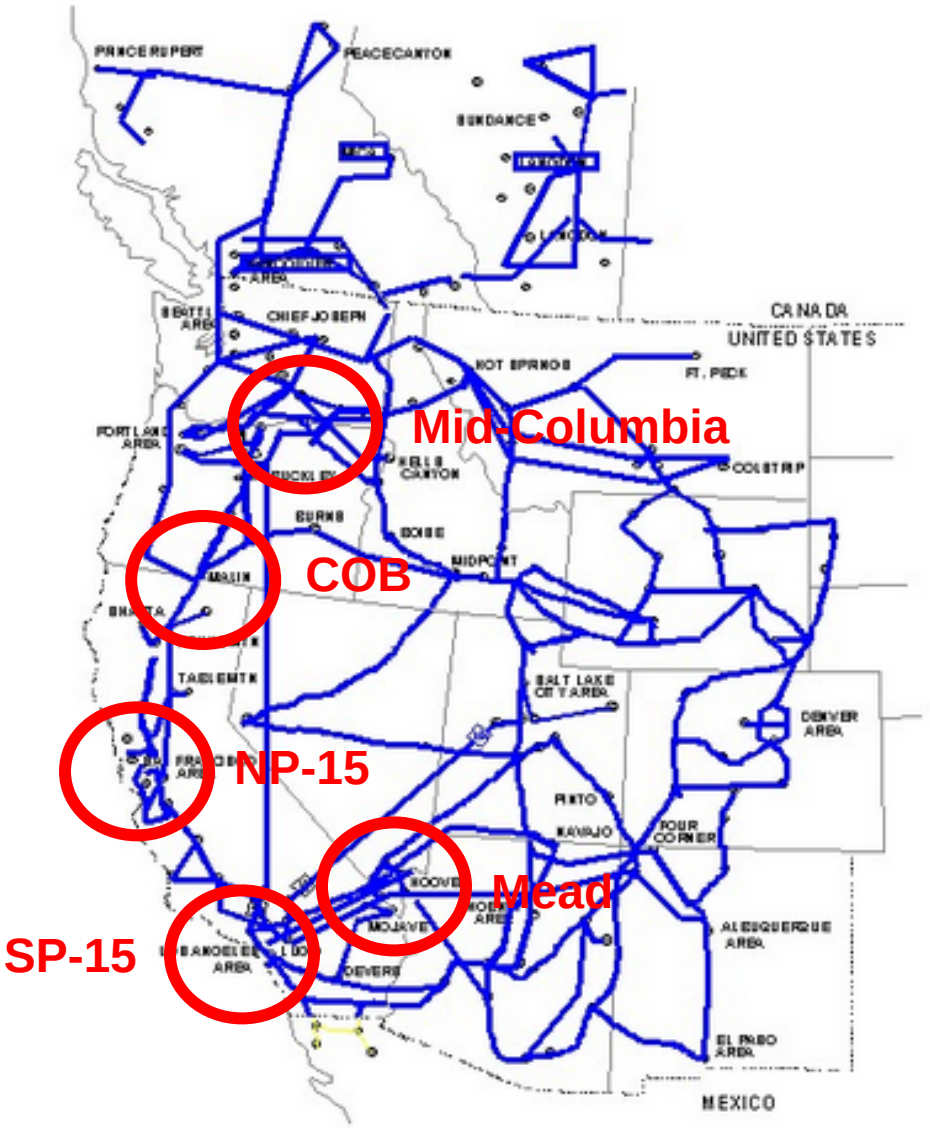
Kewaunee



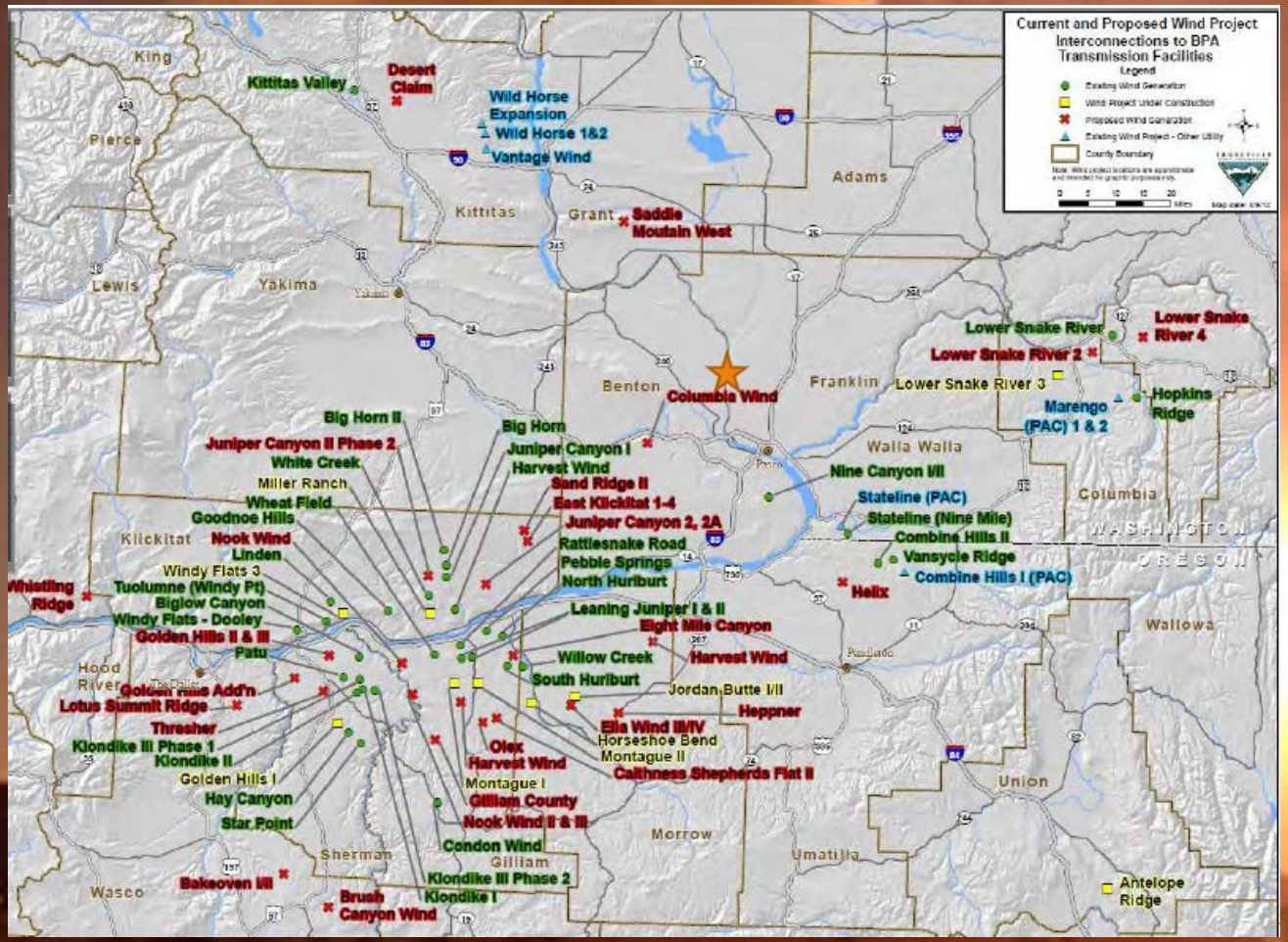
- Dominion Resources
- Closure based on economics
- Spent fuel is approximately one third of the decommissioning expense

Geography

- Courtesy of FDR, Portland is the hub of the west coast
- Mid-Columbia Hub
- Recent generation changes

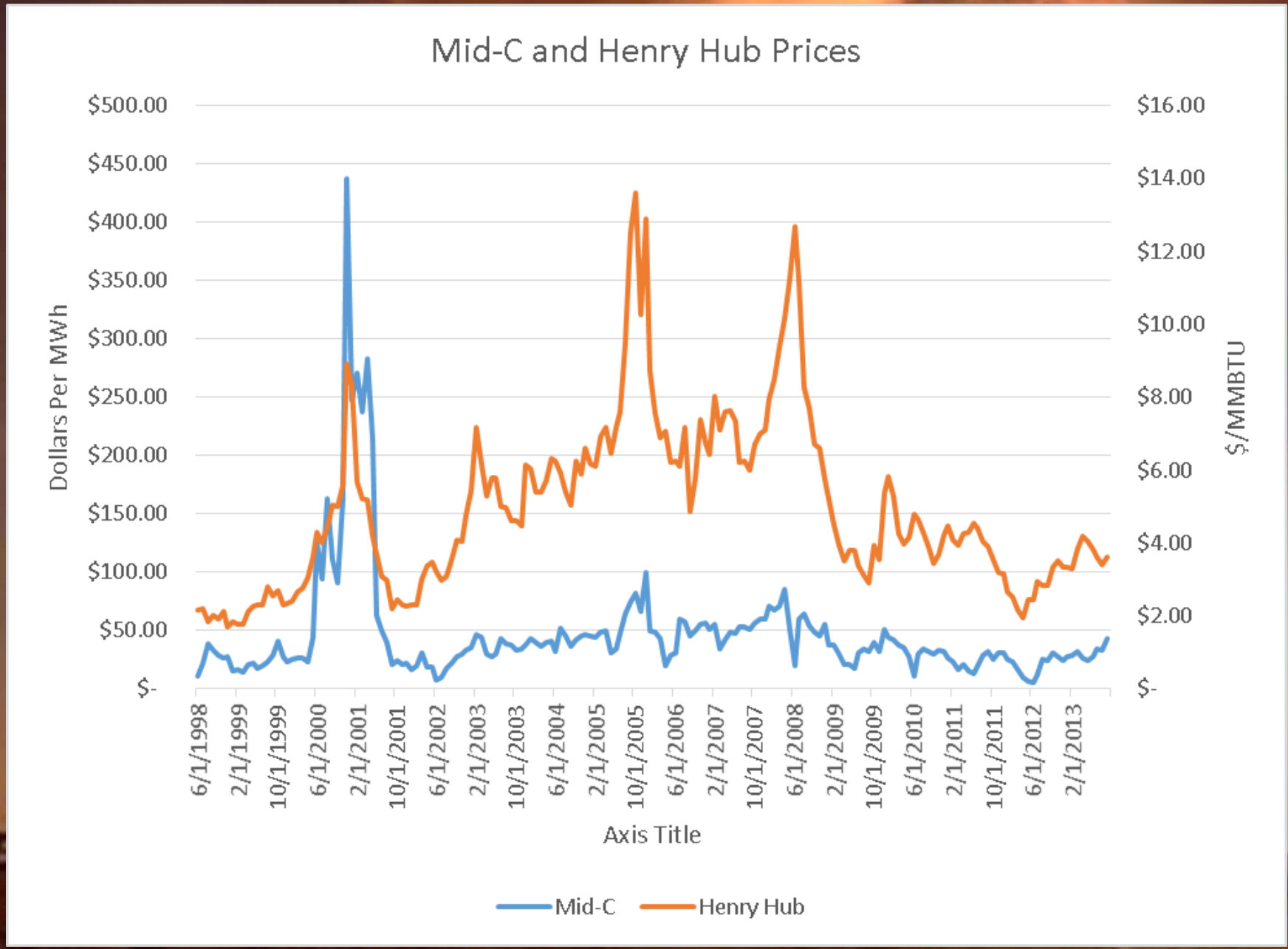

Mid-Columbia
COB
NP-15
Mead
SP-15
PRINCE RUPERT
PEACE CANYON
SUNDANCE
CHIEF JOSEPH
HOT SPRINGS
FT. PECK
CANADA
UNITED STATES
COLSTRIP
BURNS
BOISE
MIDPOINT
TABLE MTN
SALT LAKE CITY AREA
DENVER AREA
PINTO
KAIBAB
FOUR CORNER
MOJAVE
DEVERS
ALBUQUERQUE AREA
EL PASO AREA
MEXICO

Mid-Columbia Geography



Prices

- Wholesale prices outside of California are set by an open market
- California adopted an administered market where the prices are set by an administrative agency
- This is one reason why Mid-Columbia prices are so much lower than California's


Mid-C and Henry Hub Prices
$500.00
$450.00
$400.00
$350.00
$300.00
$250.00
$200.00
$150.00
$100.00
$50.00
$-
Dollars Per MWh
$16.00
$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$-
$/MMBTU
6/1/1998
2/1/1999
10/1/1999
6/1/2000
2/1/2001
10/1/2001
6/1/2002
2/1/2003
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6/1/2008
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6/1/2010
2/1/2011
10/1/2011
6/1/2012
2/1/2013
Axis Title
Mid-C
Henry Hub

The U.S. Has 100 Operating Nuclear Reactors

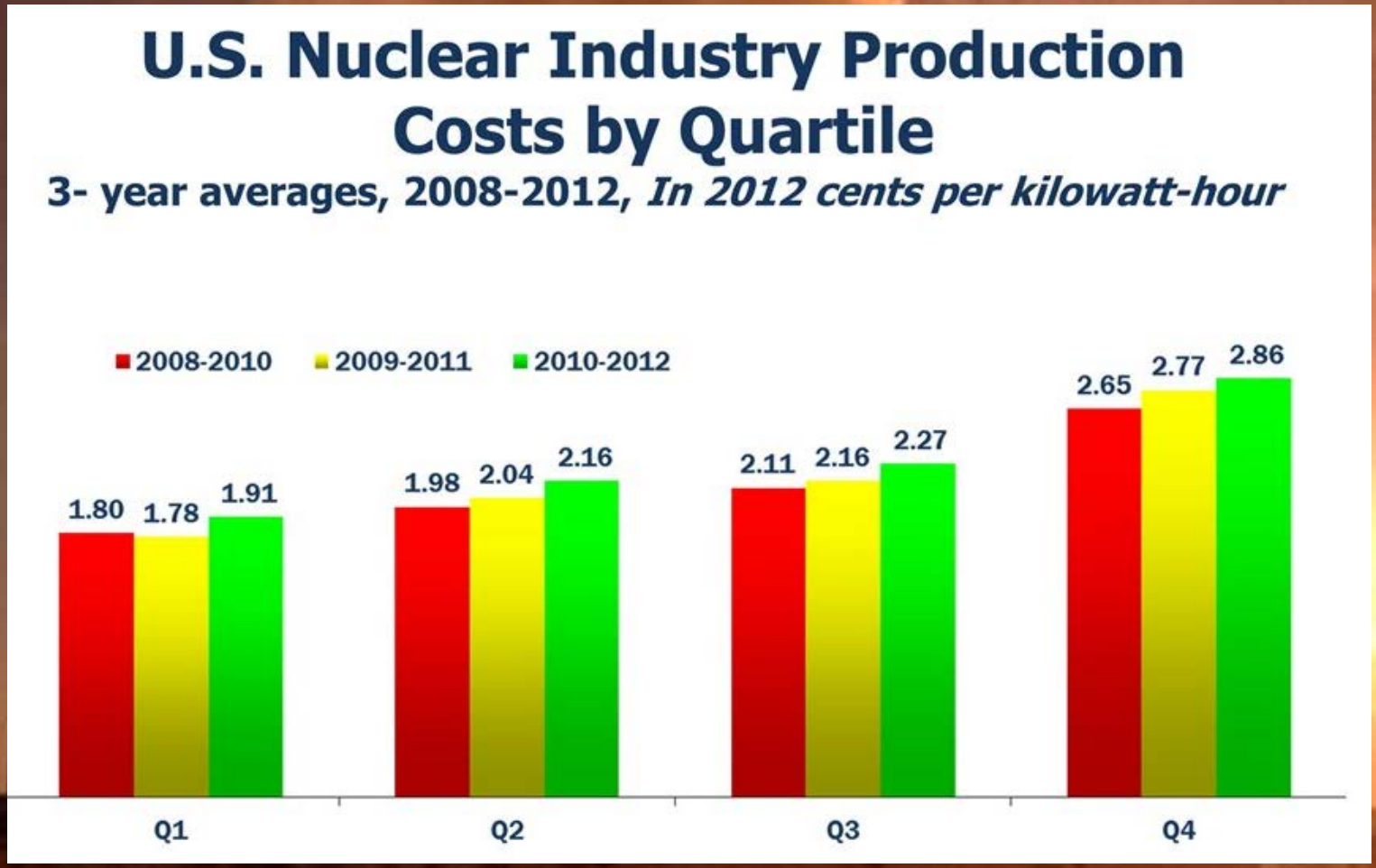
- Of these 100, only 6 are remaining on the west coast
- One is in the Pacific Northwest
- There is little understanding of the economics of these units beyond the high cost of construction

U.S. Energy Information Administration

U.S. average levelized costs (2012 $/MWh) for plants entering service in 2019

Plant type	Capacity factor (%)	Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system LCOE	Subsidy[1]	Total LCOE including Subsidy
Dispatchable Technologies								
Conventional Coal	85	60.0	4.2	30.3	1.2	95.6		
Integrated Coal-Gasification Combined Cycle (IGCC)	85	76.1	6.9	31.7	1.2	115.9		
IGCC with CCS	85	97.8	9.8	38.6	1.2	147.4		
Natural Gas-fired								
Conventional Combined Cycle	87	14.3	1.7	49.1	1.2	66.3		
Advanced Combined Cycle	87	15.7	2.0	45.5	1.2	64.4		
Advanced CC with CCS	87	30.3	4.2	55.6	1.2	91.3		
Conventional Combustion Turbine	30	40.2	2.8	82.0	3.4	128.4		
Advanced Combustion Turbine	30	27.3	2.7	70.3	3.4	103.8		
Advanced Nuclear	90	71.4	11.8	11.8	1.1	96.1	-10.0	86.1
Geothermal	92	34.2	12.2	0.0	1.4	47.9	-3.4	44.5
Biomass	83	47.4	14.5	39.5	1.2	102.6		

Nuclear Energy Institute

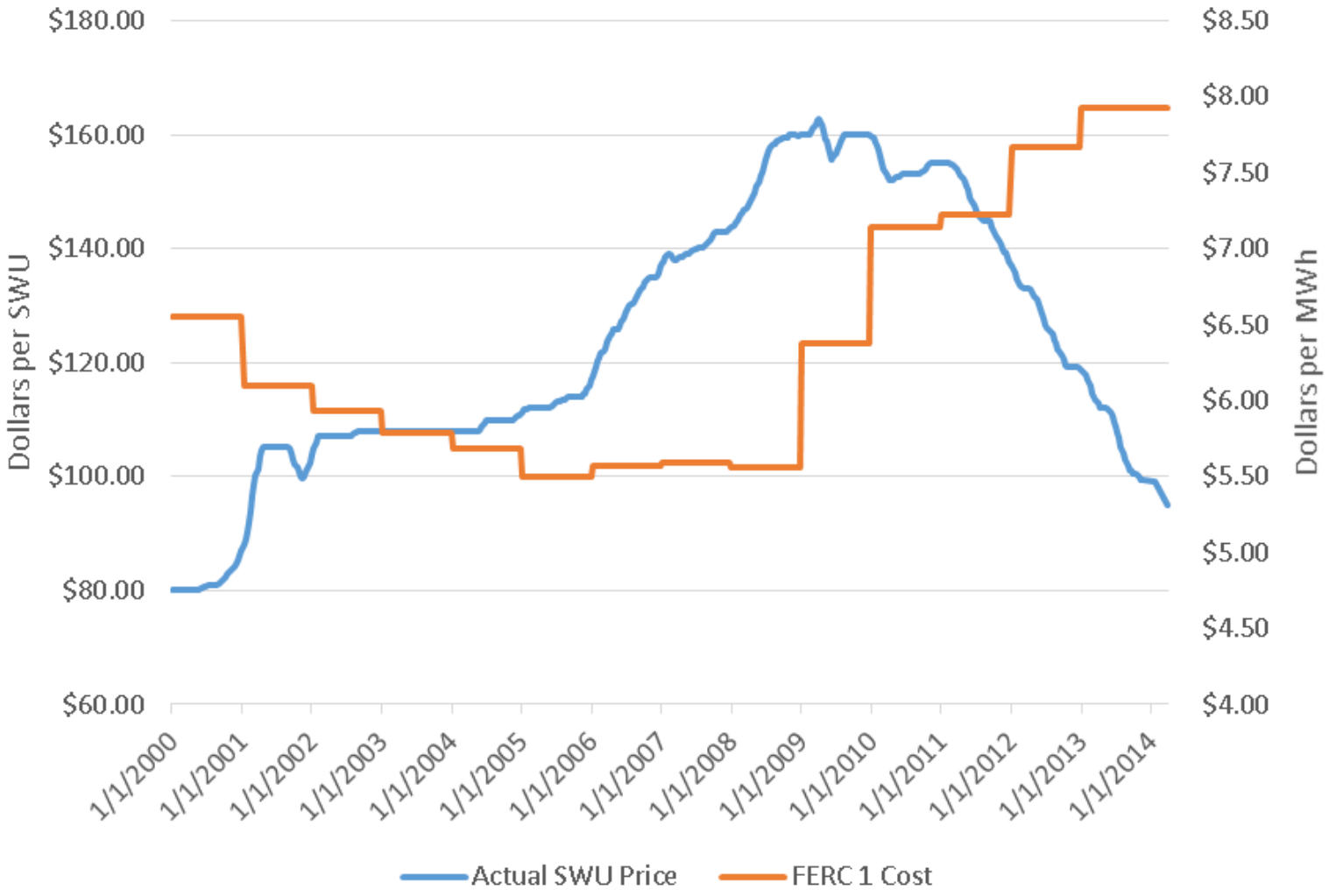


	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Item Description (Final FY 14 Updated 5/2/13 LP Years)		FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
	BPA Rate	BPA Rate Period		BPA Rate Period		BPA Rate Period		BPA Rate Period		BPA Rate Period		
Direct and Indirect O&M Costs												
Baseline Costs		$ 125,453	$ 118,345	$ 121,133	$ 117,795	$ 119,993	$ 119,895	$ 123,093	$ 119,895	$ 122,693	$ 119,895	$ 119,895
Outage Costs (Incremental)		-	29,750	-	25,200	-	34,800	-	25,200	-	25,200	
Admin / General (A&G)		67,138	66,020	68,272	64,711	68,638	66,561	72,323	71,646	74,081	71,897	71,524
O&M Projects		9,058	49,966	14,263	39,777	9,828	44,174	12,907	41,931	11,261	43,752	43,752
Facilities O&M Projects		780	890	890	890	890	890	890	890	890	890	890
O&M Risk Reserve		1,588	3,336	1,532	2,694	1,294	2,694	1,242	2,694	1,123	2,694	2,694
Subtotal Direct & Indirect O&M Costs		**$ 204,017**	**$ 268,307**	**$ 206,090**	**$ 251,067**	**$ 200,643**	**$ 269,014**	**$ 210,455**	**$ 262,256**	**$ 210,048**	**$ 264,328**	**$ 238,755**
Escalation on Direct & Indirect (3.5%)			**9,391**	**14,679**	**27,295**	**29,599**	**50,490**	**48,248**	**71,328**	**66,545**	**95,924**	**98,033**
Total Direct & Indirect O&M Costs (includes escalation)		**$ 204,017**	**$ 277,698**	**$ 220,769**	**$ 278,362**	**$ 230,242**	**$ 319,504**	**$ 258,703**	**$ 333,584**	**$ 276,593**	**$ 360,252**	**$ 336,788**
Capital Costs												
PRC Capital Projects		$ 54,246	$ 55,420	$ 34,443	$ 53,095	$ 29,517	$ 48,982	$ 24,807	$ 27,625	$ 16,450	$ 27,318	$ 33,889
Moveable Capital & Downtown Capital Projects		$ 1,281	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507	$ 1,507
Facilities Capital Projects		$ 500	$ 530	$ 535	$ 565	$ 565	$ 565	$ 565	$ 565	$ 565	$ 565	$ 565
Information Technology Capital Projects		$ 9,276	$ 8,235	$ 9,996	$ 8,288	$ 10,206	$ 9,286	$ 10,550	$ 9,887	$ 9,595	$ 9,701	$ 9,771
Admin / General (A&G)		$ 13,470	$ 14,920	$ 12,668	$ 16,229	$ 12,302	$ 14,379	$ 8,617	$ 9,294	$ 6,859	$ 9,043	$ 9,416
Capital Risk Reserve		$ 4,000	$ 8,000	$ 4,000	$ 6,000	$ 4,000	$ 6,000	$ 4,000	$ 4,110	$ 4,000	$ 4,000	$ 4,000
Fukushima Impacts		$ 18,080	$ 9,900	$ 16,710	$ 13,940							
Management Discretion-Special Projects**		$ -	$ 5,250	$ 30,400	$ 29,894	$ 28,546	$ 8,300	$ 3,100	$ 3,100	$ 3,100	$ 3,100	$ 5,801
Subtotal Capital Costs		**$ 100,853**	**$ 103,762**	**$ 110,259**	**$ 129,518**	**$ 86,643**	**$ 89,019**	**$ 53,146**	**$ 56,088**	**$ 42,076**	**$ 55,234**	**$ 64,949**
Escalation on Capital (3.5%)			**$ 3,632**	**$ 7,853**	**$ 14,081**	**$ 12,782**	**$ 16,708**	**$ 11,760**	**$ 14,848**	**$ 12,905**	**$ 19,619**	**$ 26,668**
Total Capital Costs (includes escalation)		**$ 100,853**	**$ 107,394**	**$ 118,112**	**$ 143,599**	**$ 99,425**	**$ 105,727**	**$ 64,906**	**$ 70,936**	**$ 54,981**	**$ 74,853**	**$ 91,617**
Fuel Related Costs												
Nuclear Fuel Amortization		50,811	44,447	57,895	51,184	60,576	53,678	62,239	55,014	63,729	57,340	57,340
Spent Fuel Fee		8,768	7,594	8,956	7,901	8,932	7,899	8,918	7,867	8,894	7,989	7,989
Subtotal Fuel Related Costs		**$ 59,579**	**$ 52,041**	**$ 66,851**	**$ 59,085**	**$ 69,508**	**$ 61,577**	**$ 71,157**	**$ 62,881**	**$ 72,623**	**$ 65,329**	**$ 65,329**
Total Unescalated Budget		**$ 364,449**	**$ 424,110**	**$ 383,200**	**$ 439,670**	**$ 356,794**	**$ 419,610**	**$ 334,758**	**$ 381,225**	**$ 324,747**	**$ 384,891**	**$ 369,033**
Total Escalation		**-**	**13,022**	**22,532**	**41,376**	**42,381**	**67,198**	**60,008**	**86,176**	**79,450**	**115,543**	**124,700**
Total Cost - Industry Basis		**$ 364,449**	**$ 437,132**	**$ 405,732**	**$ 481,046**	**$ 399,175**	**$ 486,808**	**$ 394,766**	**$ 467,401**	**$ 404,197**	**$ 500,434**	**$ 493,733**
Total Net Generation (Gwh)		9,468	8,291	9,799	8,701	9,772	8,299	9,799	8,701	9,772	8,701	9,799
Outage Days		-	47	-	40	-	55	-	40	-	40	
Cost of Power (Cents per kWh, constant FY14$)		$ 3.85	$ 5.12	$ 3.91	$ 5.05	$ 3.65	$ 5.06	$ 3.42	$ 4.38	$ 3.32	$ 4.42	$ 3.77
Cost of Power (Cents per kWh, escalated)		$ 3.85	$ 5.27	$ 4.14	$ 5.53	$ 4.08	$ 5.87	$ 4.03	$ 5.37	$ 4.14	$ 5.75	$ 5.04

Nuclear Fuel

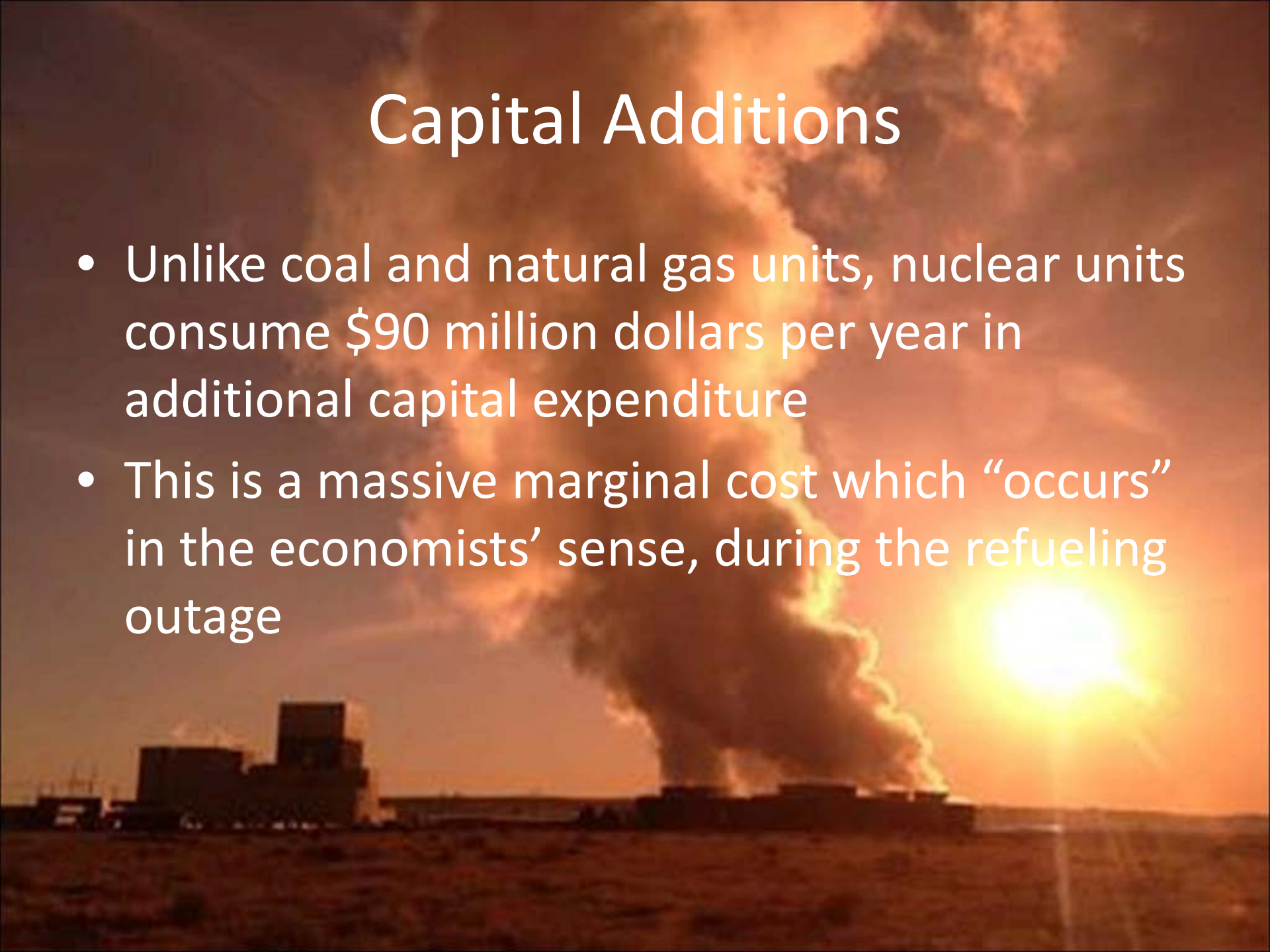
- Nuclear fuel cycles can extend ten years between uranium mining and spent fuel
- The marginal cost of operations is the market price of the fuel in the early stages
- The accounting values (as shown by EIA and NEI) have little to do with operations.

FERC Form 1 Fuel and Market SWU Prices



Capital Additions

- Unlike coal and natural gas units, nuclear units consume $90 million dollars per year in additional capital expenditure
- This is a massive marginal cost which “occurs” in the economists’ sense, during the refueling outage



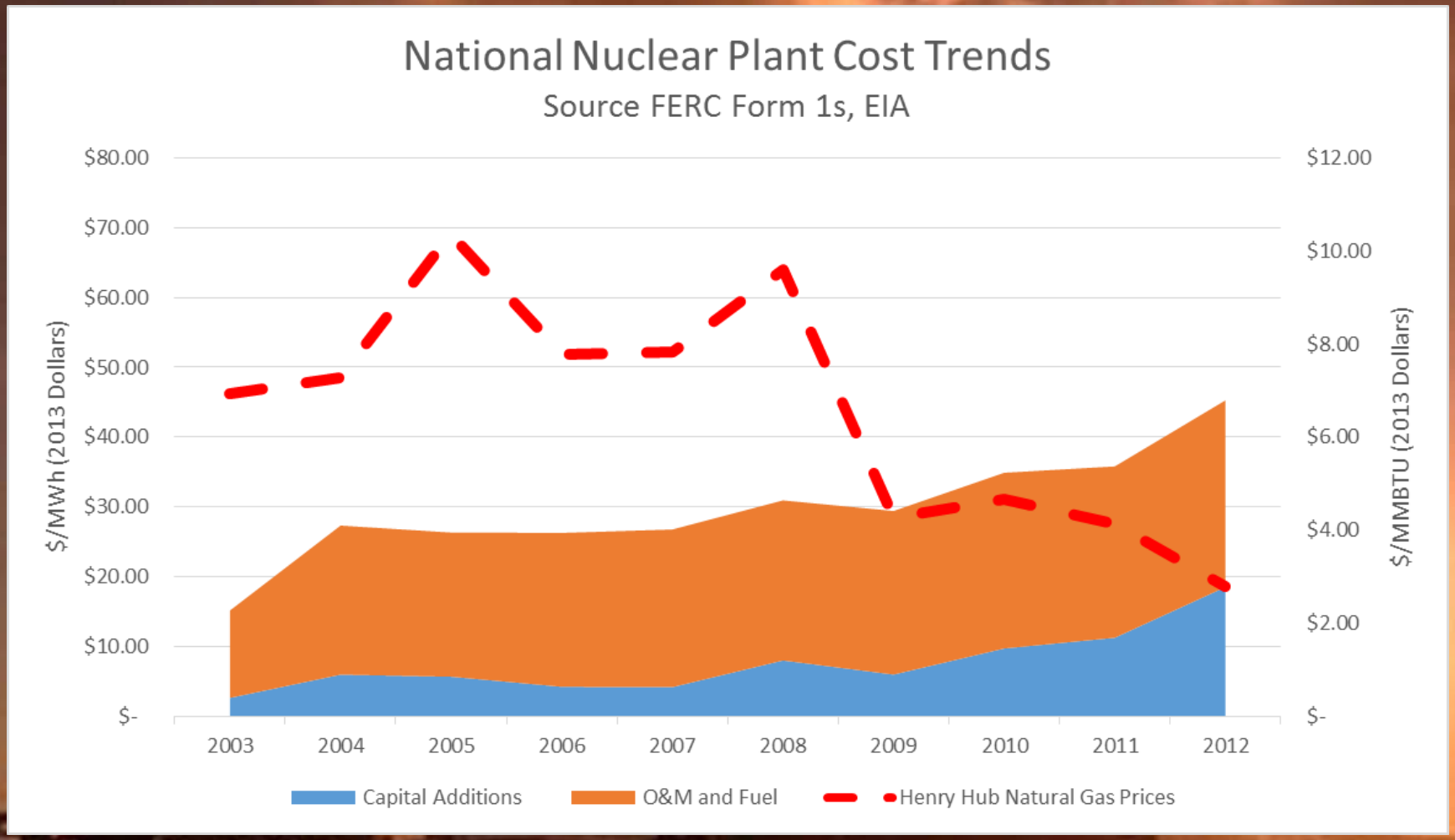
Aging Plants Cost More

Regression Statistics	
Multiple R	0.878846602
R Square	0.77237135
Adjusted R Square	0.770822856
Standard Error	55599178.3
Observations	297

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.08378E+18	1.54189E+18	498.7886569	3.25355E-95
Residual	294	9.08833E+17	3.09127E+15		
Total	296	3.99261E+18			

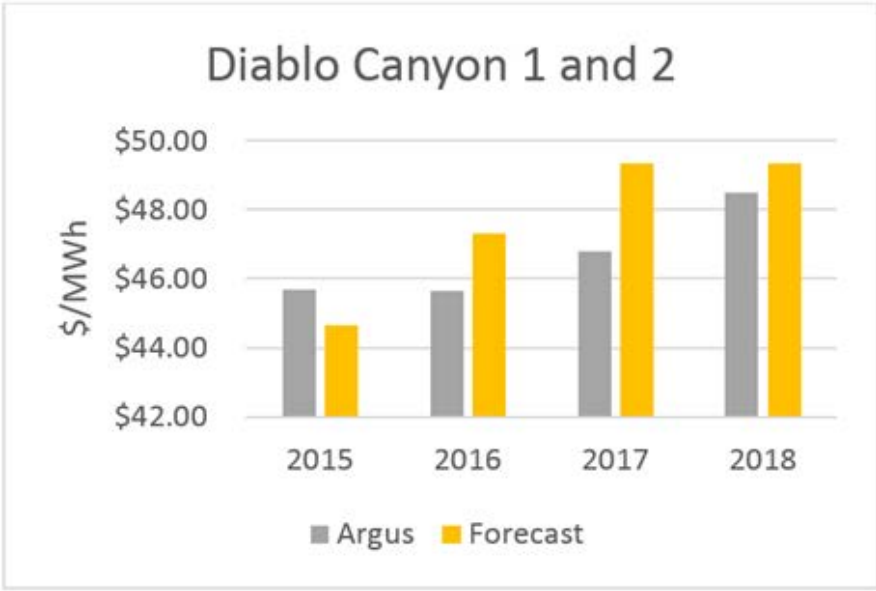
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 99.0%*	*Upper 99.0%*
Intercept	-15743317.76	14553115.78	-1.08	0.28	-44384805.60	12898170.09	-53474525.37	21987889.85
Net Generation	0.02	0.00	30.44	0.00	0.02	0.02	0.02	0.02
Age	1316108.25	466224.24	2.82	0.01	398548.31	2233668.19	107349.66	2524866.84

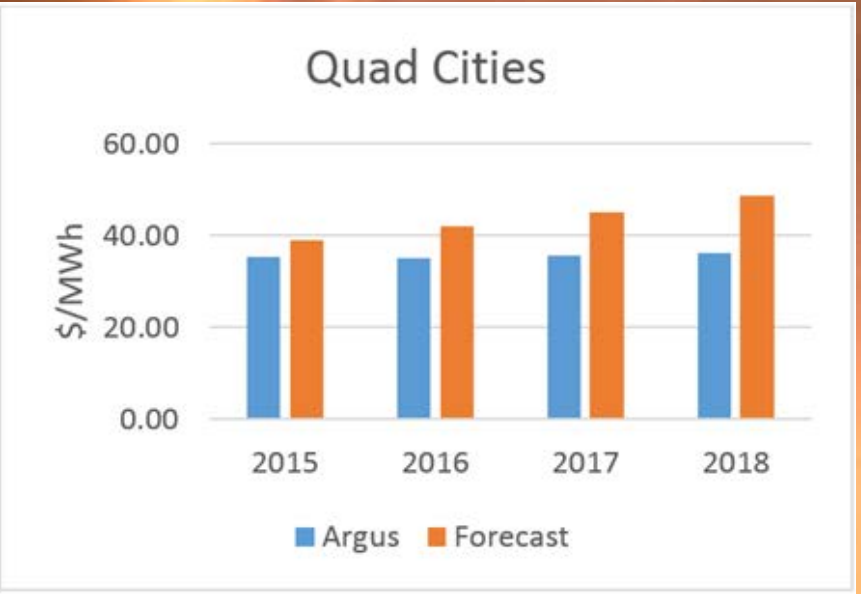

National Nuclear Plant Cost Trends
Source FERC Form 1s, EIA
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$-
$/MWh (2013 Dollars)
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$-
$/MMBTU (2013 Dollars)
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Capital Additions
O&M and Fuel
Henry Hub Natural Gas Prices

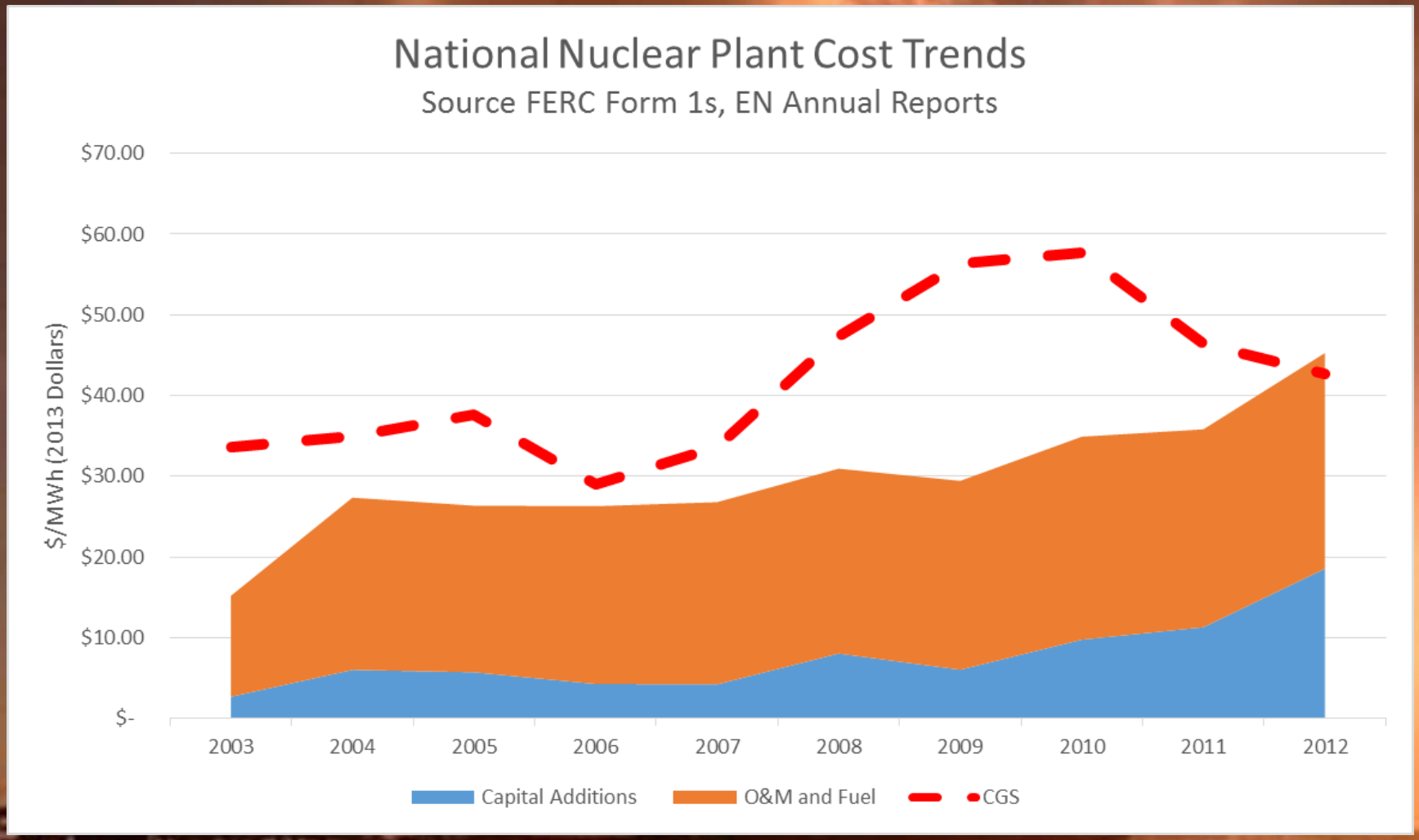
What does this mean to society?

- Where data is available, it means that nuclear stations now cost more than the market
- Two examples:
  - Exelon's Quad Cities in Illinois
  - PG&E's Diablo Canyon in California
  - Columbia Generating Station in Washington

Market Alternatives






National Nuclear Plant Cost Trends
Source FERC Form 1s, EN Annual Reports
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$-
$/MWh (2013 Dollars)
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Capital Additions
O&M and Fuel
CGS

Columbia Generating Station

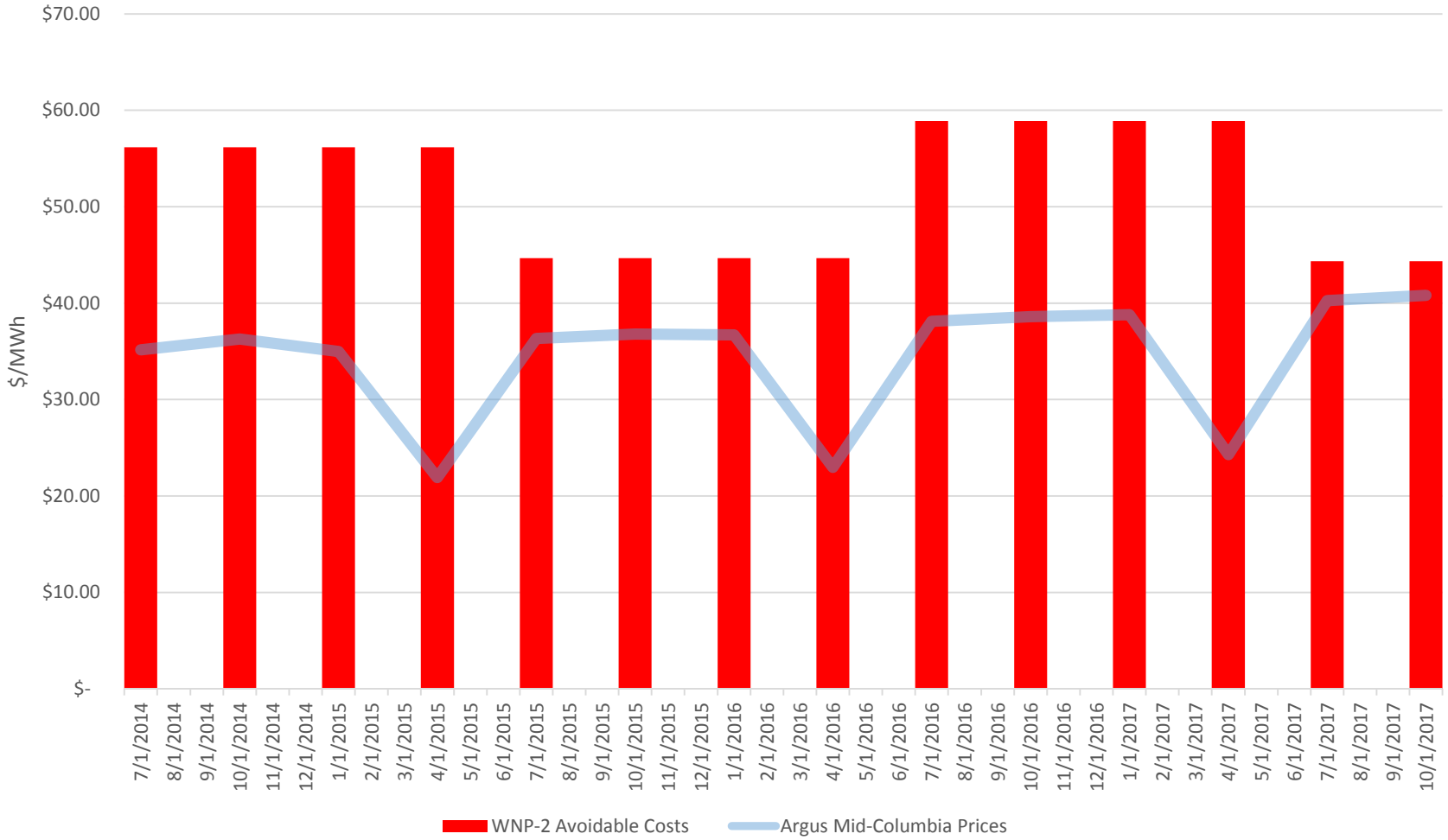
- 1984 In-service date
- 1992 Last substantive cost review at BPA
- 1999 BPA and Energy Northwest adopt "Market Test"
- 2005 CGS begins buying fuel from high GHG emissions source
- 2008 Operating costs pass market prices
- 2011 Condenser repair
- 2022 Turbine replacement
- 2030 Probable closure date

Market Test

- In 1998 the four northwestern governors initiated a comprehensive review of BPA's role in the regional power system.
- The review adopted a "Market Test" which was adopted by BPA and Energy Northwest
- Every two years CGS's operation was made subject to comparison with market prices
- CGS has failed the test since 2009

FY 2015 Market Test

Argus Forward Prices at Mid-Columbia and CGS Long Run Avoidable Costs



Problems and Opportunities

- CGS's institutional structure is a continuing challenge for BPA
  - Management without ownership
  - Unmanageable "Project Consultant" arbitration
- Costs, particularly O&M appear to be diverging from industry levels
- CGS's location places it in the center of over-generation and far from load
- Mid-Columbia prices have been lower than "avoided costs" and this appears to be the case for years to come

Recommendations

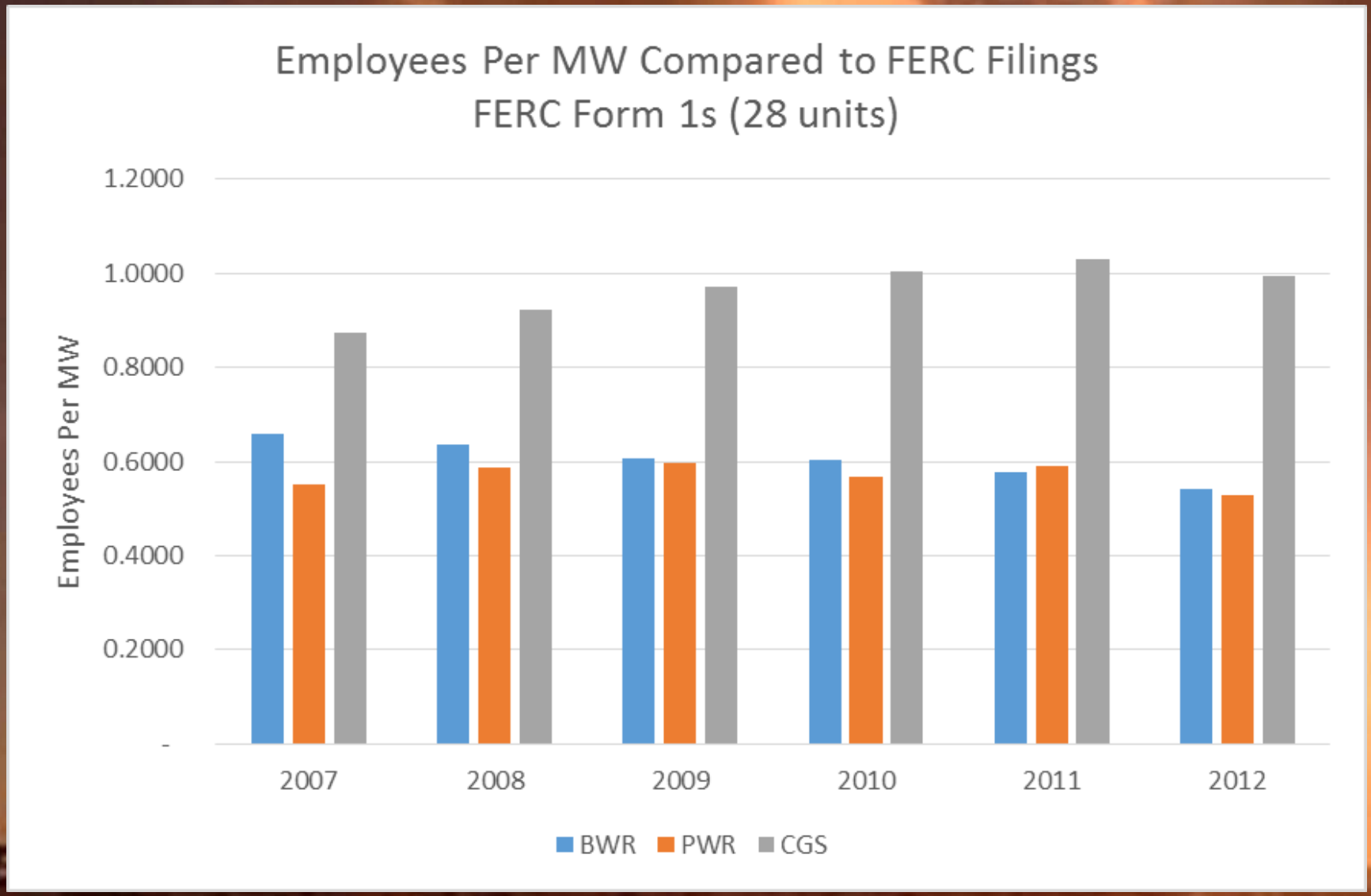
- Verify that Section 15(c) of the 1971 Project Agreement gives the Administrator the power to direct the termination of CGS.
- BPA should issue a Request For Proposals on behalf of Energy Northwest seeking 1,130 MW.
- BPA staff would assemble responses and share the response data with the region.
- The final portfolio would be implemented by Energy Northwest.

Recommendations

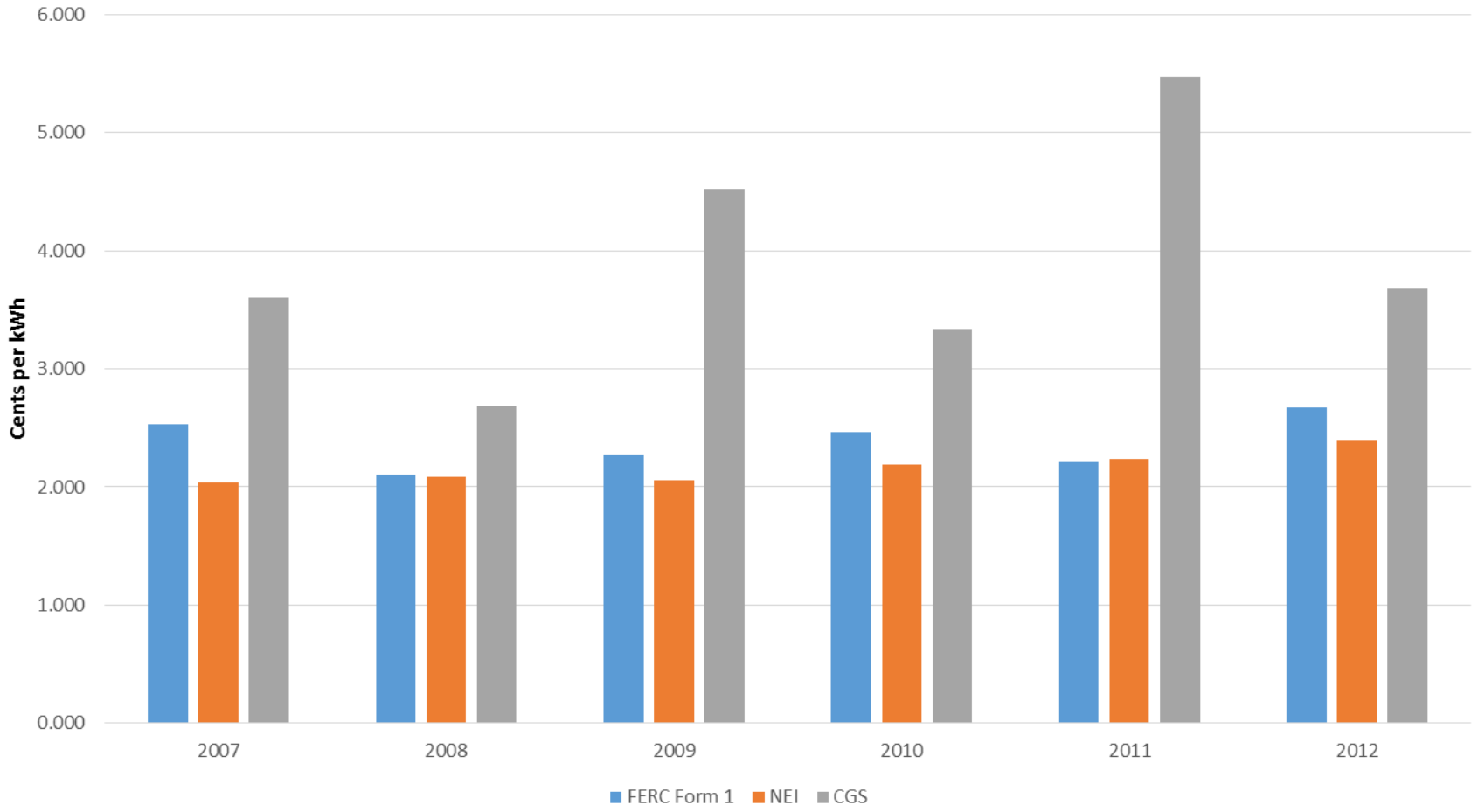
- After contract implementation, CGS would begin DECON decommissioning in May 2015.
- Energy Northwest would handle employment transitions by a combination of methods. First, implementing DECON rather than SAFSTOR decommissioning. Second, training and employing workers in plant decommissioning – following the example of PGE (Trojan) and SMUD (Rancho Seco).

The Bottom Line

- If we had replaced the plant on July 1, 2012, BPA would have paid $200 million less for power in FY 2013
- This translates to a 10.67% rate decrease at BPA


Employees Per MW Compared to FERC Filings
FERC Form 1s (28 units)
Employees Per MW
1.2000
1.0000
0.8000
0.6000
0.4000
0.2000
-
2007
2008
2009
2010
2011
2012
BWR
PWR
CGS

Operating Cost per kWh
FERC, NEI, and CGS



O&M Request to BPA

Enclosed are two reports from 1992 and 1993 where the maintenance costs are supplied. Our staff, Ms. Dana Sandlin, the Authorizing Official for this request, reports that the format for financial reports provided to BPA from Energy NW changed after 1993. In the new format the maintenance cost were no longer broken out. Therefore, for the years 1994 to 2012 we have no responsive records.

CGS Life Expectancy

- NRC licenses are akin to marriage licenses – they permit a happy ever after outcome, but do not guarantee that this will happen
- Almost all decommissioned units in the U.S. have closed for economic grounds
  - Rancho Seco
  - Trojan
  - San Onofre
- CGS only has a 23% chance of living to 60

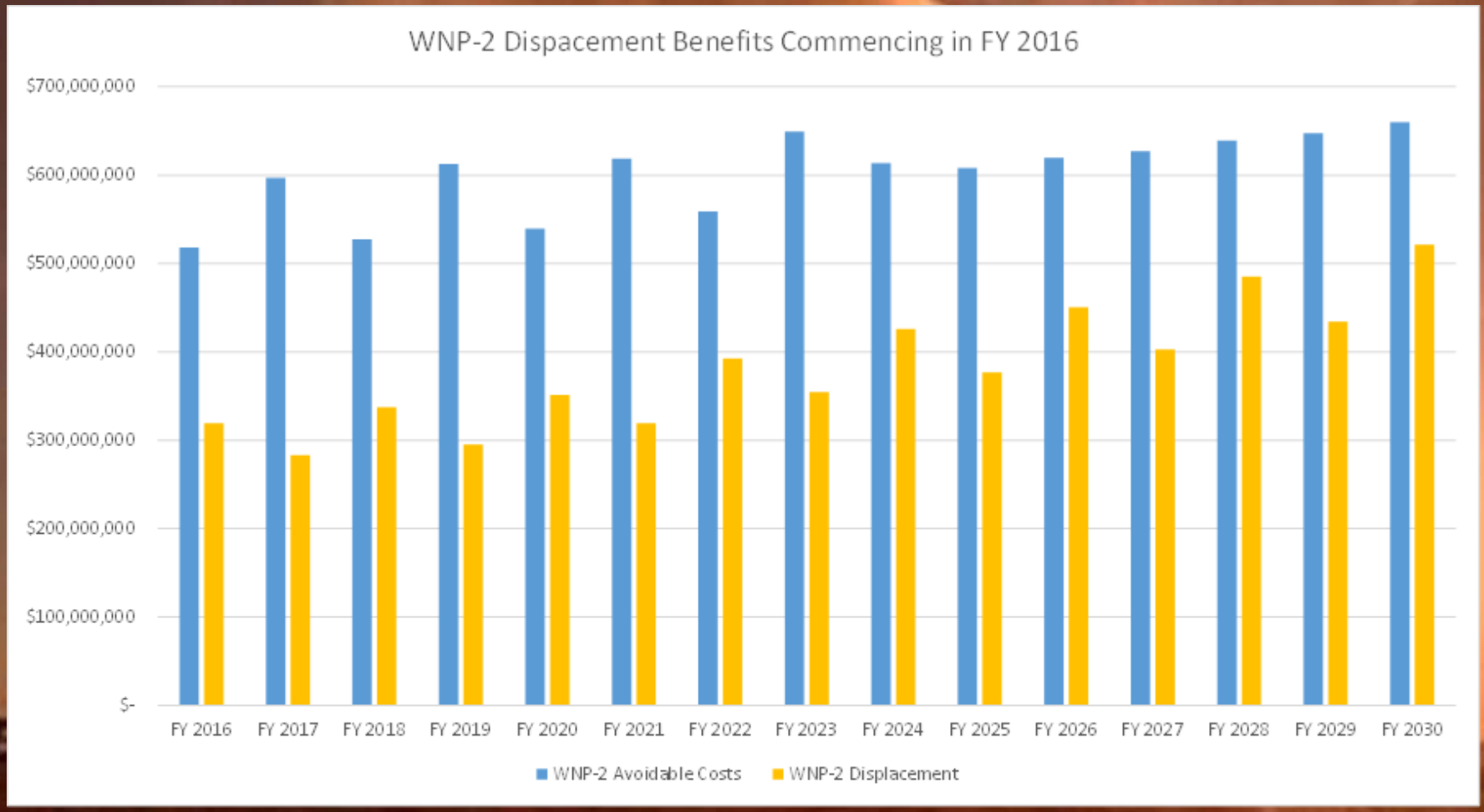
CGS Life Table

	Probability of plant closure between ages x and x + n	Number surviving to age x	Number plant closure between ages x and x + n	Plant-years lived between ages x and x + n	Total number of Plant-years lived above age x	Expectation of life at age x
	n qx	lx	n dx	n Lx	Tx	ex
1-5	0.0%	13.0	0.0	13.0	397.8	30.6
6-10	13.3%	13.0	1.7	25.1	332.8	25.6
11-15	15.4%	11.3	1.7	35.5	272.2	24.2
16-20	9.1%	9.5	0.9	44.6	220.2	23.1
21-25	10.0%	8.7	0.9	52.9	174.7	20.2
26-30	11.1%	7.8	0.9	60.2	133.5	17.1
31-35	25.0%	6.9	1.7	66.3	96.7	13.9
36-40	25.0%	5.2	1.3	70.9	66.3	12.8
41-45	25.0%	3.9	1.0	74.3	43.6	11.2
46-50	25.0%	2.9	0.7	76.8	26.5	9.1
51-55	25.0%	2.2	0.5	78.7	13.7	6.3
56-60	25.0%	1.6	1.6	80.2	4.1	2.5

Aurora Runs

- We used the standard Aurora data set updated for the Oregon, Washington, and California Renewable Portfolio Standards (RPS)
- We also updated the natural gas forecast to match the EIA's 2013 AEO
- We ran build outs through 2045 in with and with out CGS cases
- Overall, we ran 35,000 games with stochastic wind and hydro

Replacement Benefits



Policy Considerations

- Contract Risk
- Paducah Enrichment Program
- Decommissioning costs

Contract Comparison

	1971 Project Agreement	EEI Master Contract
Structure	Take or Pay	Take and Pay
Duration	Unknown	Set per agreement
Commissioning	Completed	Set per agreement
Pricing	Cost plus	Set per agreement
Credit Support	Nuclear Insurance and BPA's Customers	Vendor
Fuel Source	Nuclear	Unknown (probably Gas/Wind)
Operating Risks	Nuclear	Force Majeure
Insurance	Nuclear insurance	Set per agreement
Environmental Issues	None	Set per agreement

Emissions

- CGS is less “emissions free” than “emissions elsewhere”
- Energy Northwest agreed to speculate in nuclear fuel
- The basic framework was for a $700 million payment for reprocessing tailings with deliveries to TVA over the next decade
- The transaction lost $150 million when signed and has deteriorated simce then
- This leaves CGS with the dirtiest fuel in the industry for years to come

Carbon Release

- Energy Northwest's one year contract with Paducah required 1,328 MW of coal based generation in Kentucky
- Paducah also released 197.3 metric tons of freon with a carbon equivalence of 1,973,000 tons
- Overall, the Paducah transaction released carbon and carbon equivalents of 15 million metric tons in FY 2013
- This is the rough equivalent of 3,000,000 cars

April 5,2013 Conference Call With NRC

- NRC: "Historically, I would say that uh probably the minimum decommissioning funding formula has increased probably on average around 8 to 9 percent a year. Uh this, the primary driver would probably be the burial costs. Uh disposal of low-level waste is getting to be a very expensive proposition for a variety of economic reasons. There are very few places you can dispose of this; there are also 3 major classifications for spen..., excuse me, for low-level waste, such that the uh higher radiological content of the waste will incur higher costs for disposal. However, this has been offset to some degree by the techniques and technologies that are now available to the industry, to decontaminated plants, so therefore the uh mix, of what, what we classify as a, b, and c low-level waste can change in such a manner that the economics can usually be a little bit more beneficial.

Nuclear Waste Policy Act of 1982

"Because the Secretary is apparently unable to conduct a legally adequate fee assessment, the Secretary is ordered to submit to Congress a proposal to change the fee to zero until such a time as either the Secretary chooses to comply with the Act as it is currently written, or until Congress enacts an alternative waste management plan."

November 19, 2013, United States Court of Appeals for the District of Columbia Circuit

Canadian Hydro

- British Columbia Hydro is adding a new major facility, Site C
- It is also considering upgrades at other hydro facilities like Mica
- We need intrayear storage and associated capacity to complete mandated renewables
- This is significantly cheaper than our alternatives